
Building Your World

Conceptual Design and Visualization with AutoCAD®

Autodesk®

January 2007

Copyright © 2007 Autodesk, Inc.

All Rights Reserved

This publication, or parts thereof, may not be reproduced in any form, by any method, for any purpose.

AUTODESK, INC., MAKES NO WARRANTY, EITHER EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE REGARDING THESE MATERIALS, AND MAKES SUCH MATERIALS AVAILABLE SOLELY ON AN "AS-IS" BASIS.

IN NO EVENT SHALL AUTODESK, INC., BE LIABLE TO ANYONE FOR SPECIAL, COLLATERAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF ACQUISITION OR USE OF THESE MATERIALS. THE SOLE AND EXCLUSIVE LIABILITY TO AUTODESK, INC., REGARDLESS OF THE FORM OF ACTION, SHALL NOT EXCEED THE PURCHASE PRICE, IF ANY, OF THE MATERIALS DESCRIBED HEREIN.

Autodesk, Inc., reserves the right to revise and improve its products as it sees fit. This publication describes the state of this product at the time of its publication, and may not reflect the product at all times in the future.

Autodesk Trademarks

The following are registered trademarks or trademarks of Autodesk, Inc., in the USA and other countries: 3DEC (design/logo), 3December, 3December.com, 3ds Max, ActiveShapes, Actrix, ADI, Alias, Alias (swirl design/logo), AliasStudio, AliasWavefront (design/logo), ATC, AUGI, AutoCAD, AutoCAD Learning Assistance, AutoCAD LT, AutoCAD Simulator, AutoCAD SQL Extension, AutoCAD SQL Interface, Autodesk, Autodesk Envision, Autodesk Insight, Autodesk Intent, Autodesk Inventor, Autodesk Map, Autodesk MapGuide, Autodesk Streamline, AutoLISP, AutoSnap, AutoSketch, AutoTrack, Backdraft, Built with ObjectARX (logo), Burn, Buzzsaw, CAiCE, Can You Imagine, Character Studio, Cinestream, Civil 3D, Cleaner, Cleaner Central, ClearScale, Colour Warper, Combustion, Communication Specification, Constructware, Content Explorer, Create>what's>Next> (design/logo), Dancing Baby (image), DesignCenter, Design Doctor, Designer's Toolkit, DesignKids, DesignProf, DesignServer, DesignStudio, DesignStudio (design/logo), Design Your World, Design Your World (design/logo), DWF, DWG, DWG (logo), DWG TrueConvert, DWG TrueView, DXF, EditDV, Education by Design, Extending the Design Team, FBX, Filmbox, FMDesktop, GDX Driver, Gmax, Heads-up Design, Heidi, HOOPS, HumanIK, i-drop, iMOUT, Incinerator, IntroDV, Kaydara, Kaydara (design/logo), LocationLogic, Lustre, Maya, Mechanical Desktop, MotionBuilder, ObjectARX, ObjectDBX, Open Reality, PolarSnap, PortfolioWall, Powered with Autodesk Technology, Productstream, ProjectPoint, Reactor, RealDWG, Real-time Roto, Render Queue, Revit, Showcase, SketchBook, StudioTools, Topobase, Toxik, Visual, Visual Bridge, Visual Construction, Visual Drainage, Visual Hydro, Visual Landscape, Visual Roads, Visual Survey, Visual Syllabus, Visual Toolbox, Visual Tugboat, Visual LISP, Voice Reality, Volo, and Wiretap.

The following are registered trademarks or trademarks of Autodesk Canada Co. in the USA and/or Canada and other countries: Backburner, Discreet, Fire, Flame, Flint, Frost, Inferno, Multi-Master Editing, River, Smoke, Sparks, Stone, Wire.

Third-Party Trademarks

All other brand names, product names, or trademarks belong to their respective holders.

Third-Party Software Program Credits

ACIS Copyright © 1989-2001 Spatial Corp.

Copyright © 1999-2000 The Apache Software Foundation. All rights reserved. This product includes software developed by the Apache Software Foundation (<http://www.apache.org>) subject to its license terms and conditions (<http://xml.apache.org/dist/LICENSE.txt>).

Typefaces from the Bitstream ® typeface library Copyright © 1992.

HLM © Copyright D-Cubed Ltd. 1996-2006. HLM is a trademark of D-Cubed Ltd.

AutoCAD ®2008 and AutoCAD LT ®2008 are produced under a license of data derived from DIC Color Guide ®from Dainippon Ink and Chemicals, Inc. Copyright © Dainippon Ink and Chemicals, Inc. All rights reserved. DIC and DIC Color Guide are registered trademarks of Dainippon Ink and Chemicals, Inc.

Portions of this software are based on the work of the Independent JPEG Group.

Active Delivery™2.0 © 1999-2004 Inner Media, Inc. All rights reserved.

ISYS and the ISYS logo are registered trademarks or trademarks of ISYS®Search Software Inc

Copyright © 1988-1997 Sam Leffler. Copyright © 1991-1997 Silicon Graphics, Inc.

Copyright © Lingea s.r.o. 2006.

The New Features Workshop contains Macromedia Flash™Player software by Macromedia, Inc. Copyright © 1995-2005 Macromedia, Inc. All rights reserved. Macromedia ®and Flash ® are registered trademarks or trademarks of Adobe Systems Incorporated in the United States or other countries.

Copyright © 1996-2006 Macrovision Corporation. All rights reserved.

Copyright © 1996-2006 Microsoft Corporation. All rights reserved

Copyright © 2002 Joseph M. O'Leary.

PANTONE ®Colors displayed in the software application or in the user documentation may not match PANTONE-identified standards. Consult current PANTONE Color Publications for accurate color.

PANTONE ®and other Pantone, Inc. trademarks are the property of Pantone, Inc. © Pantone, Inc., 2004.

Pantone, Inc. is the copyright owner of color data and/or software which are licensed to Autodesk, Inc., to distribute for use only in combination with certain Autodesk software products. PANTONE Color Data and/or Software shall not be copied onto another disk or into memory unless as part of the execution of this Autodesk software product.

Typefaces from Payne Loving Trust © 1992, 1996. All rights reserved.

RAL DESIGN © RAL, Sankt Augustin, 2004.

RAL CLASSIC © RAL, Sankt Augustin, 2004.

Representation of the RAL Colors is done with the approval of RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V. (RAL German Institute for Quality Assurance and Certification, re. Assoc.), D-53757 Sankt Augustin.

This product includes code licensed from RSA Security, Inc. Some portions licensed from IBM are available at <http://oss.software.ibm.com/icu4j/>.

The Sentry Spelling-Checker Engine Copyright © 1994-2003 Wintertree Software, Inc.

Portions of this product include one or more Boost libraries. Use of the Boost libraries is subject to its license agreement http://www.boost.org/LICENSE_1_0.txt.

GOVERNMENT USE

Use, duplication, or disclosure by the U.S. Government is subject to restrictions as set forth in FAR 12.212 (Commercial Computer Software-Restricted Rights) and DFAR 227.7202 (Rights in Technical Data and Computer Software), as applicable.

Contents

Chapter 1	Welcome and Setup	1
	Objectives	2
	Prerequisites	2
	Setup	3
	Drawing File Location	3
Chapter 2	Introduction to Solid Models	5
	Use Your 2D Drawings to Create Solid Models.	6
	Visualize Your Designs While You Work.	8
	Explore Design Alternatives.	9
	Apply Analysis Tools	10
	Present Your Designs	11
Chapter 3	View Models in 3D	13
	Change Views Dynamically	14
	Control the Display Properties of Solid Models	18
	Specify Precise Views.	21
	Use the Dashboard	24
Chapter 4	Control the Workplane	27
	Understand the Role of Coordinate Systems	28
	Work with Other UCS Options	32
	Use the Dynamic UCS Feature for Speed	35

Chapter 5	Create Basic Solids	37
	Extrude 2D Objects	38
	Revolve 2D Objects Around an Axis	45
	Sweep 2D Objects Along a Path	49
	Use Primitives	52
	Create Landscaping	54
Chapter 6	Combine and Modify Solids	57
	Add and Subtract Solids	58
	Intersect Extruded Profiles	68
	Control the Level of Detail	74
	Use Detail to Control Attention	76
Chapter 7	Put Your Work to Use	79
	Where to Go From Here	80
	Edit Subobjects and Component Objects	81
	Create Sections	83
	Flatten 3D Views	85
	Calculate Mass Properties	86
	Walk Through or Fly Over 3D Models	87
	Check for Interferences	89
	Create Files for Manufacturing	93
	Make 3D Solids Transparent	94
	Create Realistic Images for Presentation	96
	Final Thoughts	97

Welcome and Setup

What's inside...

Welcome to *Building Your World*, an exciting introduction to design and visualization with AutoCAD solid modeling! If you have never had time to try solid modeling, or if you have and hope to find some good tips and tricks, you've come to the right place.

Objectives	2
Prerequisites	2
Setup	3
Drawing File Location	3

Objectives

Building Your World will provide you with important concepts and techniques in solid modeling. The information can be used for conceptual design and visualization in many disciplines, such as architecture, mechanical design, and civil engineering. The objectives of this guide are

- To provide a strong foundation in the basics of solid modeling in AutoCAD
- To present practical information about efficient techniques and common pitfalls of solid modeling
- To provide a learning environment for additional study and experimentation

Prerequisites

This guide is intended for experienced AutoCAD users. To complete the exercises in this guide, you should know how to do the following:

- Zoom and pan
- Specify 2D Cartesian coordinates
- Use object snaps
- Create, select, and modify 2D objects
- Work with layers
- Create and insert blocks
- Change system variables at the Command prompt

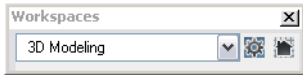
If you are new to AutoCAD, it is strongly recommended that you complete the *Getting Started* guide first. The *Getting Started* guide provides basic information and tutorials about using the program. You can obtain the *Getting Started* guide in one of the following ways:

- If available, use the documentation coupon included in the product package.
- Purchase a copy from www.autodesk.com.
- Open the free PDF version of the *Getting Started* guide that is included on your installation CD. In the Installation Wizard window, click the Documentation link at the bottom-left of the window to access the PDF.

Once you are familiar with AutoCAD, you will be ready for *Building Your World*.

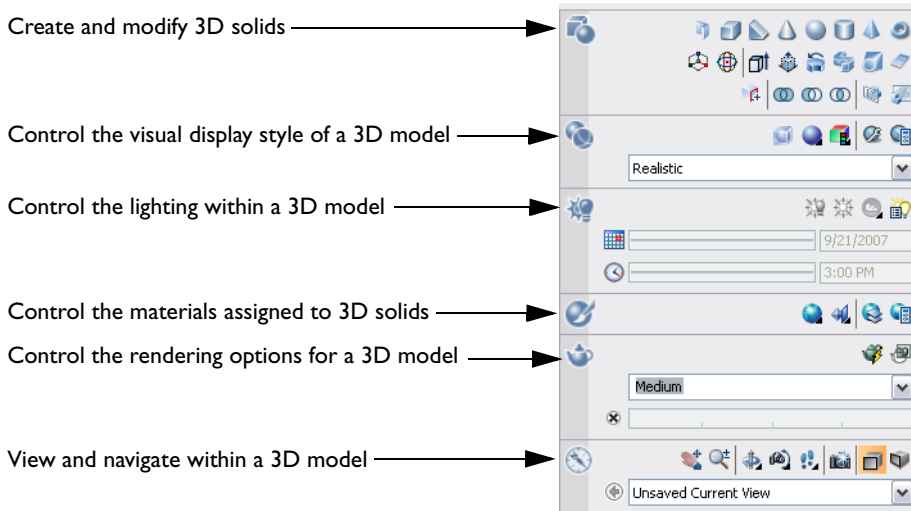
Setup

Before you begin working through this guide, start AutoCAD, and then from the Workspaces toolbar, specify the *3D Modeling* workspace. The Workspaces toolbar is located at the top-left of the AutoCAD application window by default.



If the Workspaces toolbar is not displayed, right-click any toolbar. Then, on the shortcut menu, click Workspaces. Then select 3D Modeling in the drop-down list.

The 3D Modeling workspace consolidates several toolbars and controls into the *dashboard* for convenient access to commonly used 3D modeling commands and settings.



Drawing File Location

This guide includes exercises for you to try the concepts and features that are presented. The drawing files that you need for these exercises are in the `\Help\buildyourworld` folder, which you will find in the AutoCAD installation folder.

NOTE The drawing files used in the exercises include models that use either metric or imperial units. While this affects the scale and proportion of the models, it has no significant effect on learning solid modeling.

You are now ready to begin exploring the power of 3D solid modeling with AutoCAD.

2

Introduction to Solid Models

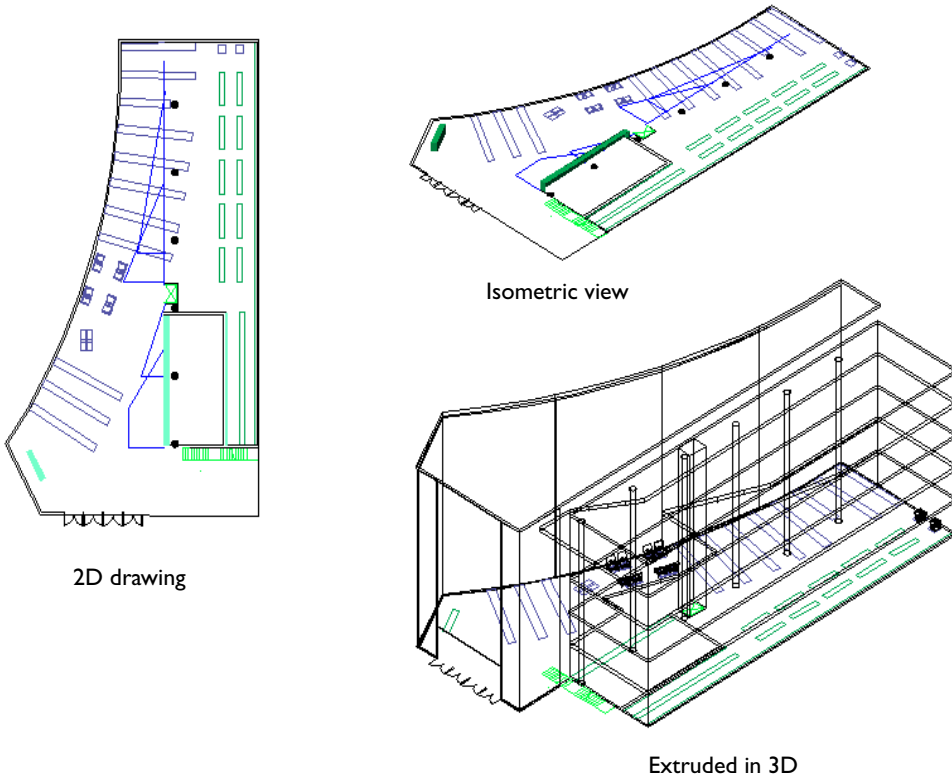
What's inside...

It's easy to create a 3D solid model from a 2D design. When you work with a 3D model, the effects of a design change are much easier to visualize. With a 3D solid model, you can analyze and present your design more effectively.

Use Your 2D Drawings to Create Solid Models	6
Visualize Your Designs While You Work	8
Explore Design Alternatives	9
Apply Analysis Tools	10
Present Your Designs	11

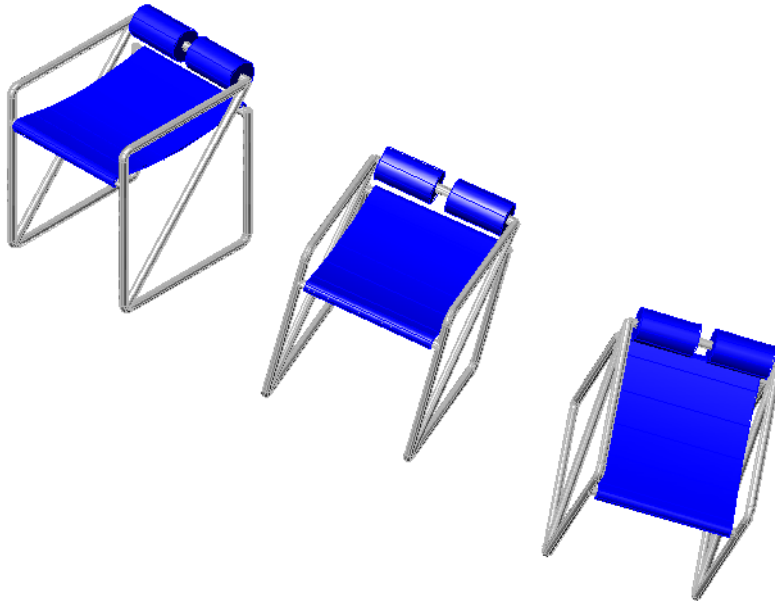
Use Your 2D Drawings to Create Solid Models

Your drawings are a treasure trove of resources that can be easily reused to create solid models. For example, this 2D library design was extruded into a 3D solid model.

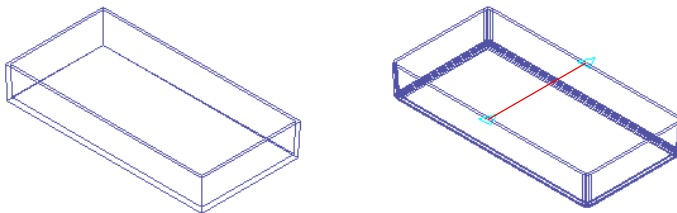


Solid models are an excellent tool for visualizing, analyzing, and presenting your designs. Visualizing a chair design is much easier using a solid model than viewing standard orthographic projections.

Most of the commands and settings that you already use for 2D drawings are also used to create and modify solid models. For example, these chairs were copied and rotated.



The FILLET command was used to round the inside and outside edges of this plastic box. Midpoint object snaps were used to create a reference line across the opening.



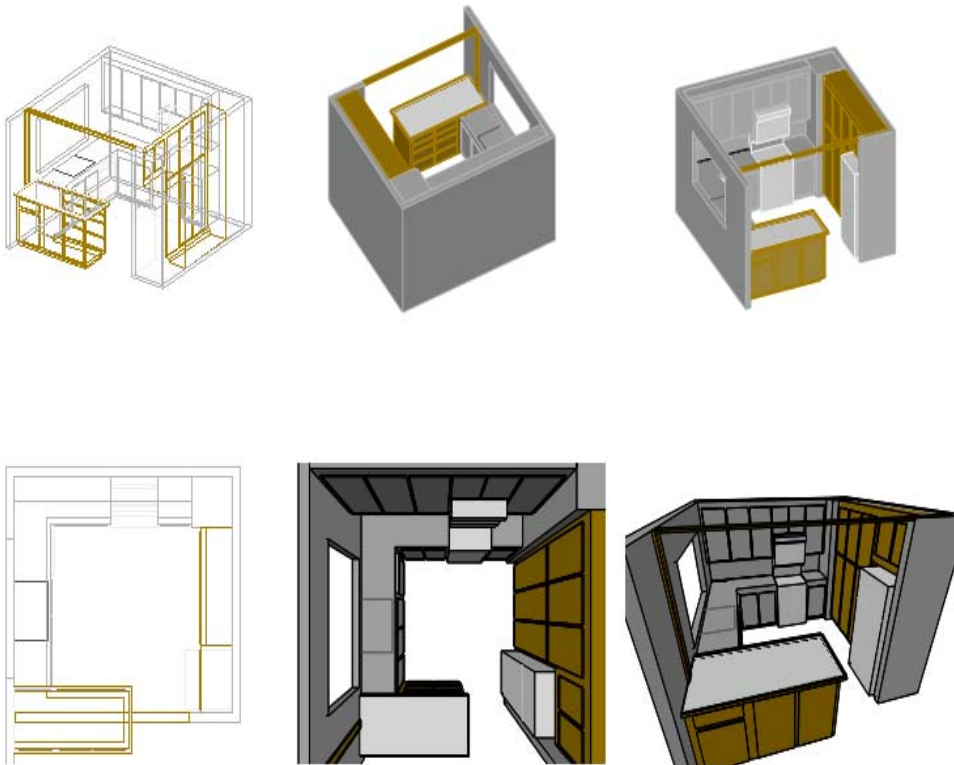
Common operations and tools used in solid modeling include

- Move
- Copy
- Rotate
- Fillet
- Object snaps
- Polar snap

Visualize Your Designs While You Work

Changing 3D perspectives and views can aid design decisions. Also, you can choose from several visual styles to increase comprehension and reduce the clutter while you create and modify solid models.

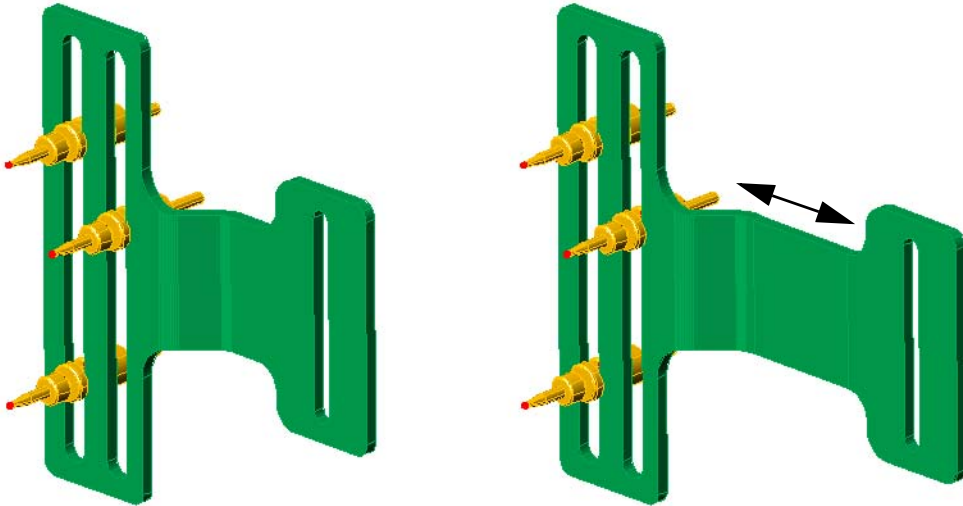
This kitchen was remodeled to include a new pantry and a peninsula (shown in brown). Several perspectives were used to confirm design decisions.



Explore Design Alternatives

You can easily modify a solid model. Speeding up and increasing the number of design iterations improves the quality of the design and reduces the probability of expensive design changes late in the process.

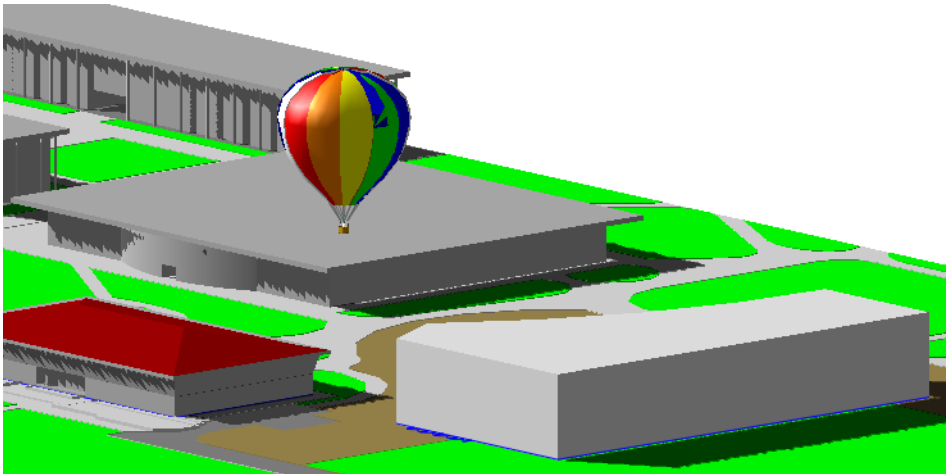
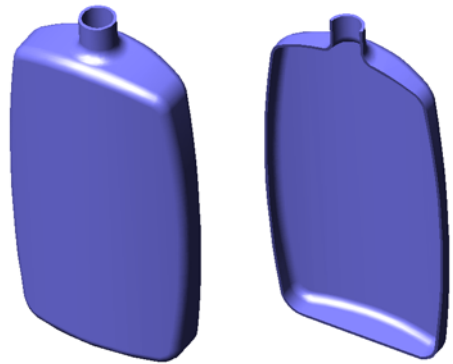
To enhance performance in archery, this old-style bow sight design was lengthened .



Apply Analysis Tools

Solid models can be used for several kinds of analysis. For example, the volume of polyethylene used in this bottle was easily obtained by using the MASSPROP command. As shown in the illustration, you can also create cross sections of a solid model easily.

Other tools are available for lighting and shadows. For example, the proposed library for this university campus may cast a significant shadow at certain times of the day during the year.



Present Your Designs

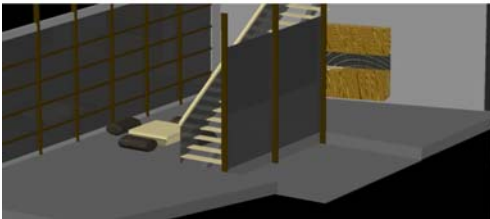
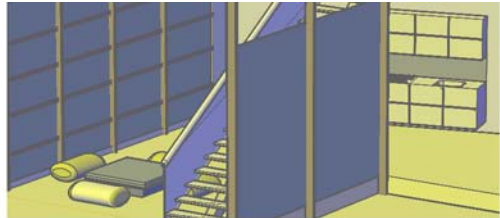
Solid models can be displayed for effective communication of design intent. Several visual styles and perspectives are at your command. Also walkthroughs and flyovers can be performed and incorporated into animated presentations.

The following images of a Japanese-style room design display the predefined visual styles in AutoCAD. Visual styles can also be customized. At the lower-left is a rendered image of the room design.

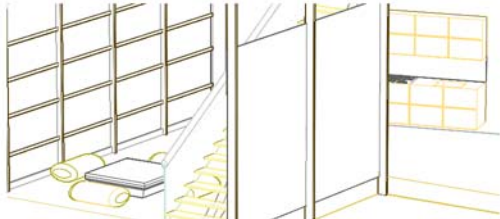
Realistic visual style



Conceptual visual style



Rendered image



Hidden visual style

Once you create a 3D solid model, it becomes a significant resource for many applications. The following chapters will show you how easy it is to create and modify 3D solids.

3

View Models in 3D

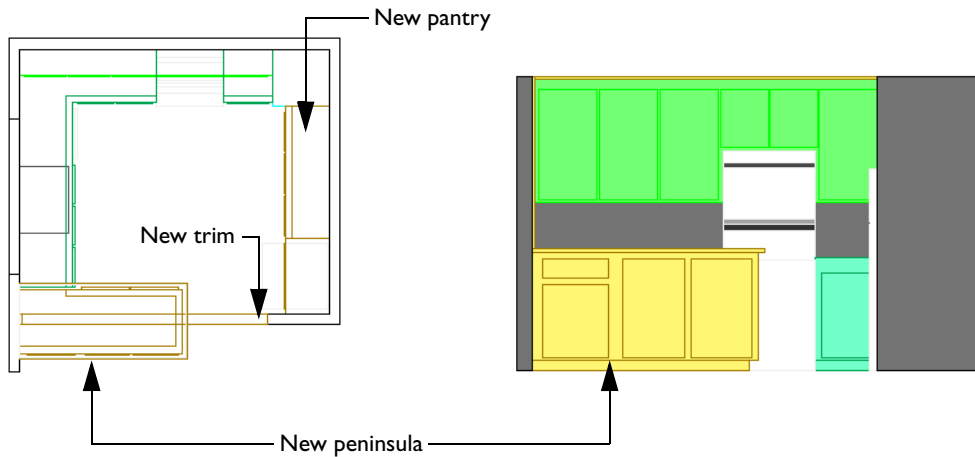
What's inside...

When you work with solid models in 3D, it is essential to become skilled at changing viewpoints and visual styles for clarity and convenience.

Change Views Dynamically	14
Control the Display Properties of Solid Models	18
Specify Precise Views	21
Use the Dashboard	24

Change Views Dynamically

In the following illustrations of a kitchen remodeling plan, a new peninsula, pantry, and trim are shown in brown lines. However, 3D views provide important additional visual information.

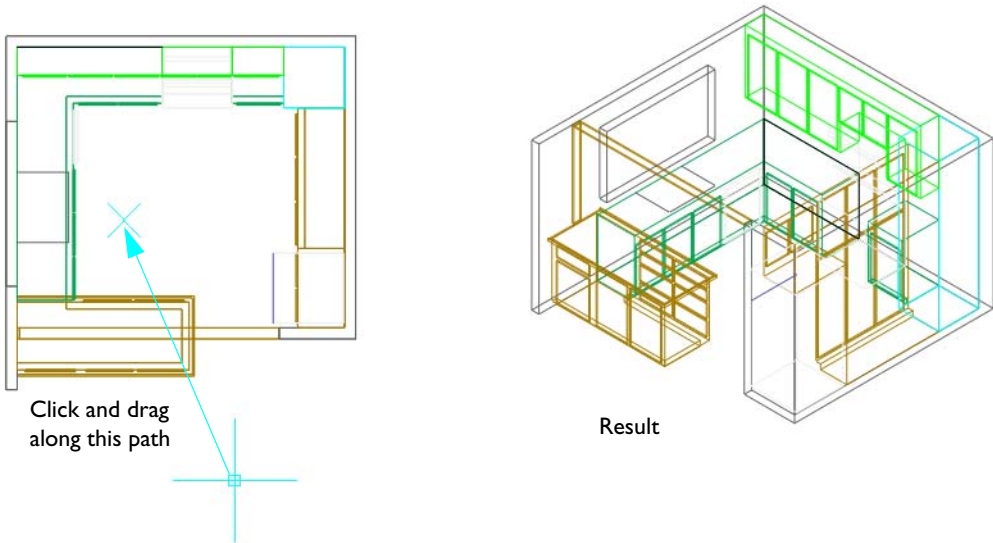


Plan view of kitchen

Front view of kitchen

The 3DORBIT command is the most convenient way to change a 3D view dynamically.

TIP Work in 3D views to select objects easily and to avoid mistakes due to visually overlapping edges.

**Try it:**

- 1 In the `\Help\buildyourworld` folder, open the drawing `31 Kitchen.dwg`.
- 2 Click View menu > Orbit > Constrained Orbit.
- 3 To specify a 3D isometric view, click and drag the cursor along the path shown by the arrow in the illustration above.
- 4 Click and drag the cursor several more times for additional viewing angles.
- 5 Press ESC to exit the command.

As you can see, 3D isometric views result in more complete, but visually complex, views.

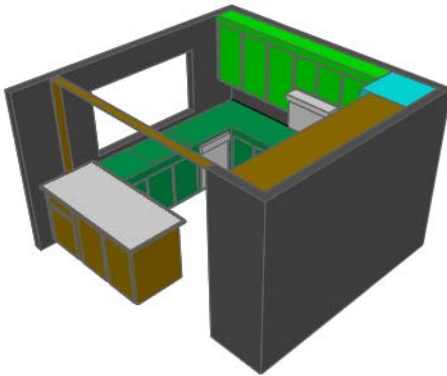
TIP It is extremely important to use layers to organize 3D models! Turn unneeded layers off to reduce the number of objects that are displayed at the same time.

16 Chapter 3 View Models in 3D

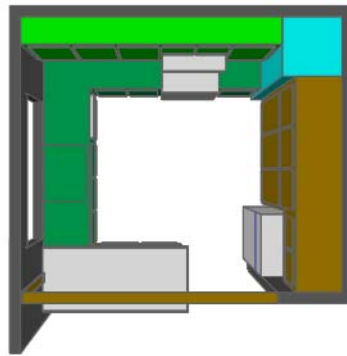
Currently, the kitchen is displayed with the 3D Wireframe visual style. You can choose from several visual styles, and you can change from an isometric view to a perspective view.

Try it:

- 1 Start the 3DORBIT command and right-click to display the shortcut menu.
- 2 Click Visual Styles > Realistic.
- 3 Change the view orientation for a better view of the remodeling plan.
- 4 On the same shortcut menu, click Perspective and try several other viewing angles.
- 5 Change your location with respect to the kitchen by clicking Other Navigation Modes > Adjust Distance, and dragging the cursor up to move into the middle of the kitchen.
- 6 Right-click and then click Other Navigation Modes > Constrained Orbit to view the kitchen from the middle of the kitchen. Press ESC to exit the command.
- 7 Click the Layout button near the middle of the status bar at the bottom of the application window to display a layout with several views of the kitchen.
- 8 Close the drawing.



Realistic visual style



Perspective turned on

TIP If you need to see only a few objects in a model, select the objects before starting 3D Orbit, and only the selected objects will be visible during 3D Orbit operations.

The next exercise uses a solid model of a connecting rod from an antique sports car.

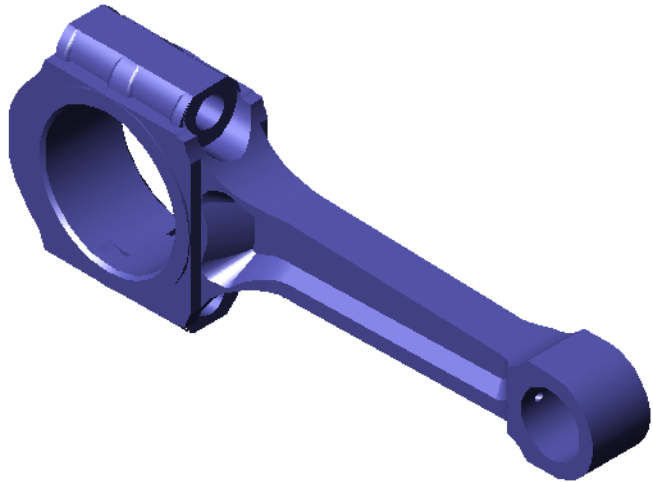
Try it:

- 1 In the `\Help\buildyourworld` folder, open the drawing `32 Conrod.dwg`.
- 2 Click View menu > Orbit > Constrained Orbit.
- 3 Click and drag to specify 3D views dynamically.
- 4 While still in 3D Orbit, right-click to display the shortcut menu. On the shortcut menu, click Other Navigation Modes > Continuous Orbit. Click and drag to give the connecting rod a spin!
- 5 Try changing the visual style and projection from the 3D Orbit shortcut menu.
- 6 Press ESC to exit the command.
- 7 Change the color of the 10 SOLID layer. Then repeat the previous steps.

However, you can still access legacy shading options on the command line.

Try it:

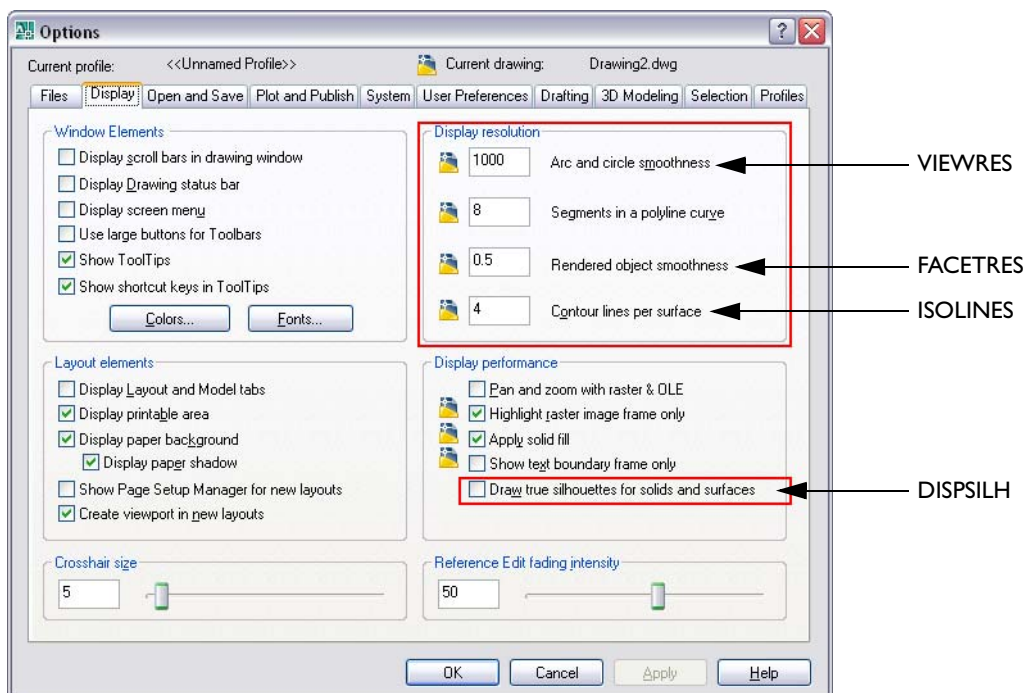
- 1 On the command line, enter `-shademode` and specify Gouraud.
- 2 Repeat to experiment with the various options. A popular option for creating and editing solids with many sharp edges is Gouraud with Edges.
- 3 Close the drawing.



TIP It is usually easier to create solid models and avoid errors by turning shading on to reduce the visual clutter in 3D views.

Control the Display Properties of Solid Models

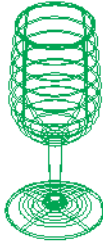
Several system variables affect the display properties of solid models. The primary ones can be changed in the Options dialog box as shown here.



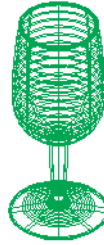
After changing any of these settings, use the REGEN command to see the effects.

NOTE For additional graphics display options, click the System tab. Click Performance Settings and then click Manual Tune. Alternatively, enter `3dconfig` on the command line. These options are optimized automatically to your hardware, but you can also control the settings manually.

ISOLINES controls the wireframe mesh density of all curved faces in a drawing. This setting applies to wireframe displays of solid models. The default value is 4, but typical values range from 0 to 16 depending on circumstances.

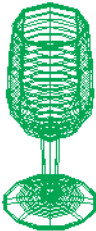


ISOLINES = 4

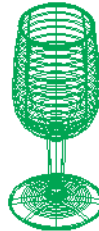


ISOLINES = 8

VIEWRES (view resolution) controls the smoothness of curved edges and isolines in wireframe displays of solid models. The default setting is 1000, but you can increase the setting even more. After changing the setting for VIEWRES, zoom in and out to see the difference.



VIEWRES = 20



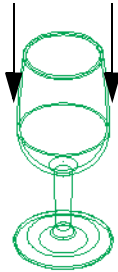
VIEWRES = 100

20 Chapter 3 View Models in 3D

DISPSILH controls whether the silhouette edges of curved faces are included in wireframe displays of solid models.

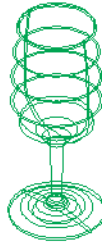
TIP You can set ISOLINES to 0 and DISPSILH to 1 as a method of displaying solid models with a minimum number of wireframe display lines.

Silhouette edges



DISPSILH = 1
ISOLINES = 0

No silhouette edges



DISPSILH = 0
ISOLINES = 2

FACETRES (facet resolution) controls the smoothness of curved edges in shaded and rendered displays of solid models. The default setting is 0.5, but many people increase it to at least 2. After changing the setting for FACETRES, use REGEN or RENDER to see the difference.



FACETRES = 0.1



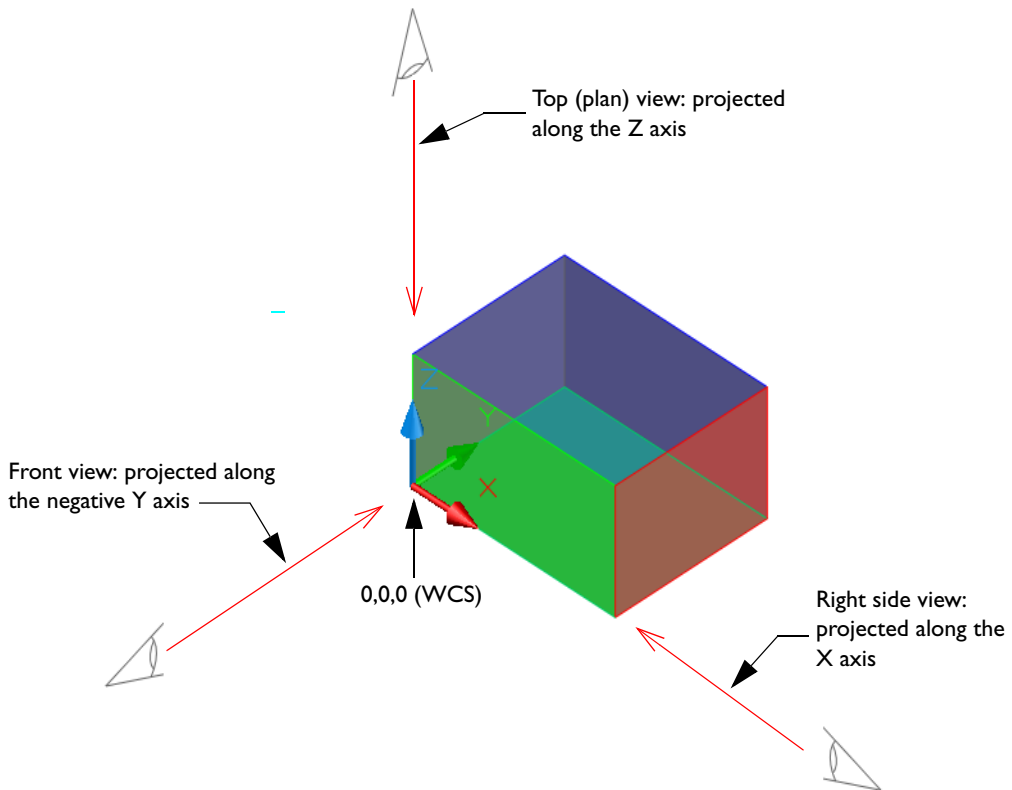
FACETRES = 5

Specify Precise Views

You can specify standard orthographic views such as front, right, top, and isometric from the 3D Orbit shortcut menu. Within 3D Orbit, you right-click, and then choose one of the following:

- For a front view: Preset Views > Front
- For a right-side view: Preset Views > Right
- For a top view: Preset Views > Top
- For an isometric view: Preset Views > SE Isometric

The illustrated viewing directions are always relative to the *world coordinate system (WCS)*, not the current user coordinate system (UCS). Furthermore, AutoCAD uses the architectural convention that defines the XY plane as the top or plan view rather than the mechanical design convention that defines the XY plane as the front view.

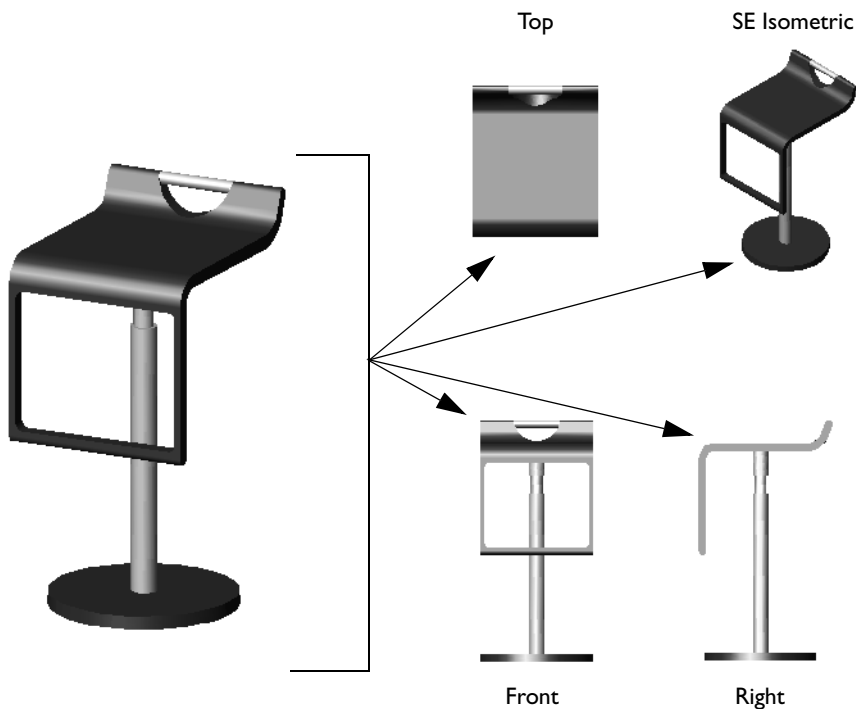


22 Chapter 3 View Models in 3D

NOTE Preset views are also accessible from the dashboard, the View toolbar, and the View menu. However, choosing a preset orthographic view from these interface elements automatically changes the UCS so that the XY plane is parallel with the plane of your screen. This may not be desirable behavior in 3D modeling.

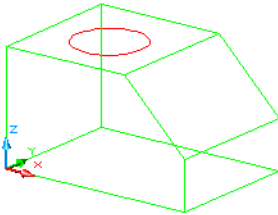
Try it:

- 1 In the `\Help\buildyourworld` folder, open the drawing `33 Stool.dwg`.
- 2 Use the 3DORBIT command to set the viewpoints in the following illustration.
- 3 After you exit 3D Orbit, click View menu > Zoom > Previous to restore the previous view.
- 4 Leave the drawing open for now.

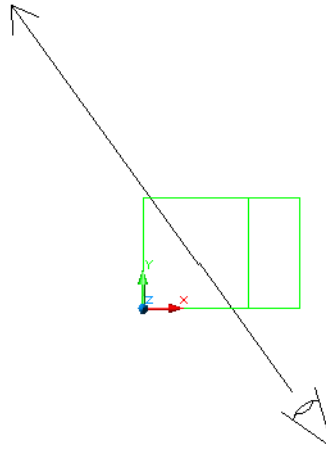


TIP Check the fidelity of 3D models with orthographic views. It's very easy to be fooled visually when working in 3D, as shown in the following illustration.

The circle appears to be on the top face of the object.

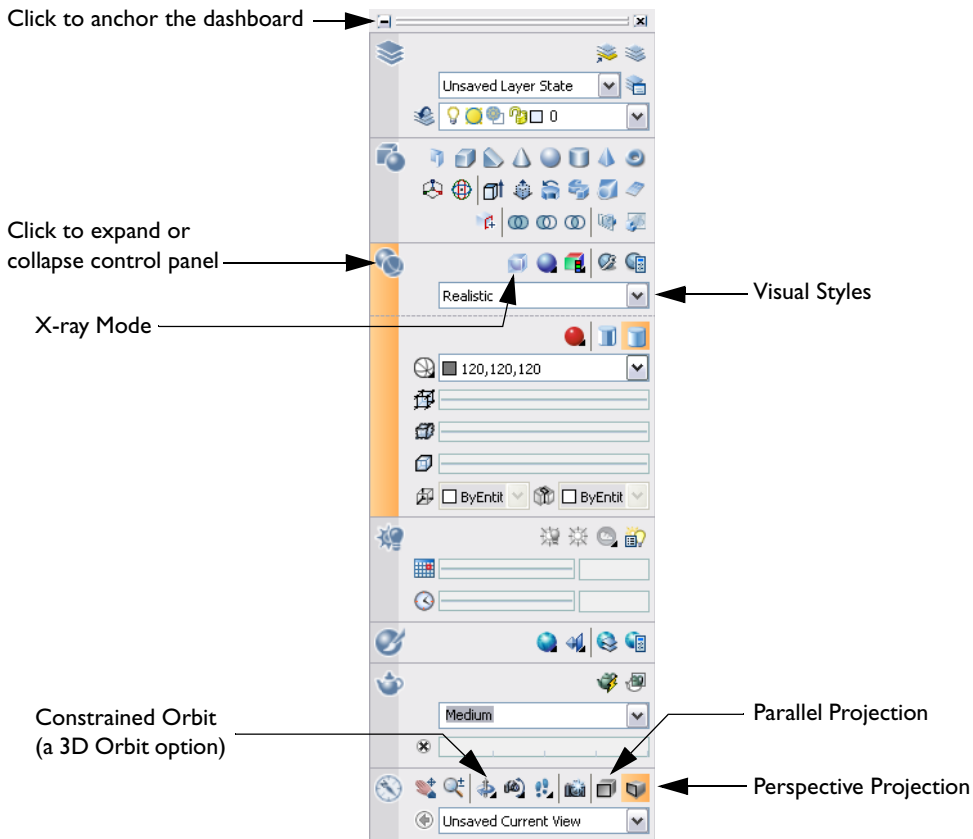


However, the top view reveals that the circle is actually behind the object



Use the Dashboard

The dashboard is a special palette that contains commands and settings for working in 3D. It eliminates the need to display many toolbars and reduces the clutter in the display area.



The dashboard displays automatically when you specify the 3D Modeling workspace. If you close the dashboard, you can redisplay it by clicking Tools menu > Palettes > Dashboard, or you can enter **dashboard** on the command line.

Try it:

- 1 If the dashboard is not docked on the side of the application window, dock the dashboard by dragging the title bar to the right side of the application window.
- 2 On the docked dashboard, in the upper-left corner, click the [-] button to anchor the dashboard. This turns on Auto-hide for the dashboard.

The dashboard rolls up conveniently to maximize the display area. It is highly recommended to keep the dashboard, the Tool Palettes window, and the Properties palette docked and anchored when you work.

- 3 Move your cursor over the rolled-up dashboard to display it. Click each large control panel icon to expand or collapse each control panel. For several control panels, an associated tool palette displays automatically.
- 4 On the dashboard, click Perspective Projection, click the Visual Styles control, and then click Realistic from the drop-down list. See the previous illustration to help you locate these controls.
- 5 On the dashboard, click Constrained Orbit. Then click and drag the view in the drawing area.
- 6 On the dashboard, click X-ray Mode.

NOTE For best results, make sure that hardware acceleration is turned on. To access this setting, enter **3dconfig** on the command line. In the Adaptive Degeneration and Performance Tuning dialog box, click Manual Tune. In the Manual Performance Tuning dialog box, click Enable Hardware Acceleration.

- 7 Click Constrained Mode. Click and drag the view in the drawing area.
Notice that the hidden edges and object snap locations are now easily accessible.
- 8 Press ESC to exit 3D Orbit. Close the drawing.

4

Control the Workplane

What's inside...

The **XY** plane of the user coordinate system (**UCS**) is called the workplane. For working in **3D**, it is essential to become skilled at changing the location and orientation of the **UCS**.

Understand the Role of Coordinate Systems.	28
Work with Other UCS Options.	32
Use the Dynamic UCS Feature for Speed	35

Understand the Role of Coordinate Systems

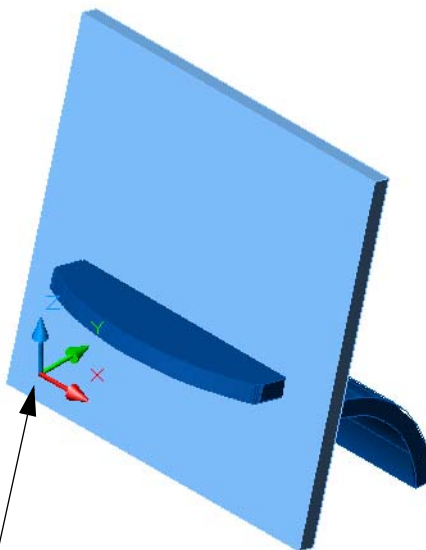
The coordinates of the world coordinate system (WCS) define the location of all objects and the standard views in AutoCAD drawings. However, the world coordinate system is permanent and invisible. It cannot be moved or rotated.

AutoCAD provides a movable coordinate system called the user coordinate system, or UCS. To create 3D solid models in AutoCAD, it is essential to become skilled at controlling the location and orientation of the UCS.

The following illustration shows a partially designed plastic desk stand. The UCS is currently aligned with the world coordinate system. To construct objects on the face plate of the desk stand, you will need to align the XY plane of the UCS—the workplane—with the face plate.

Try it:

- 1 In the `\Help\buildyourworld` folder, open the drawing `41 Stand.dwg`.
Notice that the 3D pointer uses the same colors as the UCS to represent the directions of the axes.
- 2 If the UCS icon is not displayed, click View menu > Display > UCS Icon, and then click both On and Origin. The Origin option makes the UCS icon appear at its origin (0,0,0) point within the drawing display if possible.

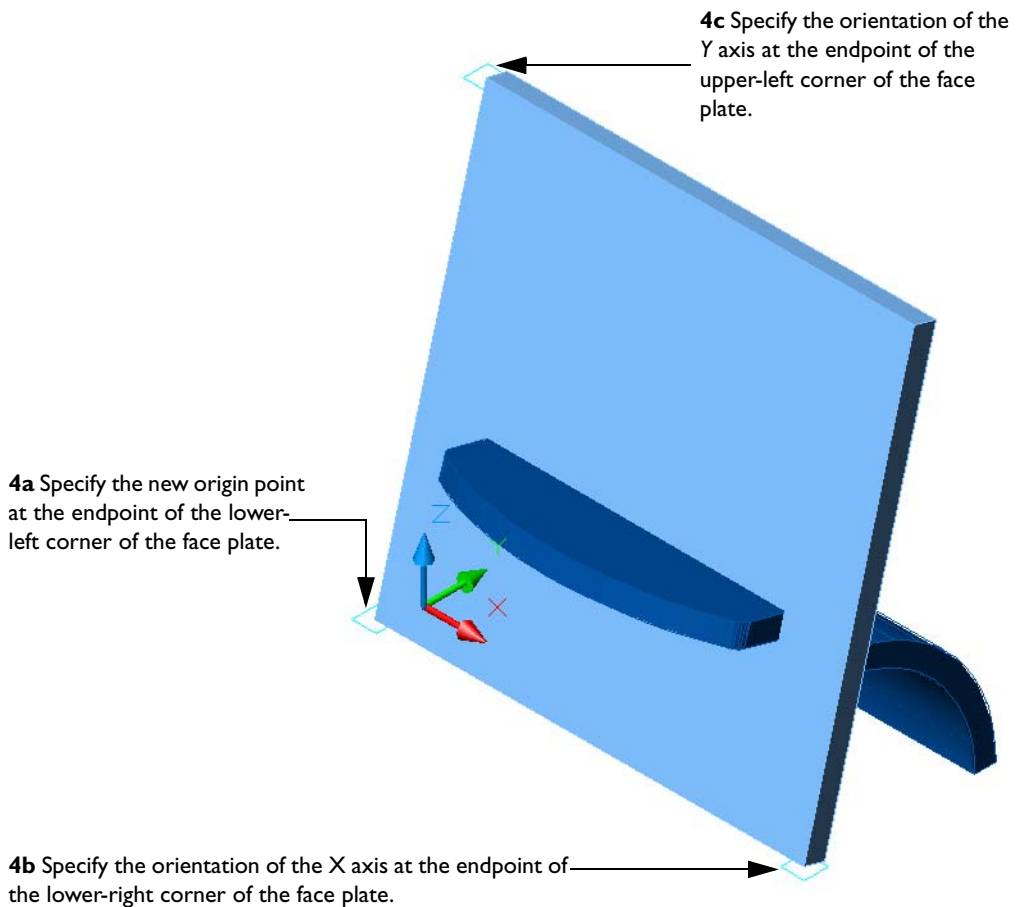


- By convention, the X axis is red, the Y axis is green, and the Z axis is blue
- The UCS is represented by a colorful 3D icon visible in 3D views
- The UCS is initially coincident with the world coordinate system
- The UCS can be relocated easily to facilitate construction in 3D

- 3 For now, make sure that the DUCS (Dynamic UCS) button on the status bar is turned off (not depressed). You will use this feature later.



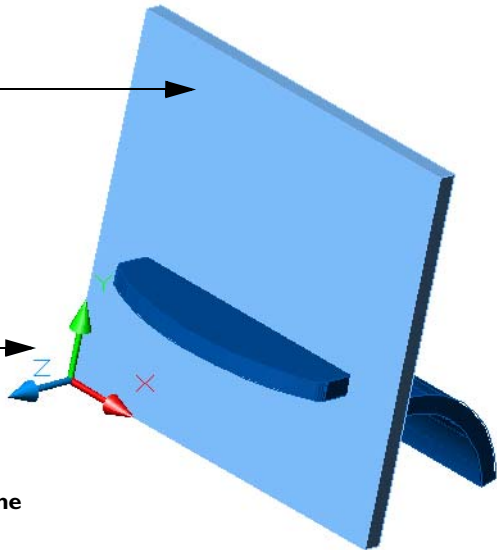
- 4 Click Tools menu > New UCS > 3 Point and specify the following point locations.



TIP It is very easy to click the wrong vertex on a relatively thin plate as in the previous steps. Use the zoom feature of a wheel mouse to magnify object snap locations that are in close proximity to each other.

The XY plane of the UCS has now been aligned with the face of the desk stand

The origin point (0,0,0) is now located in the bottom-left corner



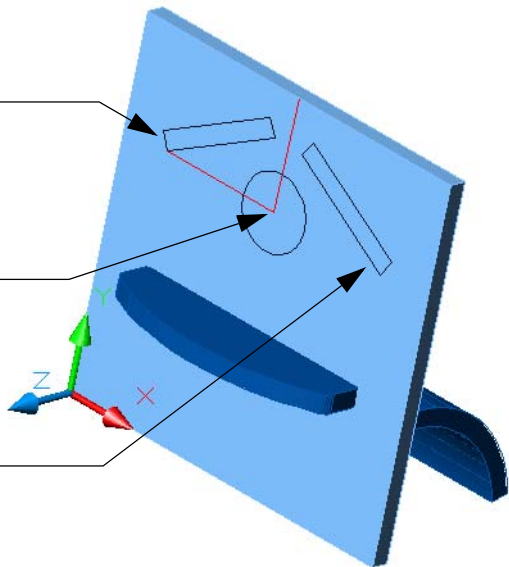
The XY plane of the UCS is also called the workplane and is useful as a construction plane

In the following example, the rectangles and circle were created on the workplane. These objects can later be converted into solids and combined with the other solids. The objects were created and modified with familiar 2D commands.

Planar objects such as the red construction lines, the rectangles, and the circle are automatically aligned with the workplane

Coordinate values, such as those of the center of the circle, are measured from the new UCS origin

The rectangles were easily rotated in the workplane—the axis of rotation is always parallel to the Z axis of the UCS



The circle and the rectangles can be used later to construct a hole and two slots in the face of the desk stand

Try it:

- 1 With Polar or Ortho mode turned on, create a 30 mm line from the midpoint of the top edge of the face plate, as shown in the previous illustration.
- 2 Create another line that extends 35 mm to the left.
- 3 Create a circle with a 20 mm diameter centered at the intersection of the two previously created lines.
- 4 Create a 35 mm x 5 mm rectangle and rotate it 30 degrees as shown previously. Then mirror it to create a second rectangle. If you have trouble selecting the rectangle, set the 3DSELECTIONMODE system variable to 0.

TIP You can specify a view of the XY plane of the current UCS with the PLAN command. This command is useful to confirm visually that the location of objects on the workplane is correct.

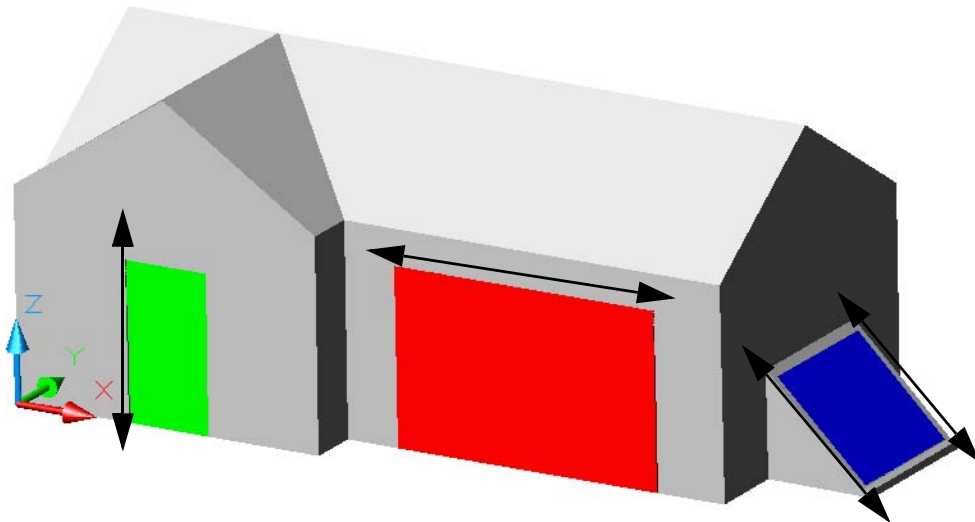
Try it:

- 1 Click View menu > 3D Views > Plan View > Current UCS.
- 2 Return to the previous view. Click View menu > Zoom > Previous.

You can easily return the UCS to be coincident with the world coordinate system. Click Tools menu > New UCS > World.

Work with Other UCS Options

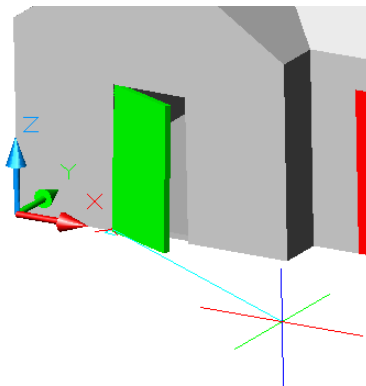
There are several situations where you need to align the Z axis of the UCS to rotate objects. For example, each of the doors on this toy house has a different rotation axis.



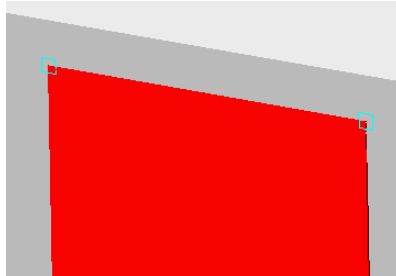
Use the ZAxis option of the UCS command to specify the Z axis directly.

Try it:

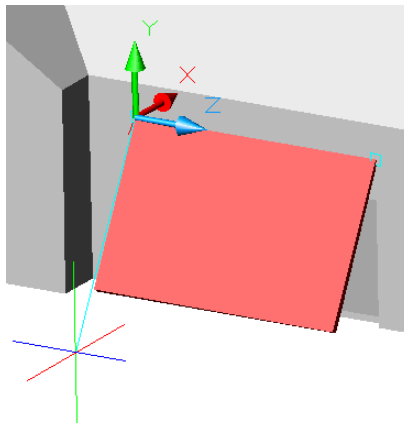
- 1 In the `\Help\buildyourworld` folder, open the drawing `42 Toy House.dwg`.
The Z axis is already parallel to the hinge of the green door.
- 2 Start the ROTATE command, select the door, and specify the endpoint on the lower-left corner of the door as the base point. Move the pointer to swing the door open.



- 3 For the red garage door, click Tools menu > New UCS > Z Axis Vector to align the UCS Z axis with two endpoints along the outside top edge of the door. Be careful not to snap to the inside edge of the door.



- 4 To swing the garage door open, start the ROTATE command, select the garage door, and specify the upper-left corner as the base point. Move the pointer to swing the garage door open.



- 5 Use the ZAxis option of the UCS to align the Z axis with the side edge of one of the blue storage doors.

This time, instead of moving the pointer to rotate these doors open, you will enter the value for an angle.

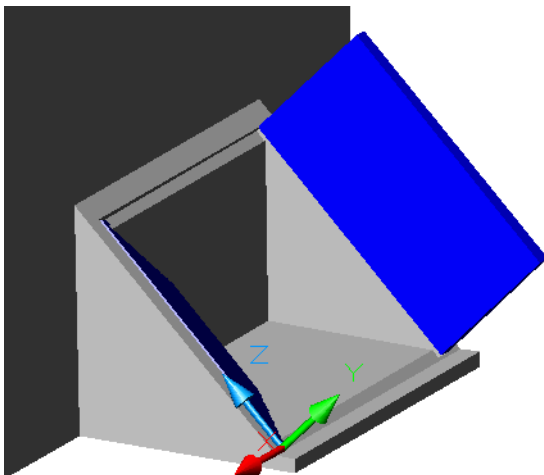
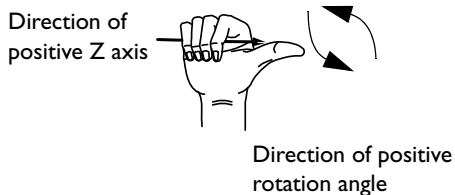
However, to open the storage doors outward, you need to know whether the rotation angle should be positive or negative. By default, a positive angle means a *counterclockwise* rotation.

34 Chapter 4 Control the Workplane

An easy way to remember the rotation direction is to use the right-hand rule for rotation. Point the thumb of your right hand in the direction of the positive UCS Z axis. Your fingers will curl in the positive rotation direction.

NOTE Use your left hand if you set AutoCAD to interpret a positive angle as a clockwise rotation.

- 6 Rotate both blue doors 150 degrees outward. One of the doors must be rotated 150 degrees, the other one -150 degrees.
- 7 Keep the drawing open.



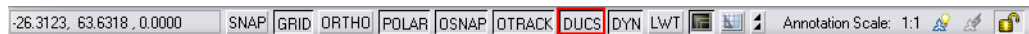
TIP It is often useful to rotate the UCS 90 degrees around one of its axes. In this case, use the X, Y, or Z options of the UCS command. Use the right-hand rule to determine whether the rotation should be positive or negative 90 degrees.

Use the Dynamic UCS Feature for Speed

You can align the XY plane of the UCS, the workplane, quickly with the Dynamic UCS feature. When Dynamic UCS is turned on, commands that create planar objects, such as circles, arcs, and lines, automatically align the workplane with any existing plane based on the location of your pointer.

Try it:

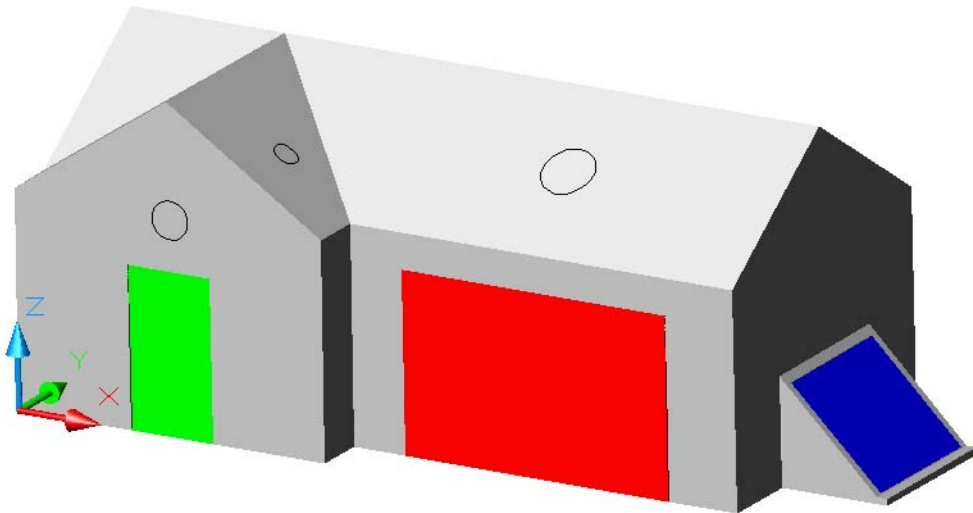
- 1 Click the DUCS (Dynamic UCS) button on the status bar to turn it on.



- 2 Change the current layer to the 00 REFERENCE layer.
- 3 Start the CIRCLE command.
- 4 Move your pointer over several planes on the toy house.

Notice that the workplane aligns with each visible plane as your cursor passes over it. Also notice that the alignment and direction of the X axis depends on the *edge* of the plane over which your pointer passes and the closest vertex on that edge.

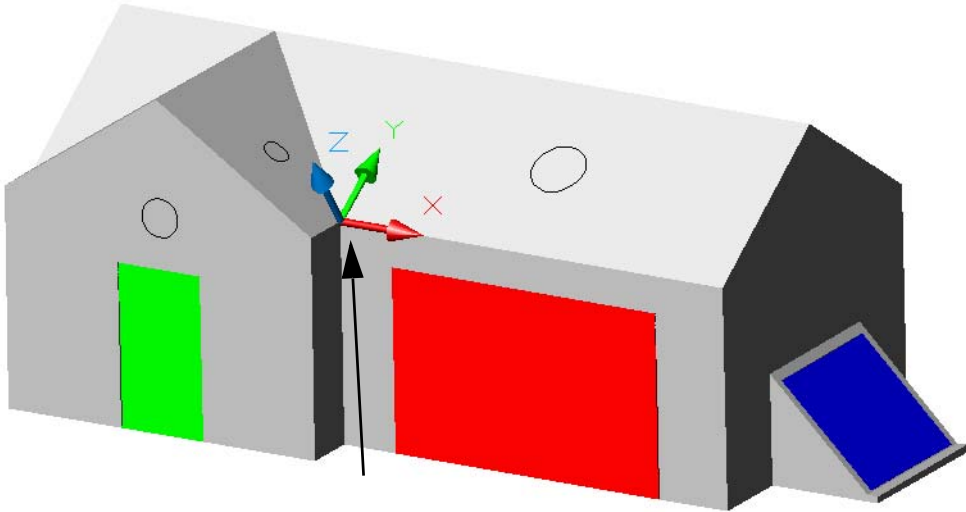
- 5 Click anywhere in each plane to create circles as shown in the illustration. Notice that after you exit the circle command, the UCS returns to its previous location automatically.



TIP You can also use the Dynamic UCS feature during the UCS command. This is a fast and reliable technique to make sure that the XY plane of the UCS is located exactly on the plane that you want to work on.

Try it:

- 1 Start the UCS command.
- 2 To orient the X and Y axes as in the following illustration, move your pointer as indicated by the blue arrow so that it crosses the roof edge near the arrowhead.



- 3 Click near the vertex to cause the Endpoint object snap to locate the UCS origin at the vertex. Be careful not to cross another edge with the pointer.
- 4 Use this technique to locate the UCS with precision on several other planes.
- 5 Close the drawing file.

NOTE Turn off DUCS when you need to use object snap tracking (OTRACK) or polar tracking (POLAR).

5

Create Basic Solids

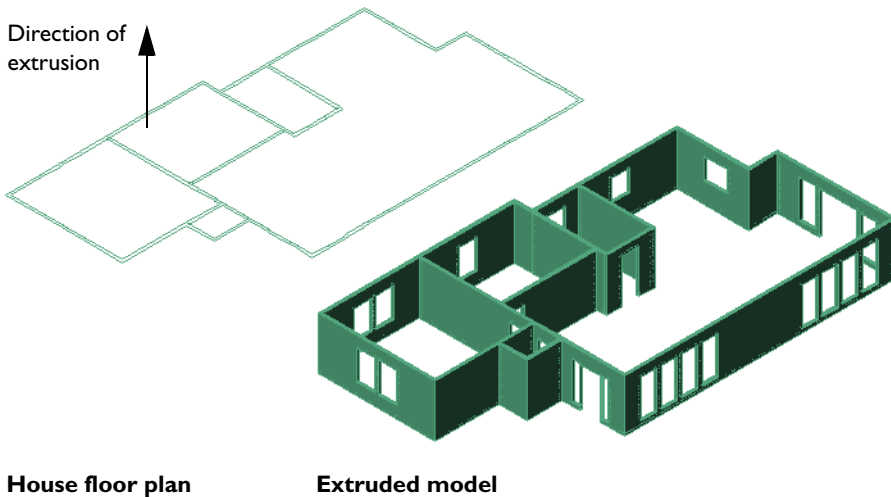
What's inside...

To create basic 3D solid objects, you can extrude closed objects, such as closed 2D polylines, revolve them around an axis, or sweep them along a path. You can also create solids using primitives, which include boxes, cylinders, pyramids, and spheres.

Extrude 2D Objects	38
Revolve 2D Objects Around an Axis	45
Sweep 2D Objects Along a Path	49
Use Primitives	52
Create Landscaping	54

Extrude 2D Objects

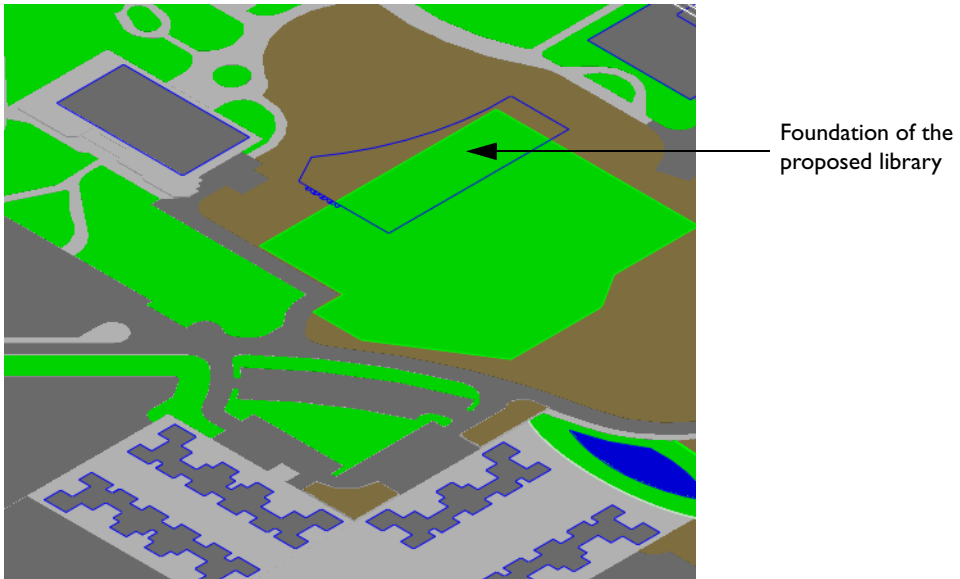
One of the best things about creating solid models with AutoCAD is that you can start with 2D drawings. For example, the floor plan illustrated below was extruded to form a 3D solid model.



After you create basic solids, you can then combine them with other solids to create more complex solids. For example, in the illustration, the window openings were subtracted from the solid walls. How to combine solids will be explained in the next chapter. It is important to become familiar with how to create basic solids first.

Try it:

- 1 Open the drawing *51 Campus.dwg*.
This is a plan view of part of a university to be used for a massing study for a new library.
- 2 Use 3D Orbit to obtain an isometric view. Right-click and set the projection style to Perspective.
- 3 Locate and zoom into the site for the new library.



Notice that the foundation of the building is composed of lines and an arc. To extrude these as a single object, they need to be joined together into a single 2D polyline. To do this, you can use the Join option of the PEDIT command, or you can use the much faster BOUNDARY command.

- 4 Change the current layer to 32 LIBRARY and zoom into the lines and arc of the library foundation.
- 5 Turn off the following layers: 20 CURBS AND WALKWAYS, 21 LANDSCAPE, 30 BUILDINGS, and 31 ATHLETICS.
- 6 On the command line, enter **boundary**.

40 Chapter 5 Create Basic Solids

- 7 In the Boundary Creation dialog box, clear the Island Detection box. Then click Pick Points and click anywhere within the outline of the library foundation. After the boundary is displayed, press ENTER to end the command.

A closed 2D polyline in the shape of the library foundation is created on the current layer, 32 LIBRARY. The original lines and arc are still on the 03 FOUNDATIONS layer to use later if needed.

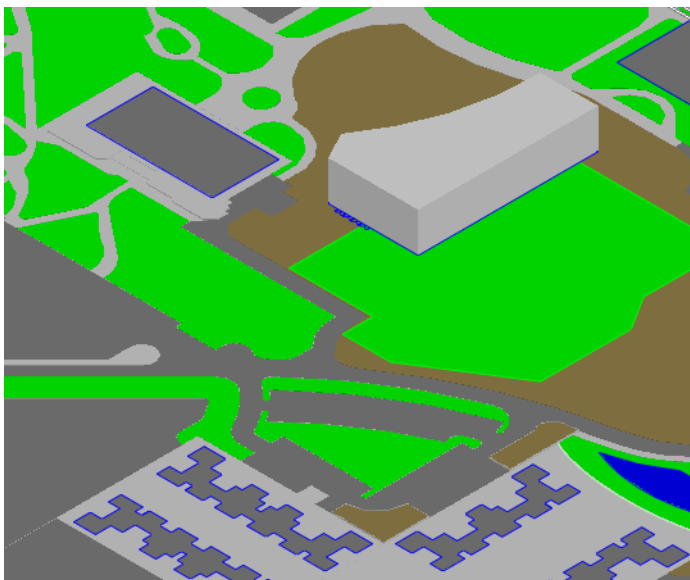
TIP Turn off unnecessary layers and zoom into the area of the boundary to be created. This speeds up the operation by reducing the number of objects to be processed. Always make sure that the XY plane of the UCS is in the same plane as the objects to be used to create the boundary.

- 8 Turn the 03 FOUNDATIONS layer off.
- 9 Click Draw menu > Modeling > Extrude and select the polyline. Enter **62** as the height and press ENTER to specify a 0 degree taper angle.
- 10 Turn the 03 FOUNDATIONS, 20 CURBS AND WALKWAYS, 21 LANDSCAPE, 30 BUILDINGS, and 31 ATHLETICS layers back on.
- 11 Zoom out to see the overall effect. Keep the drawing file open.

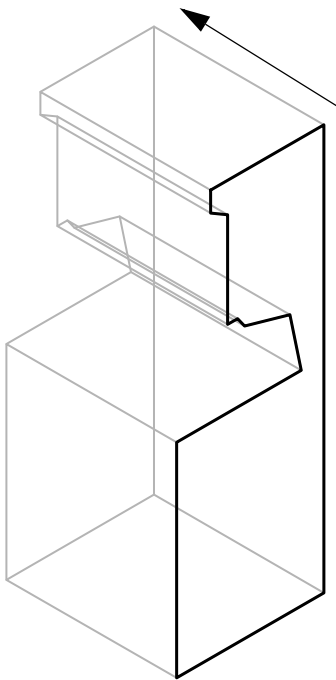
A basic 3D representation of the building is now visible.

Note that the 2D polyline was deleted in the process of extruding the building. If you want to retain the 2D objects that generate 3D solids, you can set the DELOBJ system variable to 0 (off).

TIP Solid objects created from 2D polylines or regions are always created on the current layer, not the layers of the original 2D objects.

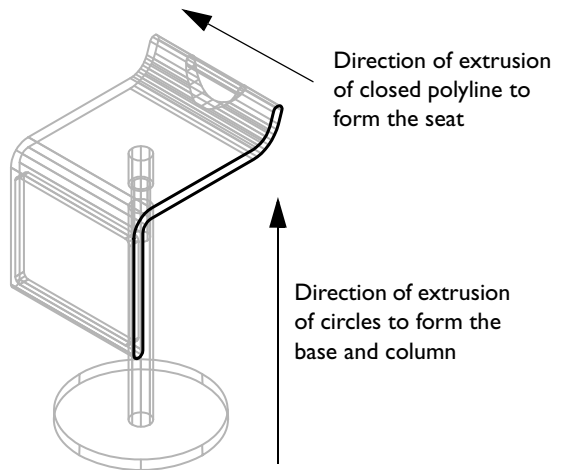


Extrusions don't all have to be "upward." It is often useful to extrude objects "sideways." This is how the kitchen stove and the stool used in previous illustrations were created.



Direction of extrusion of closed polyline

Kitchen stove from 31 Kitchen.dwg



Direction of extrusion of closed polyline to form the seat

Direction of extrusion of circles to form the base and column

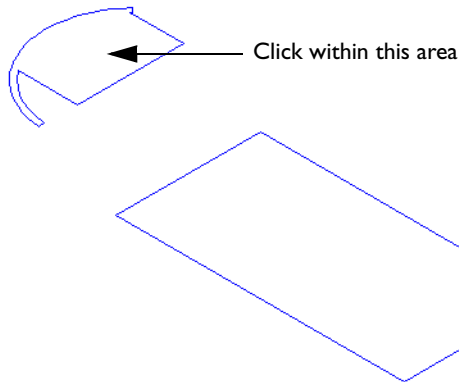
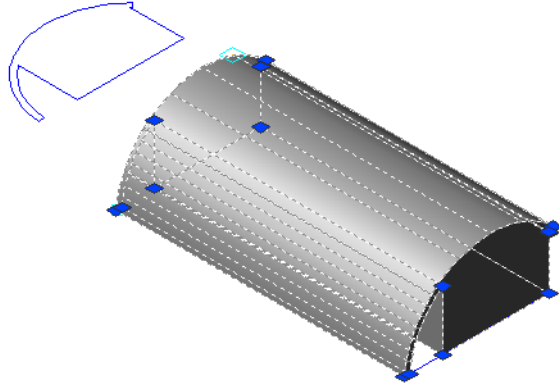
Stool from 33 Stool.dwg

42 Chapter 5 Create Basic Solids

For example, you can create a steel storage building for this campus using this method.

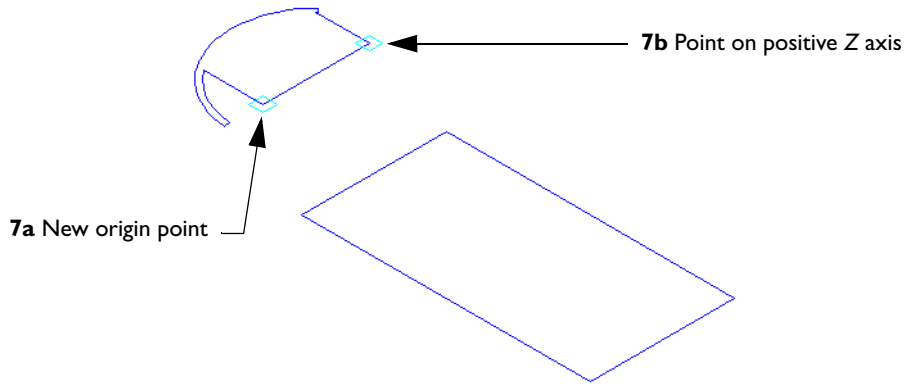
Try it:

- 1 Zoom in on the existing storage building and delete it.
- 2 Set the current layer to 30 BUILDINGS. Turn off the layers 10 BASE, 21 LANDSCAPE, and 20 CURBS AND WALKWAYS.
- 3 On the command line, enter **boundary**.
- 4 In the Boundary Creation dialog box, clear the Island Detection box. Then click Pick Points and click anywhere within the outline of the storage building profile. After the boundary is displayed, press ENTER to end the command.

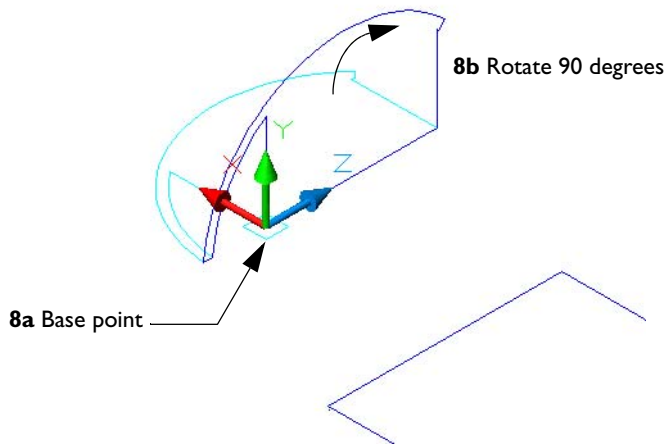


- 5 If necessary, click the DUCS button on the status bar to turn it off.
- 6 Click Tools menu > New UCS > Z Axis Vector.

7 Specify the Z axis of the UCS by clicking two endpoints as illustrated.



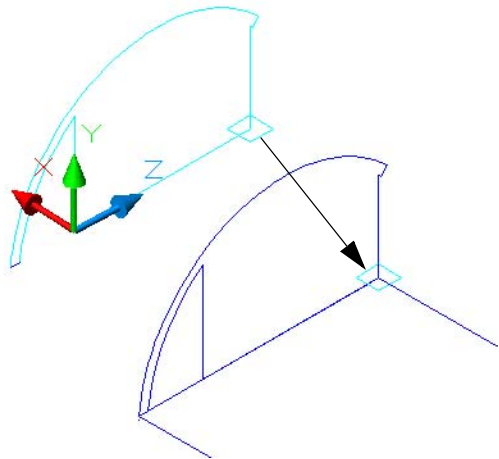
8 Select the polyline boundary of the storage building and then rotate it 90 degrees as illustrated.



44 Chapter 5 Create Basic Solids

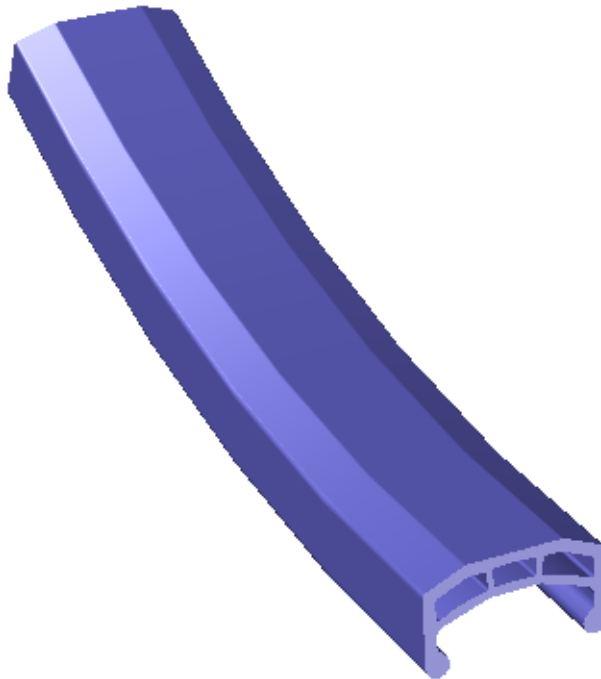
- 9 Move the polyline boundary into place onto the edge of the building foundation using object snaps as illustrated.
- 10 Click Draw menu > Modeling > Extrude and select the polyline boundary. Enter **105** as the length.
- 11 Turn the 10 BASE, 21 LANDSCAPE, and 20 CURBS AND WALKWAYS layers back on to see the storage building in context. Turn off the 03 FOUNDATIONS layer, which contains the building footprints in this drawing.
- 12 Close the drawing.

NOTE There may be an additional prompt whether to delete the extruded objects depending on the setting for the DELOBJ system variable.



Revolve 2D Objects Around an Axis

In addition to extruding 2D polylines, circles, ellipses, and regions in a linear direction, you can also create 3D solid objects by revolving them around an axis. For example, let's say you need a dramatic illustration to advertise a new bicycle rim. You want the result to look like this.



To create the 3D solid, you start with the 2D section of the bike rim. Once you locate the axis of revolution, you can revolve the section up to 360 degrees.

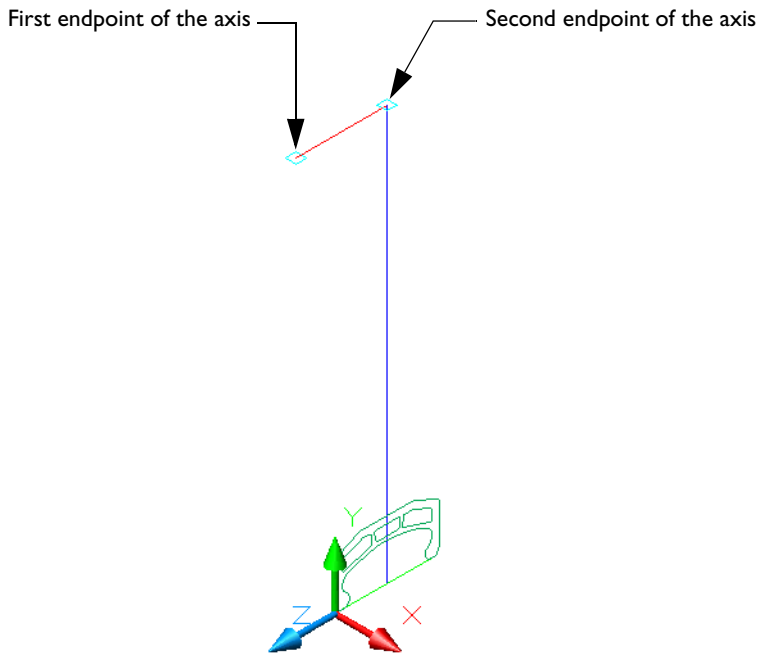
Try it:

- 1 Open the drawing *52 Bike Rim.dwg*.
- 2 Click Tools menu > Inquiry > Distance and verify the length of the dark blue line. This line represents the distance between the outside edge of the rim and the red centerline of the hub of the wheel. The radius of the bike rim is 311 mm.

TIP When working in 3D, it is an excellent idea to check coordinates, distances, and lengths of objects frequently.

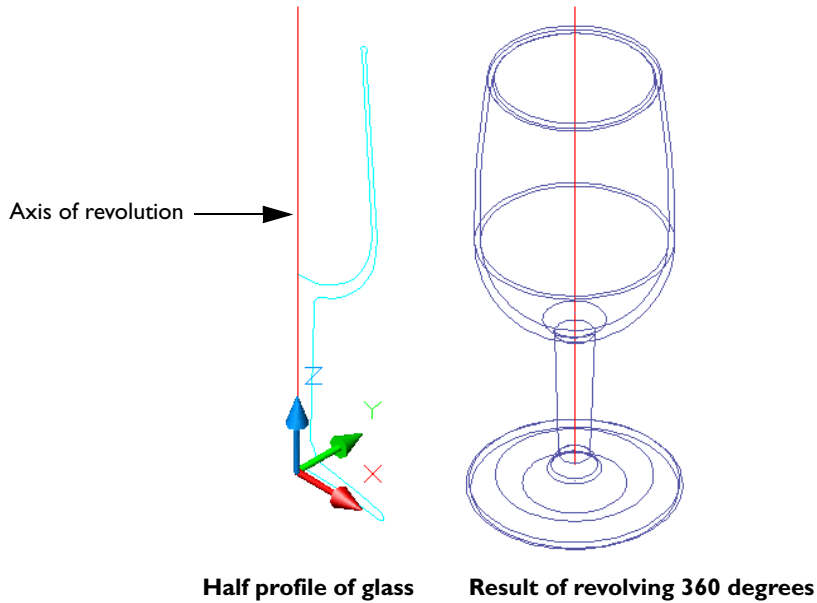
46 Chapter 5 Create Basic Solids

- 3 Click Draw menu > Modeling > Revolve. Select the bike rim section and then specify the endpoints of the red axis of revolution as illustrated.



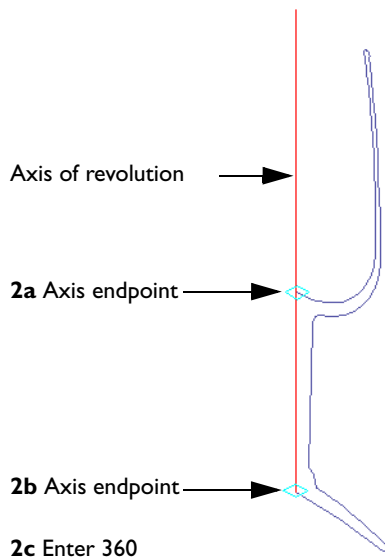
- 4 For the angle of revolution, enter **30** degrees.
- 5 Turn off the 00 REFERENCE layer. You can turn off the display of the UCS icon by clicking View menu > Display > UCS Icon, and clearing the On item.
- 6 Use 3D Orbit to experiment with visual styles, perspective projection, and viewing angles.
- 7 Close the drawing file.

In some circumstances, you will need to revolve an object around an axis that is internal to the solid. In this case, you revolve only half the profile around the axis as shown in the following drawing of a glass.



Try it:

- 1 Open the drawing *53 Glass.dwg*.
- 2 Revolve the profile 360 degrees around the endpoints of the centerline of the glass.



TIP Sometimes snapping to an endpoint when you specify an axis involves locating an object in an area that is densely populated with other objects. Instead of zooming in to the endpoint, you can often save time and avoid errors by using a midpoint object snap instead.

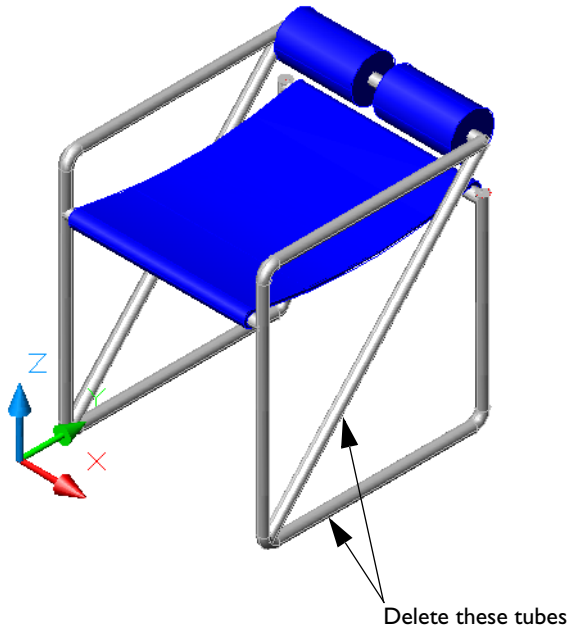
- 3 Use 3D Orbit to change the visual style and view of the glass.
- 4 Enter **-shademode** on the command line and specify Gouraud. Click the X-ray Mode button on the dashboard. Use 3D Orbit to view the glass.
- 5 Close the drawing file.

Sweep 2D Objects Along a Path

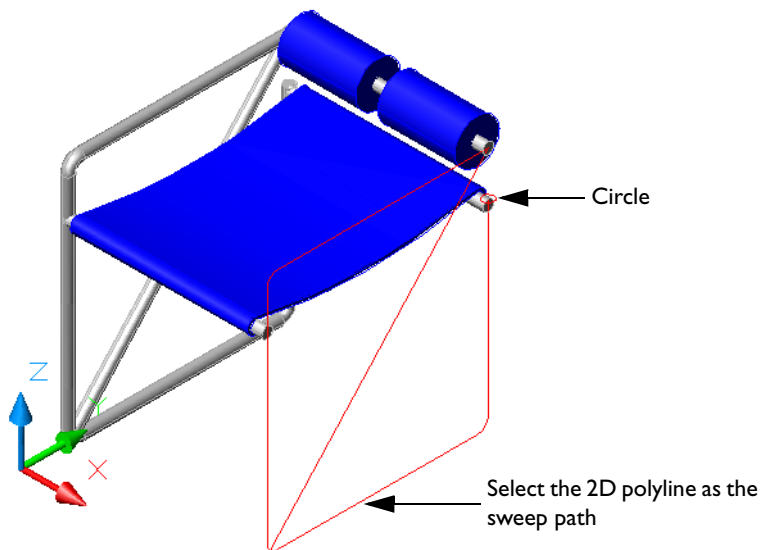
You can create a solid by sweeping a circle, rectangle, or other closed 2D object along a 2D or 3D path. This is an efficient method to use when you create rails, pipes, tubes, and ducts.

Try it:

- 1 Open the drawing *54 Chair.dwg*.
- 2 Delete the metal tubes as illustrated.



- 3 Turn on the 00 REFERENCE layer. The defining 2D polylines and circle are now visible.
- 4 Change the DELOBJ system variable to 0 (off). This setting retains the defining geometry for the sweep operation that follows.

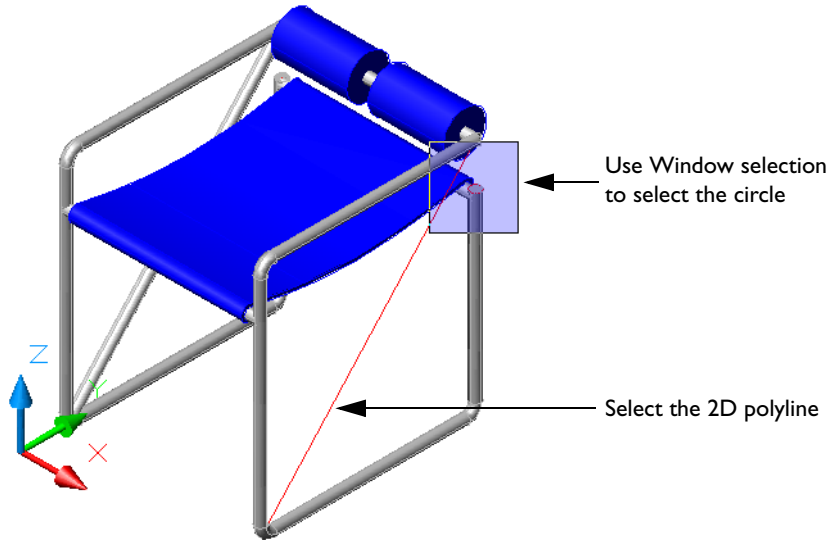


5 Click Draw menu > Modeling > Sweep. Select the circle and press ENTER.

6 Select the sweep path as illustrated. The circle is not deleted.

To create the diagonal brace, you can sweep the same circle along the diagonal polyline.
You do not have to align the circle with the path!

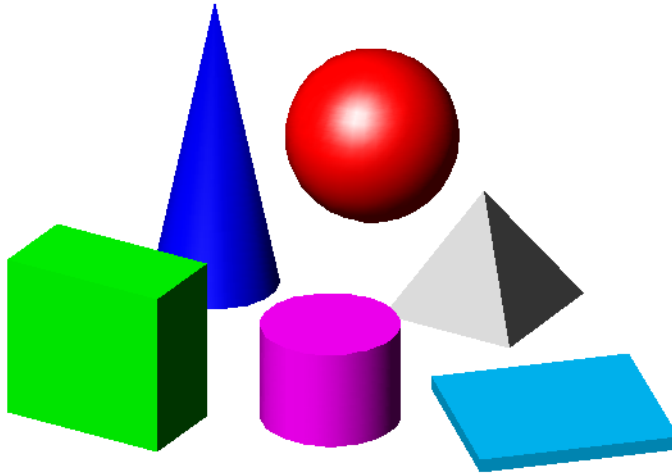
- 7 Repeat the SWEEP command and use a window selection to select the circle (enter **w** at the Select Objects prompt). This is necessary because the circle is “under” the solid tube and cannot be selected directly. Then select the remaining polyline as the path.



- 8 Take some time to experiment with sweeping your own closed objects along different paths.
- 9 Close the drawing file.

Use Primitives

A more spatially oriented method of creating solids is to model starting with solid *primitives*—boxes, pyramids, cones, cylinders, and so on.



All of these primitives are listed on the Draw > Modeling menu and on the dashboard in the 3D Modeling workspace. They are easy and intuitive to use.

Try it:

- 1 Open the drawing *51 Campus.dwg*.
- 2 Zoom into the upper-left corner of the model and use 3D Orbit to display an isometric view.

Some enterprising but mischievous engineering students have dismantled and removed a famous sculpture from its circular pad.



You have been commissioned to create a new sculpture in its place.

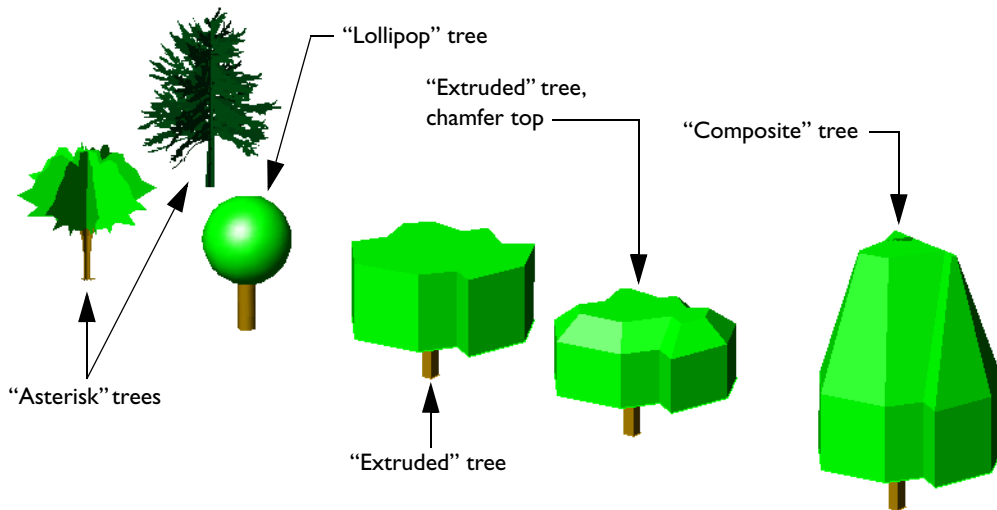
- 3 Use solid primitives to make a creative and colorful replacement. Don't forget to change the orientation of the UCS workplane to orient several primitives.
- 4 Close the drawing file.

Create Landscaping

Landscaping presents a special challenge to architectural models. It is not necessary or advisable to model a tree or shrub down to its leaves and twigs. Thus, there are several choices regarding the appropriate type and level of abstraction that you can use. Consider the following:

- Landscaping is typically meant to convey an effect or idea without drawing unnecessary attention to itself and away from the architecture.
- 3D landscaping can be used to check views and visual interferences.
- Excessive detail will make a model unnecessarily large and will slow performance.
- Excessive abstraction will draw attention to unlikely looking landscaping.

The following illustration shows several techniques for creating trees or shrubs.

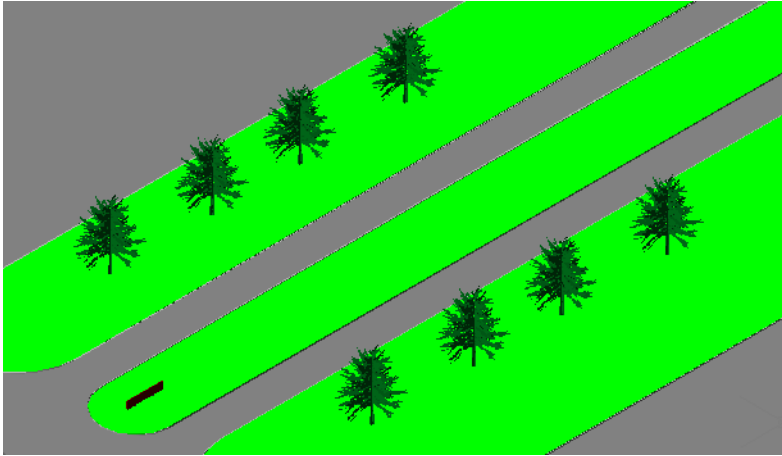


Try it:

- 1 Open the drawing *55 Trees.dwg*.
- 2 Use 3D Orbit to view the tree representations from different angles, including the top.
- 3 Try creating your own version of a tree.
- 4 Open the drawing *51 Campus.dwg*.

- 5 Zoom into the lower-left corner of the campus model and use 3D Orbit to view the “asterisk” trees inserted along the university entrance.

These trees were created by tracing an imported image in AutoCAD and then converting the polylines into regions. Four regions were copied and rotated to create an asterisk pattern when viewed from the top. The result was saved as a block.



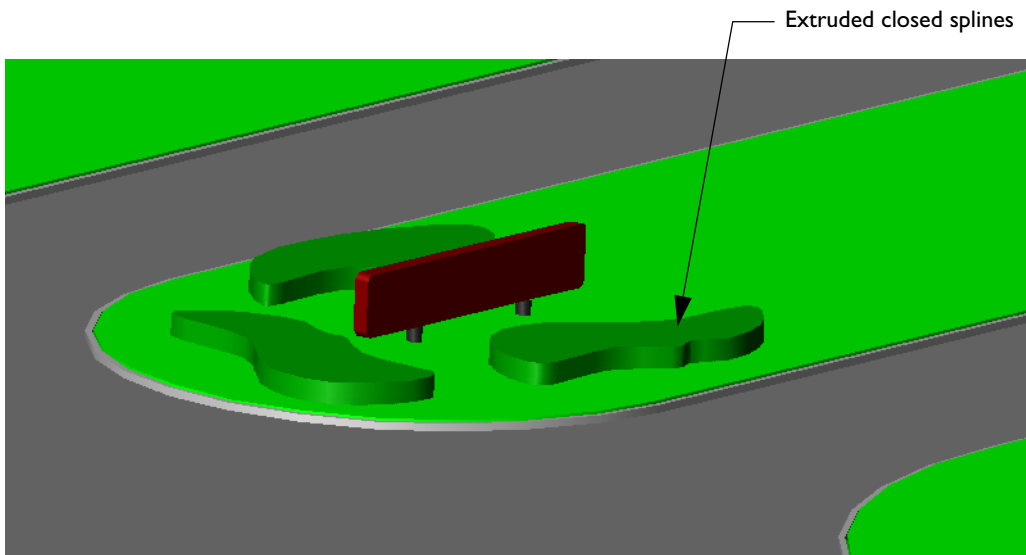
- 6 Copy the trees to other locations on campus.
- 7 Experiment with other styles of trees or make more of your own.

TIP After creating a tree, save it as a block. This reduces the size of a drawing if you insert the block multiple times.

56 Chapter 5 Create Basic Solids

To create some simple shrubs, you can extrude closed splines.

- 1 Zoom into the area of the sign that is visible in the lower-left corner of the campus. If necessary, use 3D Orbit to adjust the viewing angle.
- 2 Set the current layer to 21 LANDSCAPE.
- 3 If necessary, open the Properties palette.
- 4 Using the Properties palette, override the BYLAYER color to a darker shade of green.
- 5 Click the DUCS button on the status bar to turn on Dynamic UCS.
- 6 Start the UCS command, click the grass area near the sign, and press ENTER. This locates the XY plane of the UCS on the surface of the grass.
- 7 Click the DUCS button on the status bar to turn off Dynamic UCS.
- 8 Draw several closed splines and extrude them 2 feet to create areas covered by shrubs.
When creating the splines, turn off object snaps and change to a more nearly vertical view.



- 9 Close the drawing file.

6

Combine and Modify Solids

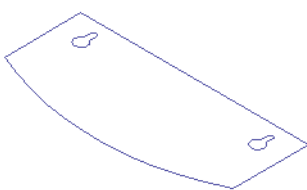
What's inside...

To merge 3D solids, you can use **Boolean** operations such as **Union** and **Subtract**. You can create new solids from the intersecting volumes of existing solids, and you can also relocate faces and edges of solids.

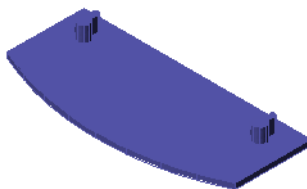
Add and Subtract Solids	58
Intersect Extruded Profiles	68
Control the Level of Detail	74
Use Detail to Control Attention	76

Add and Subtract Solids

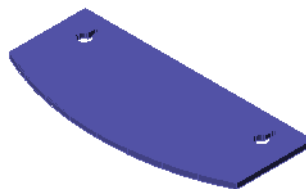
After you create 3D solids, you can join them together with *Boolean operations* such as Union and Subtract. For example, to create keyhole slots in a panel, you subtract the keyholes from the panel, as shown in the illustration—the keyholes were extruded a greater distance than necessary to make them easier to see and select.



Original polylines

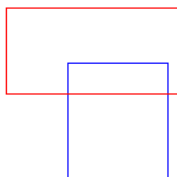


Extruded solids

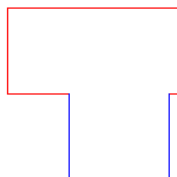


Result after subtraction

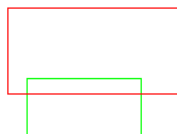
You can also use Boolean operations to combine several 2D region objects into a single region before extruding them. For example, the rectangles in the following illustrations were first converted into regions and then combined.



Two regions



Union the red and blue regions



Two regions



Subtract the green region from the red region

NOTE Edge and face colors of 2D regions and 3D solids are retained after Boolean operations.

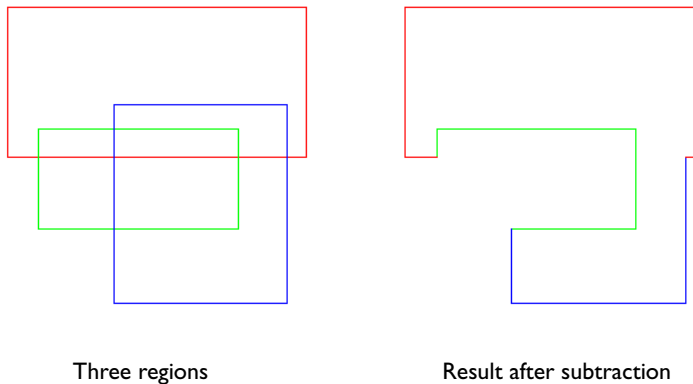
Try it:

- 1 Open a new drawing and display a 2D plan view.
- 2 On the command line, enter `delobj`. Make sure it is set to 1 (on).
- 3 Create several overlapping closed polylines, rectangles, and circles.

- 4 Click Draw menu > Region and select all the objects you created.
- 5 Press ENTER.
These objects have now been converted into region objects.
- 6 Click Modify menu > Solid Editing > Union and select two overlapping objects.
- 7 Click Modify menu > Solid Editing > Subtract.
- 8 Select another object and press ENTER.
- 9 Select an overlapping object that you want to subtract from the previously selected object and press ENTER.

Notice that the SUBTRACT command works like the TRIM and EXTEND commands in that they use two selection sets: the objects to keep and the objects to subtract from them.

In the following illustration of the Subtract operation, the red and blue regions are selected first. Then the green region is selected to subtract from the first two regions. The result combines the three rectangles into a single region.



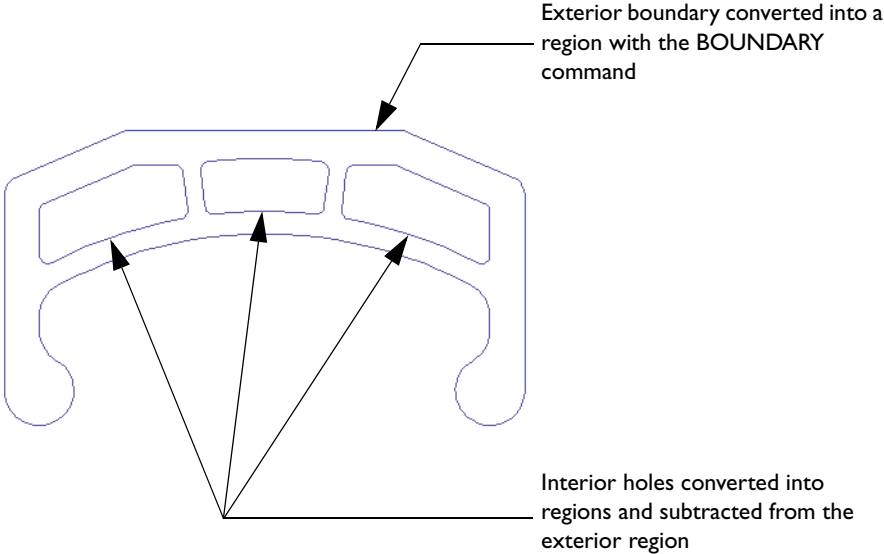
Try it:

- 1 Create three regions as shown in the illustration. Use RECTANG and then REGION.
- 2 Click Modify menu > Solid Editing > Subtract.
- 3 Select two overlapping regions and press ENTER.
- 4 Select another overlapping region and press ENTER.
- 5 Try several more examples using circular, rectangular, and polygonal regions.
- 6 Extrude or revolve the resulting complex region as a single object.

TIP You can create solid models efficiently by combining regions in 2D and then extruding, revolving, or sweeping them in 3D.

60 Chapter 6 Combine and Modify Solids

The 2D section of a bicycle rim in the previous chapter was created using this method.

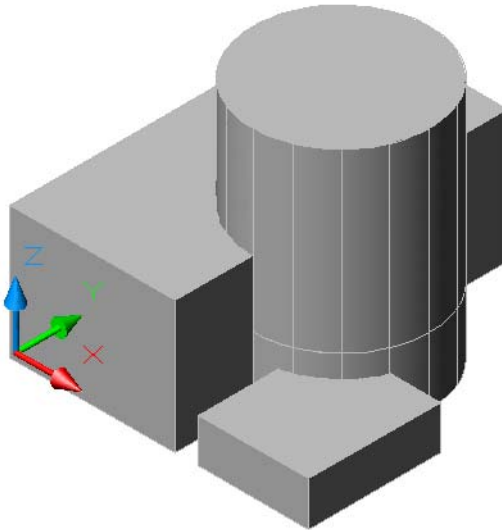


The Union and Subtract operations work identically with 3D extrusions and primitives.

Try it:

- 1 Open the drawing *61 Hall.dwg*.

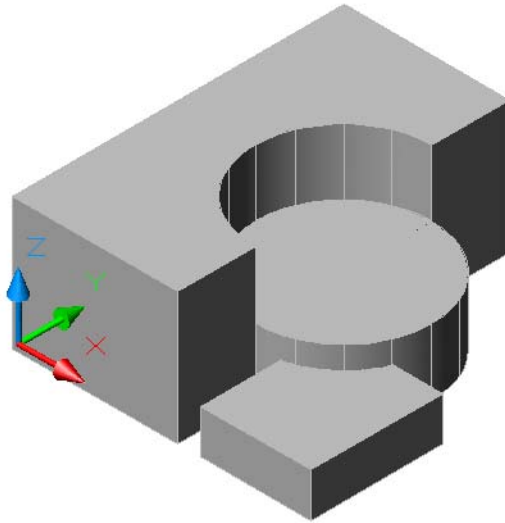
This is the beginning of a gray-colored massing model of a concert hall.



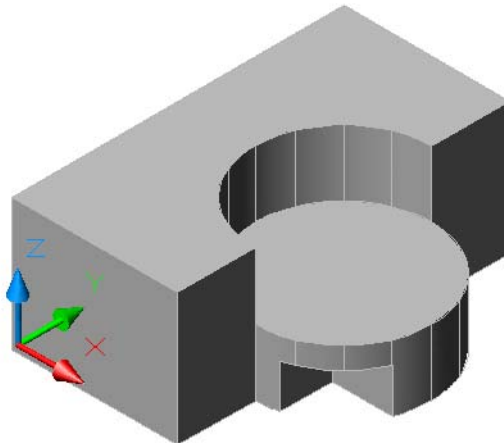
TIP Avoid using index color 7, White, for solids. Objects created with index color 7 display as black or white depending on the current background color. For white objects, use a True Color setting of 255,255,255 instead.

62 Chapter 6 Combine and Modify Solids

- 2 Subtract the top cylinder from the large box.



- 3 Union the remaining cylinder and the complex solid.
- 4 Subtract the small box from the complex solid.

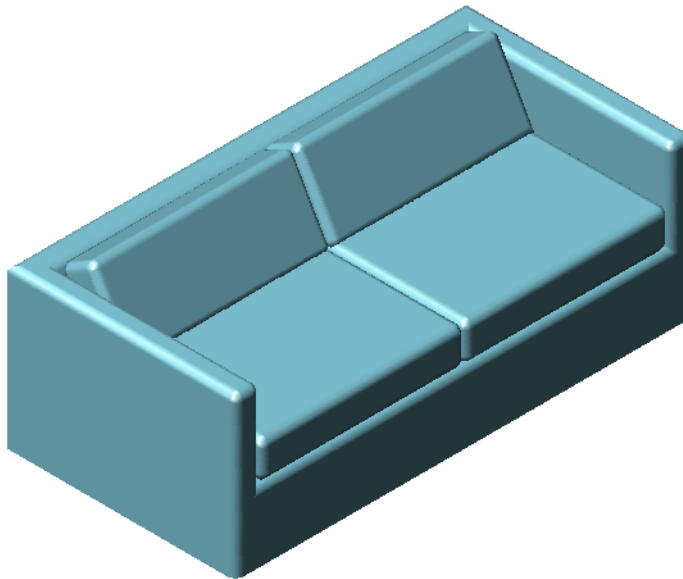


- 5 Undo all your previous steps and see whether you can get the same result with a single subtract operation.

TIP There are two selection sets in the SUBTRACT command.

- 6 Close the drawing file.

There are usually several ways to create any solid model. For example, the couch in the illustration could have been created using primitives and a series of Union operations. It is easier in this case to use a Subtract operation.



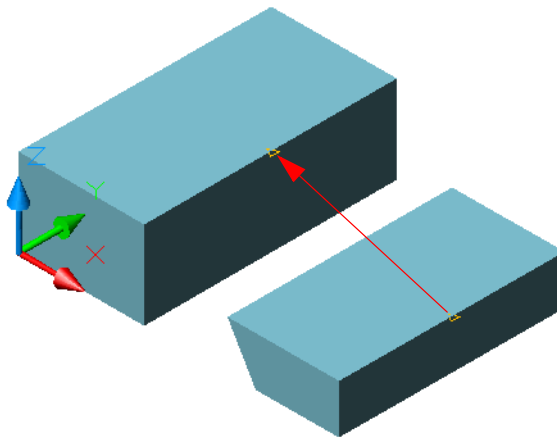
Try it:

- 1 Open the drawing *62 Couch.dwg*.

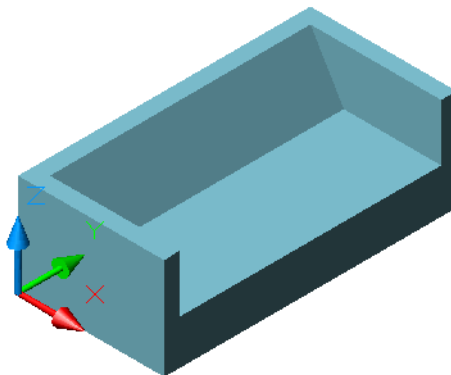
This drawing contains two solids: a box primitive and an extruded trapezoidal polyline.

64 Chapter 6 Combine and Modify Solids

- 2 Move the extruded solid onto the box as illustrated, using Midpoint object snaps.

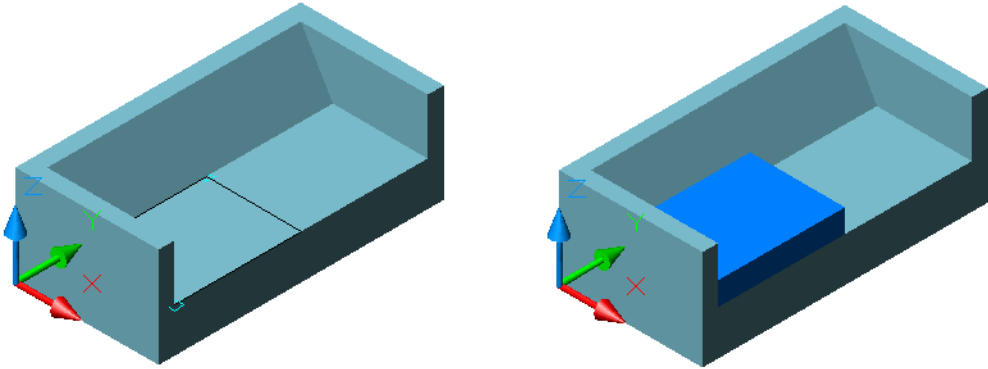


- 3 On the command line, enter `3dselectionmode` and then enter 0. This enables you to select the object you moved, which is now inside the box primitive.
- 4 Subtract the extruded solid from the box primitive. After you start the Subtract operation, select the box, press ENTER, and then select the extruded object. The basic shape of the couch is complete.

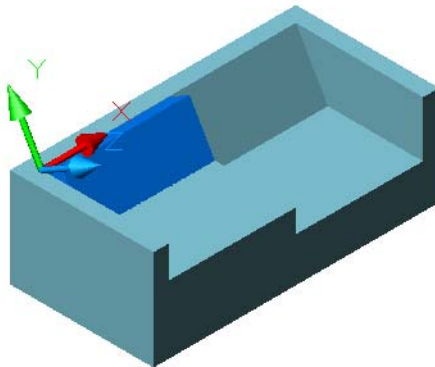


- 5 Before creating the cushions, set the current layer to 20 CUSHION.

- 6 Create a box using the object snaps shown in the illustration and give the box a height of 150 mm.

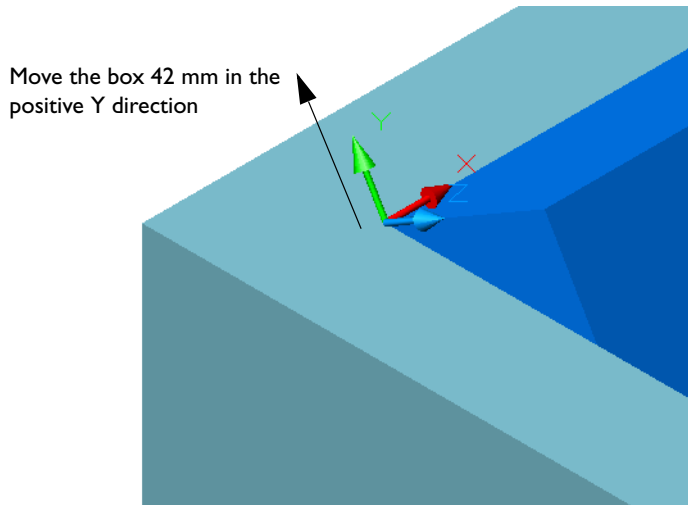


- 7 Set the UCS working plane on the angled face of the couch using the Face option of the UCS command. Click near the upper-left corner of the couch.
- 8 Create a box on the working plane starting at the origin point with a length of 815 mm, a width of *negative* 330 mm, and a height of 150 mm.

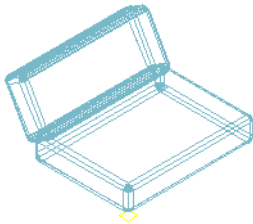


66 Chapter 6 Combine and Modify Solids

- 9 Move the box 42 mm in the Y axis as illustrated. Then return the UCS to its previous (WCS) location.



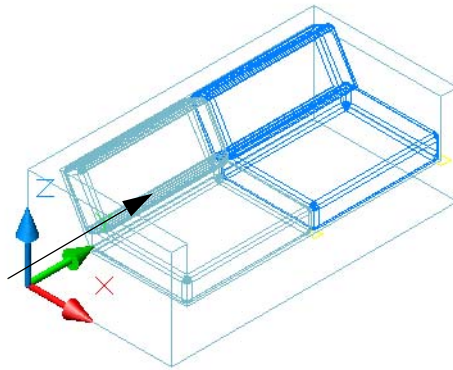
- 10 Turn off layer 10 COUCH.
- 11 Change the visual style of the couch to 3D Wireframe. Use the FILLET command to round all 12 edges of each cushion with a fillet radius of 30 mm.



TIP To make sure that the corners of solids blend correctly, select all intersecting edges of each object in a single FILLET command.

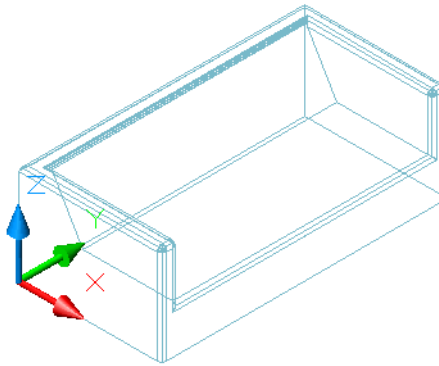
- 12 Turn layer 10 COUCH back on.

13 Use object snaps to copy the seat and back cushions as illustrated.



14 Turn off layer 20 CUSHION.

15 Round the corners of the couch as illustrated. Use a fillet radius of 30 mm.



TIP Delay filleting and rounding edges until the very end. You will find that sharp edges and corners are often needed as reference locations to create, move, copy, and mirror other objects.

16 Turn layer 20 CUSHION back on.

17 Change the visual style to Realistic or enter **-shademode** to specify Gouraud.

18 Use 3D Orbit to view your completed model.

19 Turn layer 30 PILLOW on for a special touch.

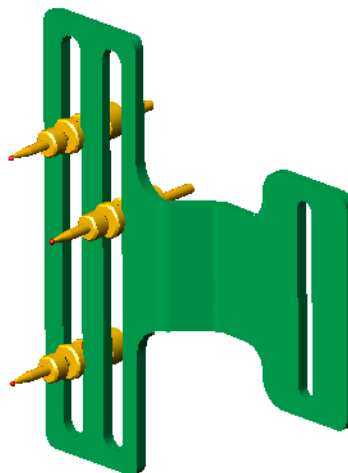
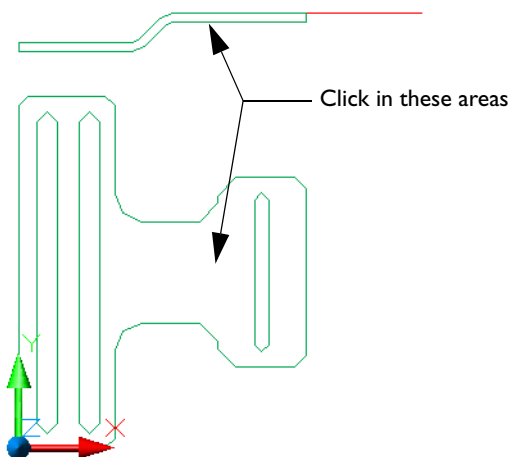
20 Close the drawing file.

Intersect Extruded Profiles

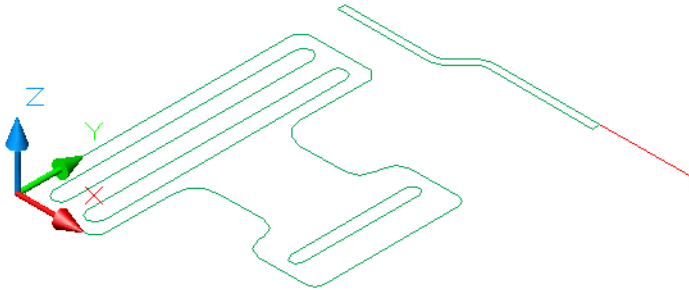
Another powerful Boolean command is INTERSECT. Intersect operations create solid objects from the common volumes of overlapping solids. There are several efficient construction techniques that use Intersect operations. For example, you can easily create the bracket from an old-fashioned bow sight used in the sport of archery by intersecting the extruded 2D views.

Try it:

- 1 Open the drawing *63 Bowsight.dwg*.
- 2 Use the BOUNDARY command to create regions out of each of the closed loops in the drawing. In the Boundary Creation dialog box under Object Type, click Region from the drop-down list. Click Pick Points and click in the areas as shown in the illustration.



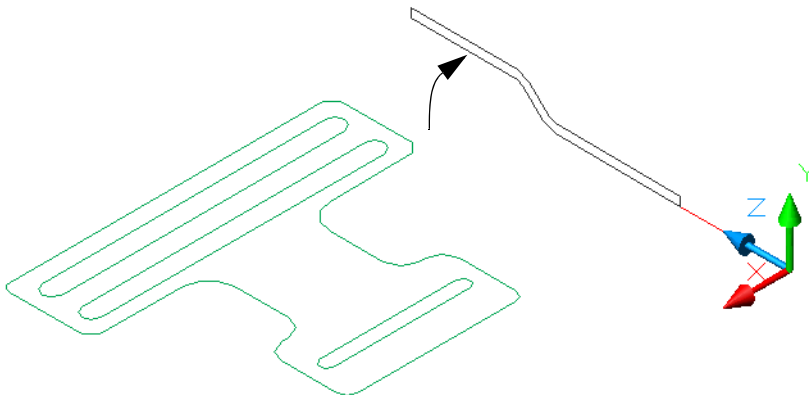
- 3 Use the SUBTRACT command to subtract the three slots from the bracket. You should be left with two region objects: a top profile and a front profile.



- 4 Use 3D Orbit to display a 3D view of the bracket.
- 5 Turn off the layers 10 FRONT and 20 TOP. You used the objects on these layers to create the profiles on the current layer, 30 SOLID.

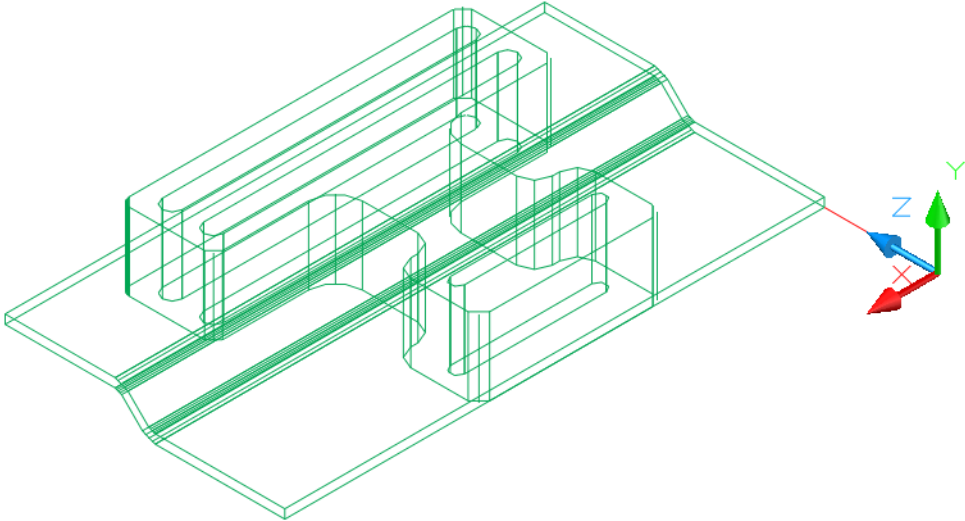
TIP Always retain 2D reference geometry and construction lines. These objects will be very handy for future additions and changes. Whether these objects are retained or deleted depends on the setting of the DELOBJ (delete object) system variable.

- 6 Align the Z axis of the UCS with the red reference line and rotate the top profile 90 degrees as illustrated.

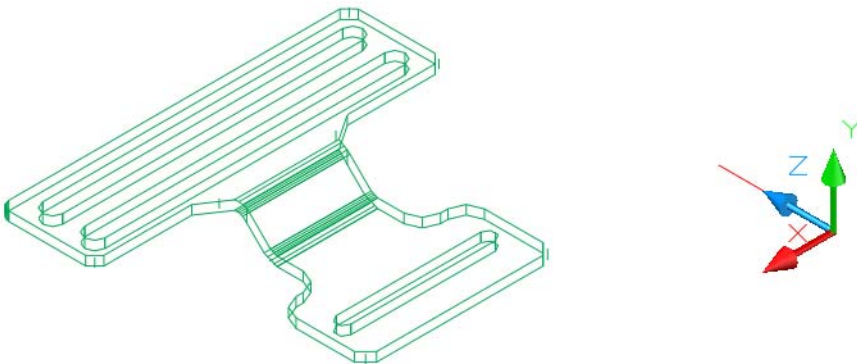


70 Chapter 6 Combine and Modify Solids

- 7 Extrude both profiles. To specify the extrusion distance, click a starting point and move the pointer. The exact distance does not matter, only that the extrusions pass completely through each other.

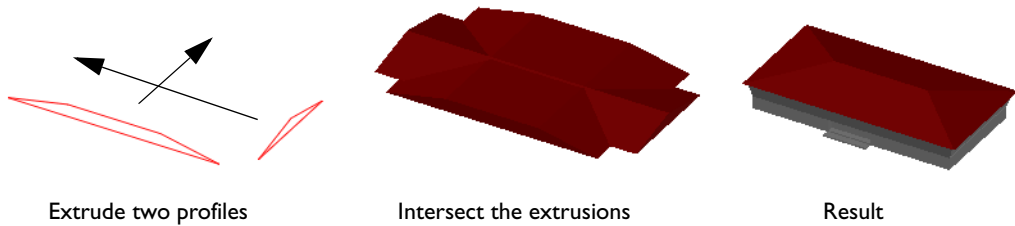


- 8 Start the INTERSECT command, select both extrusions, and press ENTER.

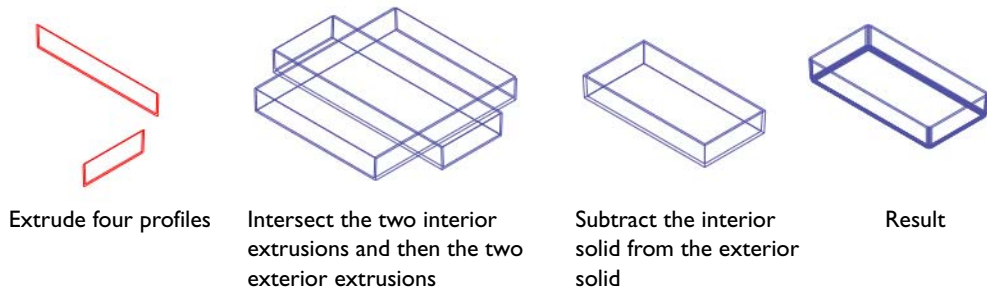


- 9 The bracket model is complete. Use the 3DORBIT command to specify different visual styles, projections, and viewpoints.
- 10 Close the drawing file.

Another example of intersecting two extruded profiles is shown in the following illustration of a hip roof. You can examine the model in detail and try out the technique by opening the drawing *64 Roof.dwg*.

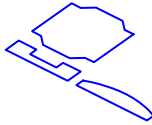


The next illustration shows how you can create a plastic box with a two-degree draft angle. In this example, two closed polylines, an interior one and an exterior one, were created for each profile. You can examine the model in detail and try out the technique by opening the drawing *65 Box.dwg*.

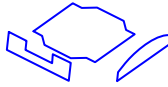


72 Chapter 6 Combine and Modify Solids

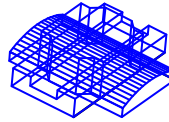
This same technique can be extended to three profiles. For example, to create a massing model of a museum, you can intersect the extrusions of the front, top, and side elevations. The steps in the process are displayed in the following illustration.



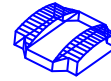
Foundation plan and two elevations



Rotate the elevations into place



Extrude the profiles through each other



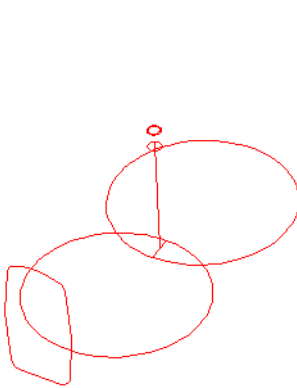
Intersect the three extrusions

Try it:

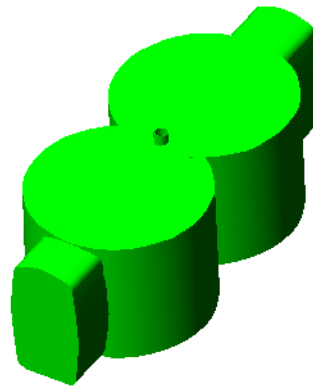
- 1 Open the drawing *66 Profiles.dwg*.
- 2 Extrude the elevations and foundation plan so they completely cross through each other.
- 3 Use the INTERSECT command to create the massing model.
- 4 Close the drawing file.

Many municipalities are beginning to require massing models as a part of the building design approval process. Some municipalities also require a second, more detailed 3D model.

The following illustration is another example of the intersection technique that was used to create the bottle in the *66 Bottle.dwg* drawing.



Reference objects



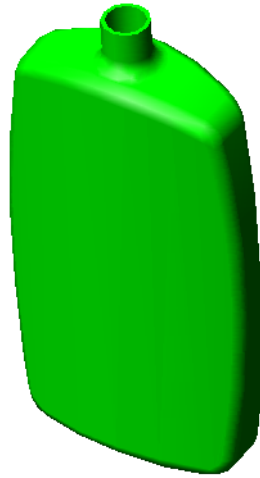
Extruded solids



Intersected solids

The final result was obtained through the union of the neck with the body of the bottle, rounding the edges with the FILLET command, and then hollowing the result with the Shell option of the SOLIDEDIT command. Finally, a small cylinder was subtracted from the top of the neck to create an opening into the hollowed interior of the bottle.

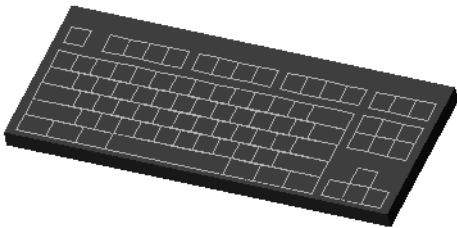
Be careful to use reasonable radius values for the FILLET command. If the radius you specify is too large, the command will fail to round or fillet the solid.



Final result after rounding edges

Control the Level of Detail

Every object that you model in AutoCAD can be constructed at different levels of detail. As you become skilled at creating solid models, you will be tempted to add more detail than necessary. For example, consider your computer keyboard. Notice the rounded edges, grooves, and curves. If you wanted to create a 3D model of the keyboard, how much detail should you include?



Low detail



Moderate detail

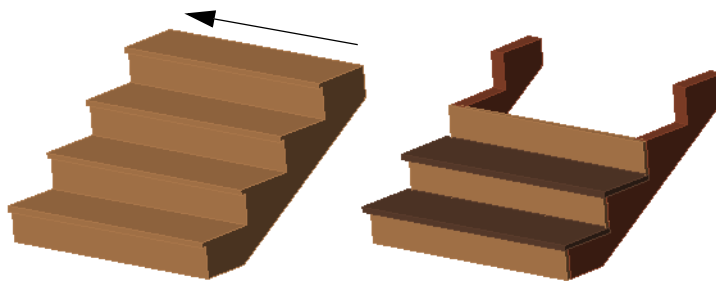
The answer depends on the intended purpose of the model. If the model is part of a representation of a furniture layout, less detail is needed. If the model is part of a detailed rendering for an advertisement, or for output to stress analysis software, much more detail is required.

Try it:

- 1 Open the drawing *67 Keyboards.dwg*. This drawing contains two representations of a keyboard, a low-detail version and a moderate-detail version.
- 2 Zoom into each keyboard model. Use 3D Orbit to view each model from several angles.
- 3 Zoom out to the point where both models appear about the same.
- 4 Close the drawing file.

Anyone want to volunteer to put the letters on the keys?

The concept of controlling detail extends to methods of model construction. For example, here are two representations of part of a staircase. Which model is better?



Extruded “sideways” from a simple polyline profile

Modeled from components to mimic construction

Again, the answer depends on what you ultimately need:

- A conceptual model for design and visualization or
- A detailed model for rendering, checking for interferences, or construction notes.

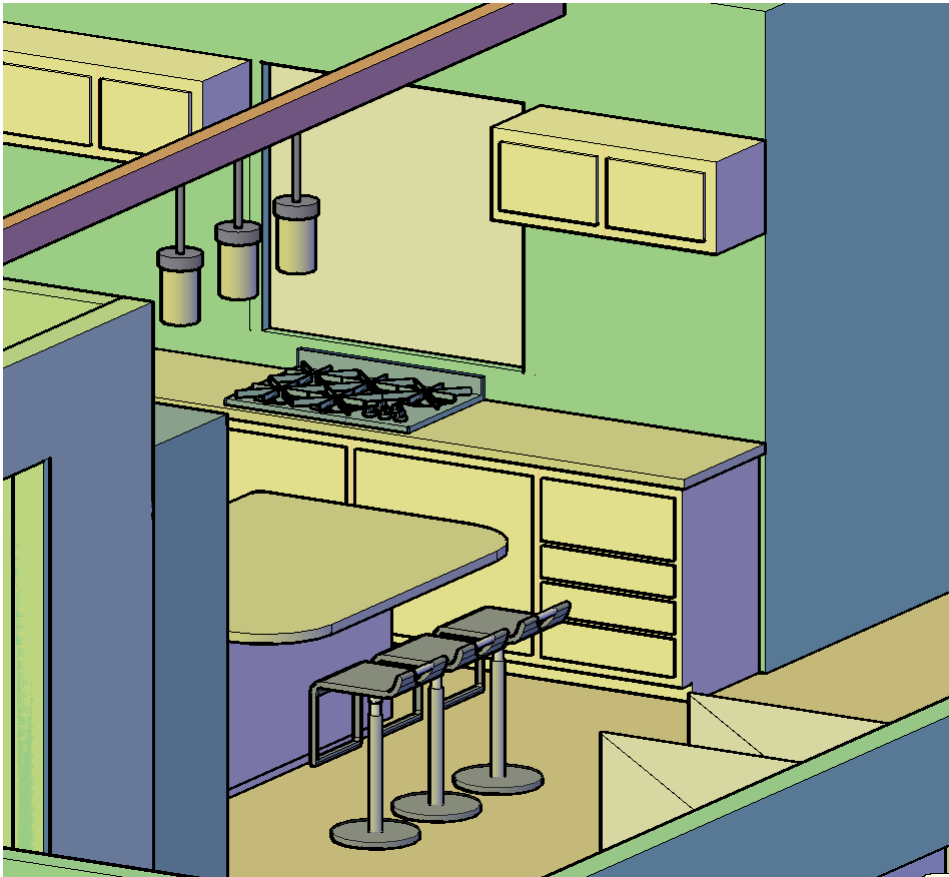
Try it:

- 1 Open the drawing *68 Stairs.dwg*. This drawing contains two representations of a small staircase, a low-detail version and a high-detail version.
- 2 Use 3D Orbit to view each model from several angles.
- 3 Close the drawing file.

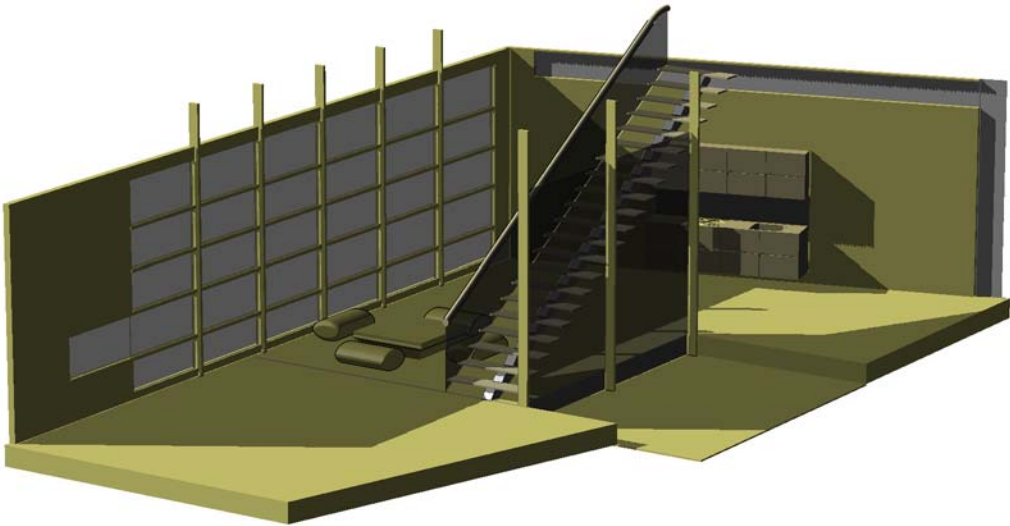
Use Detail to Control Attention

Another factor to consider involves using variations in detail level to draw attention. You can draw attention to an area of a model by increasing the level of detail in that area and reducing the level of detail in the surrounding area. The attention of your audience will be naturally drawn to the area of greater detail.

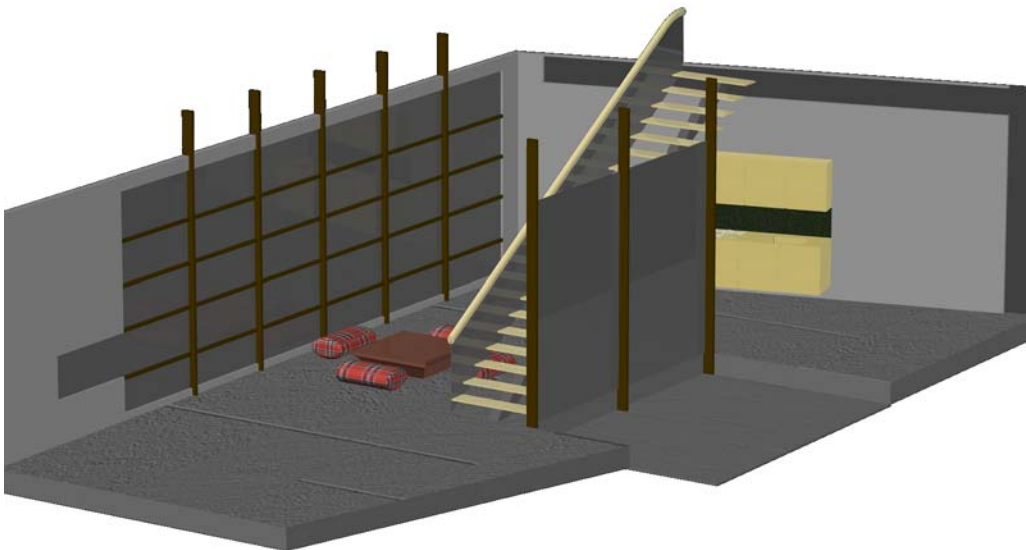
For example, in the following illustration, consider whether this image is best suited for presenting a new hanging cabinet design, or for presenting the placement of a down-draft stovetop and new lighting. What did your eye land on first?



In the following illustration, the level of detail has been kept uniform and low. The purpose is to ensure that the intended audience grasps the overall spatial effect and is not distracted by choices of materials or minor detail.



Compare the previous illustration of the room to the following rendering. What do you find your attention drawn to in the rendering?



The same principle applies to placing images of people in a model. To avoid distracting attention from your design to the clothing or expressions on the people, use outlines or translucent images of the people instead.

TIP Always remind yourself that a 3D model is a tool to achieve a purpose. Too much detail requires additional cost in time and performance. You can use detail to focus attention on a specific area of a drawing, or you can homogenize the detail in a drawing to convey an effect.



Put Your Work to Use

What's inside...

Solid models have a wide variety of uses, which include generating views for drawings, analyzing designs, and creating presentations.

- Where to Go From Here 80
- Edit Subobjects and Component Objects 81
- Create Sections 83
- Flatten 3D Views 85
- Calculate Mass Properties 86
- Walk Through or Fly Over 3D Models 87
- Check for Interferences 89
- Create Files for Manufacturing 93
- Make 3D Solids Transparent 94
- Create Realistic Images for Presentation 96
- Final Thoughts 97

Where to Go From Here

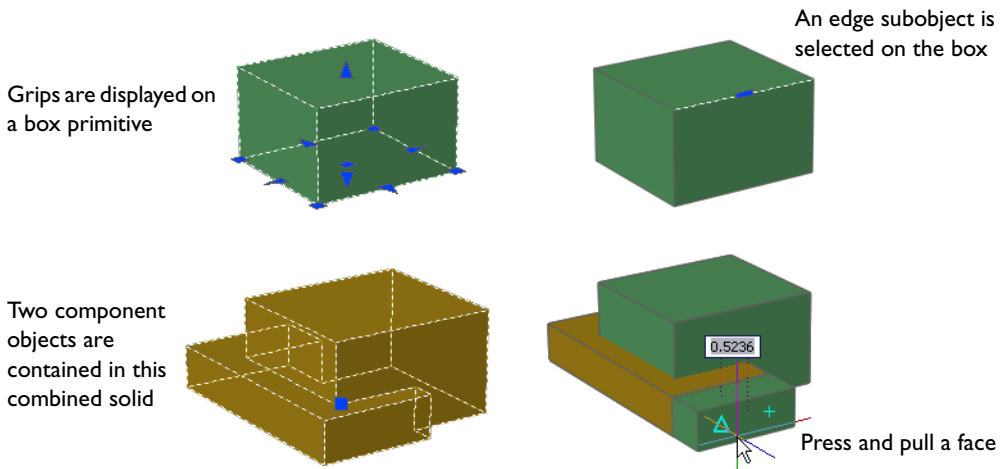
Once you create a solid model, you can use it for a variety of tasks and applications. With a solid model, you can do any of the following:

- Edit the edges, surfaces, and other subcomponents
- Create sections for analysis, visualization, and drawings
- Flatten 3D views into 2D views
- Calculate mass properties such as area or volume
- Check for visual or physical interferences
- Create files for stereolithography or numerical control manufacturing
- Perform 3D walkthroughs or flyovers
- Make 3D solids transparent or translucent
- Perform lighting studies and generate shadows
- Create presentation images using lights, materials, and textures
- Create photorealistic renderings

Some of the tasks listed will be of interest to you, while others are not relevant to your discipline. The following sections provide you with a short description of these tasks along with several illustrations and examples. References to the *User's Guide* are listed at the end of each section for additional study.

Edit Subobjects and Component Objects

By pressing CTRL as you select a solid, you can select subobjects and component objects in a 3D solid. Subobjects include edges and planar surfaces. Component objects include primitives and other solids that are combined with Boolean operations to form a complex solid. You can also edit a solid using grips to change its dimensions.



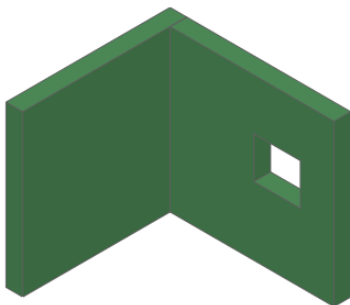
Editing subobjects and components is best suited for conceptual design. Using these features, you typically do not specify distances and angles with precision. Instead, you focus on visual and spatial effects by stretching, moving, pressing, and pulling the components of a solid model.

Try It

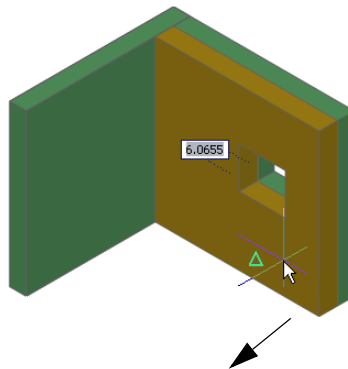
- 1 Create a model from several primitives and combine them with a Boolean operation such as UNION or SUBTRACT.
- 2 Specify a 3D isometric view and specify either the Conceptual or Realistic visual style.

82 Chapter 7 Put Your Work to Use

- 3 Enter **presspull** and move your cursor over one of the faces of the solid. You can also start PRESSPULL from the dashboard. It is located near the center of the 3D Make control panel.



Before pressing or pulling



Face is pulled, colored area indicates change

- 4 Click and then drag the surface forward and back. As you drag the face, the color of the face is set temporarily to the current color.
- 5 Click to accept the change.

Further Study in the User's Guide

Manipulate 3D Solids and Surfaces

Press or Pull Bounded Areas

Select and Modify 3D Subobjects

Use Grip Tools to Modify Objects

Create Sections

You can use several approaches to create sections. With “destructive” sectioning, you typically copy the solid model to its own layer or to a separate drawing file and then subtract another solid from your model to create the section view.

Try It

- 1 Open the drawing *71 Florett.dwg*. This is a solid model of an electric foil point used in the sport of fencing, but the interior components are not visible.
- 2 Move your cursor over the foil point. Notice that the components have been associated into several groups. Set the PICKSTYLE system variable to 0. This allows you to select grouped components individually.

TIP When you need to combine several 3D solids, but you do not want to combine them with a Union operation, assign the solids to one or more groups.

- 3 Turn off layer 10 BARREL.

Notice the interior components. Turn off several other layers to explore the design.

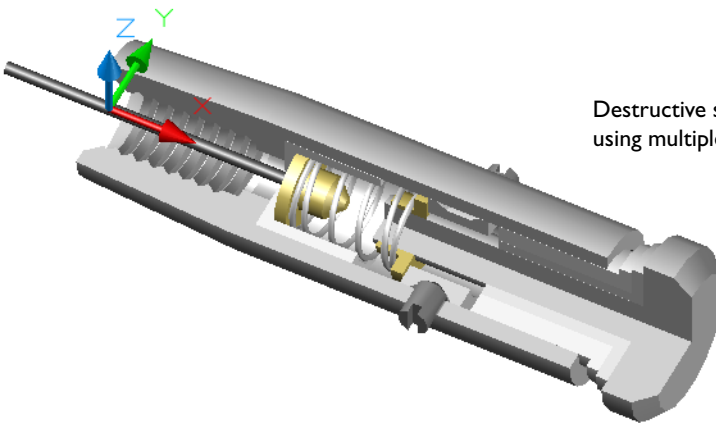
- 4 Turn off all layers except 10 BARREL and 01 BOX.

- 5 Subtract the box from the barrel. Turn on all layers except the 00 REFERENCE layer.

- 6 Use 3D Orbit to view the sectioned model.

To get a better section view, you could make a copy of the box to be subtracted, perform a Subtract operation, and then repeat for each component. If you subtract the box from all the components in one Boolean operation, it will combine the results into a single solid, which is usually not what you want to do.

- 7 Open the drawing *72 Florett-S.dwg*. This model is the result of repetitive subtractions on many of the components.



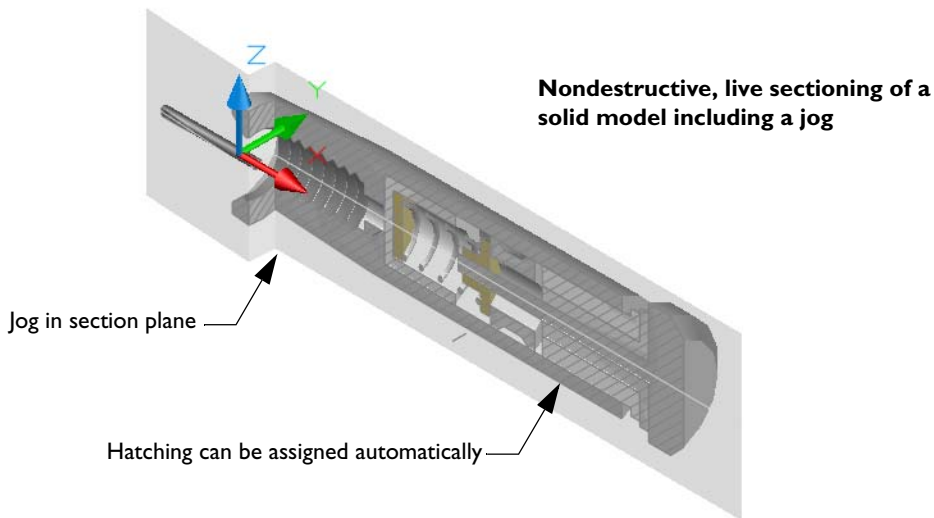
Destructive sectioning of a solid model using multiple Boolean subtractions

84 Chapter 7 Put Your Work to Use

- 8 Use 3D Orbit to view the model from several angles.
- 9 Close both drawing files.

TIP For destructive sectioning, you can create any solid shape—simple or complex—as the subtracting volume.

In contrast, you can create a “live” section that does not alter the model and can be easily relocated. To create a live section, you use the SECTIONPLANE and LIVESECTION commands. With the Draw option, you can specify a series of section lines.



Further Study in the User's Guide

Create Sections and 2D Drawings from 3D Models

Create Solids by Slicing

Flatten 3D Views

Normally, when you finish creating a solid model, you define several standard views on a layout, and the model provides these views in a visual style that you specify with no extra work needed before plotting.

However, you might encounter situations where you need a static 2D projection of a model for the purpose of modifying or hatching it.

You can choose from several commands that create static 2D projections.

- The SOLPROF command creates a 2D projection of the visible edges of a solid on a viewport-specific layer—a layer visible in only one specified viewport. Another viewport-specific layer includes only the hidden lines, also in 2D. All resulting edges are combined as blocks. A dashed linetype can be assigned to the hidden edges.
- The FLATSHOT command produces a result similar to SOLPROF, but the results are created on the current layer and on the XY plane of the UCS. The result is visible in all viewports. This is a very handy tool for creating a quick 2D snapshot from any viewpoint.
- The SECTION command creates a 2D region on the current layer defined by a section plane that is specified with three points.
- The SECTIONPLANE command creates a block that contains a 2D hatch object. The section plane is defined by at least one line—the section plane contains the line and is perpendicular to the XY plane of the UCS.

Try It

- 1 Open the drawing *33 Stool.dwg*.
- 2 Enter **ucs** on the command line and specify the View option. This orients the UCS XY plane, which is the projection plane for FLATSHOT.
- 3 Enter **flatshot** and accept the defaults in the Flatshot dialog box. FLATSHOT is also available on the dashboard in the lower-right corner of the 3D Make control panel.
- 4 To locate the block, click a point on the XY plane and press ENTER to accept all default values.
- 5 Explode the block and delete some of the 2D objects that would normally be hidden.
- 6 Close the drawing file.

You can experiment creating flattened blocks from other drawings such as the *66 Bottle* drawing or the *71 Florett* drawing.

Further Study in the User's Guide

Create a Flattened View

Calculate Mass Properties

You can use the MASSPROP and AREA commands to obtain mass and area data from a solid.

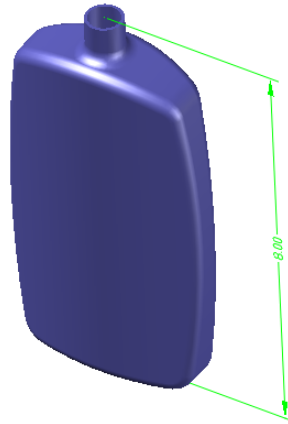
For example, assume that the small bottle that you worked with in chapter 3 is made of polyethylene with a specific gravity of 0.92 (cgs units). The volume of the polyethylene is 4.38 cubic centimeters. (The bottle is about 8 cm tall.)

NOTE Because the MASSPROP command does not “know” the specific gravity of the material used or the units of measurement, it assumes a specific gravity of 1.00 and so the computed mass is always the same as the computed volume.

Thus, the mass of the polyethylene is $4.38 \text{ cm}^3 \times 0.92 = 4.03 \text{ grams}$.

Try It

- 1 Open the drawing *66 Bottle.dwg*.
- 2 Enter **massprop** and select the bottle.
- 3 Scan through the mass property report. Press ESC.
- 4 Enter **area** and specify the Object option.
- 5 Select the bottle to display the surface area of the bottle, both external and internal.
- 6 Close the drawing file.



How would you obtain the external area or the internal volume of the bottle? In each case, you need the solid, unshelled version of the bottle. This is an example of why it is a good idea to save intermediate stages of each model.

Another useful application of MASSPROP is computing the centroids of rotating parts such as cams.

Further Study in the User's Guide

Extract Geometric Information from Objects

Walk Through or Fly Over 3D Models

The 3D Walk and 3D Fly features provide a way to gain a better 3D “feel” for interiors and exteriors of structures and other models.



For your convenience, the 3DWALK and 3DFLY commands are accessible from several places in the user interface.

- On the dashboard, locate the 3D Navigate control panel. The Walk, Fly, and Walk and Fly Settings buttons are available from a flyout on the top row.
- In 3D Orbit, right-click to display the shortcut menu. Click Other Navigation Modes and then click Walk or Fly.
- In 3D Orbit, press 6 to walk or 7 to fly.
- On the View menu, click Walk and Fly. Then click either Walk or Fly.
- Enter **3dwalk** or **3dfly** on the command line.

Try It

- 1 Open the drawing *51 Campus.dwg*.
- 2 With the 3DORBIT command, specify an isometric view. Right-click to display the shortcut menu. Turn on Perspective mode and exit the command.
- 3 Enter **3dfly** on the command line. You can press F1 to see all of the command access options that are available.
- 4 Use the arrow keys to fly over the campus. Click and hold the mouse button to steer. The keyboard controls are similar to those in many computer games. Press ESC to exit.
- 5 Close the drawing file.

Try It

- 1 In the *\Sample* folder, open the drawing *3DHouse.dwg*.
- 2 Turn on Perspective mode from the 3D Navigate control panel on the dashboard.
- 3 Enter **3dwalk** on the command line and take a tour of the house.
- 4 Close the drawing file.

Further Study in the User's Guide

Walk and Fly Through a Drawing

Check for Interferences

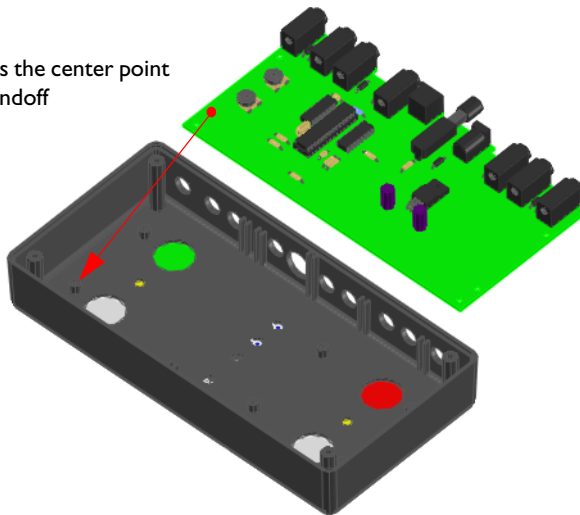
Before they become a serious and expensive problem, you can check for interferences either visually or with the Boolean INTERFERE command. The following are real-world examples.

- In *73 Eclipse.dwg*, the interference between the LEDs and the label of this electronic scoring machine used in the sport of fencing was discovered in time to add a spacer that solved the problem.
- In *74 Duct.dwg*, the construction of this school building was in progress when it was discovered that a structural steel brace was going to interfere with a duct.

Try It

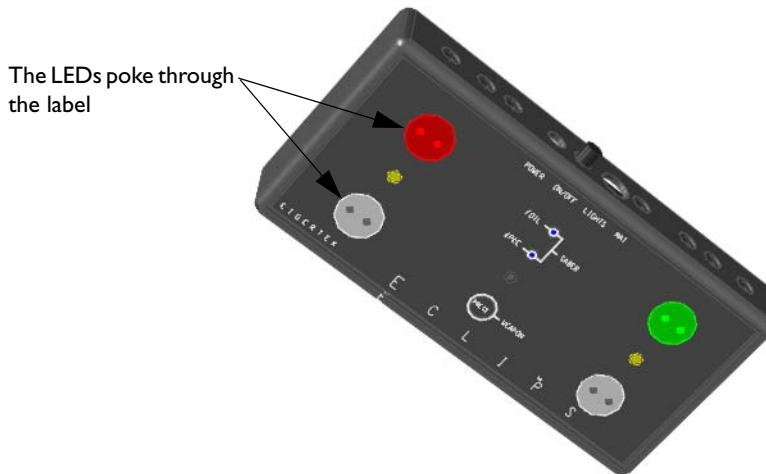
- 1 In the `\Help\buildyourworld` folder, open the drawing *73 Eclipse.dwg*.
- 2 Insert the block, 1PCBoard, into the case using the Center object snap as shown. (The circuit board is already saved as a block definition in the drawing.)

The insertion point is the center point of the top of the standoff



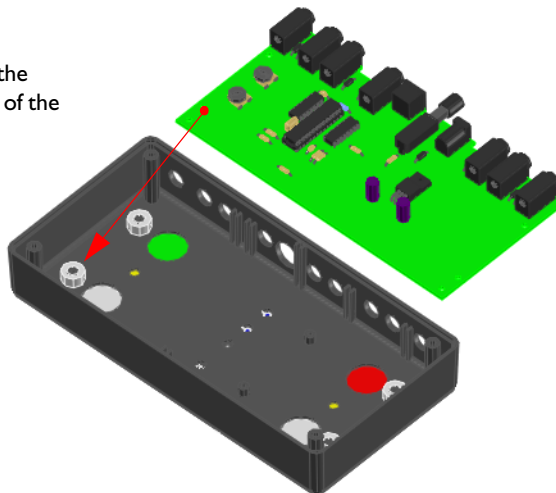
90 Chapter 7 Put Your Work to Use

- 3 Use 3D Orbit to rotate the view of the scoring machine. Notice that the LED lights are poking through the plastic label.



- 4 Restore the previous isometric view. (You can use Undo, Zoom /P, or 3D Orbit.)
- 5 Delete the circuit board block.
- 6 Turn on the layer, 37 SPACER. The four spacers increase the distance between the circuit board and the front of the case by just the right amount.
- 7 Insert the block, 1PCBoard, on top of the spacer, using the Center object snap as shown. You should zoom in to make sure that you snap to the center of the spacer.

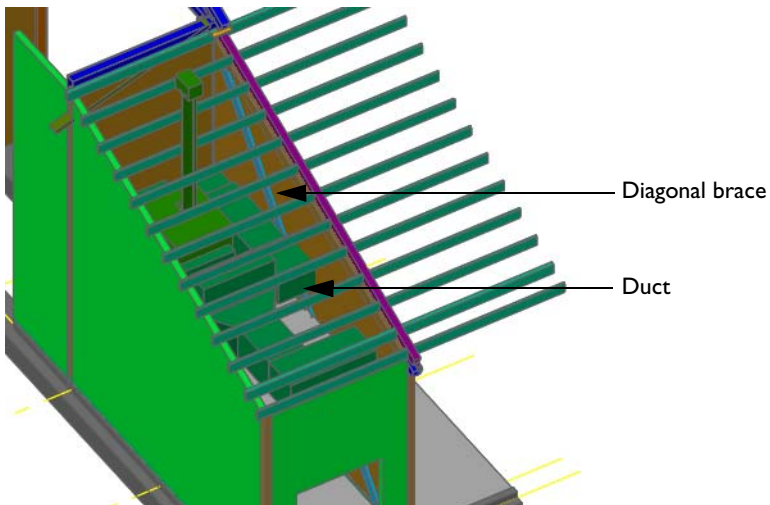
The insertion point is the center point of the top of the white spacer



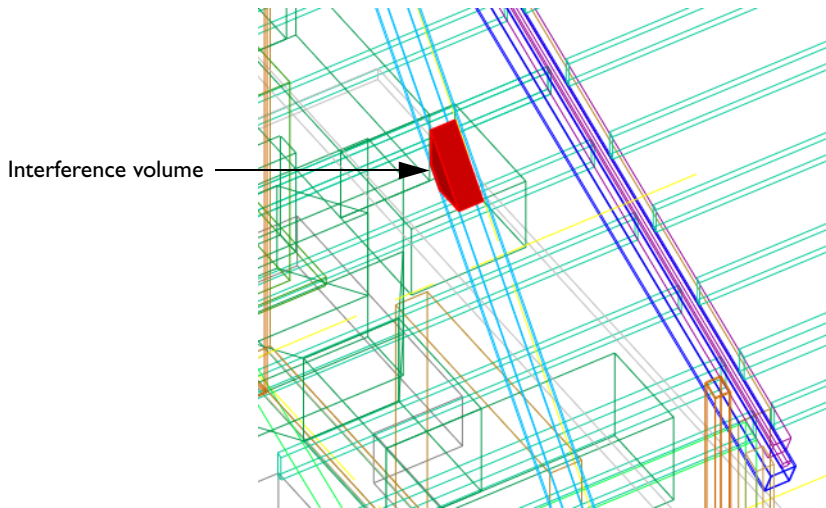
- 8 Use 3D Orbit to rotate the scoring machine until you can see the front label. Notice that the LED lights are no longer protruding.
- 9 Close the drawing file.

Try It

- 1 In the `\Help\buildyourworld\` folder, open the drawing `74 Duct.dwg`.
- 2 Use 3D Orbit to specify the Realistic visual style. Then rotate the view as shown below and exit 3D Orbit.
- 3 Make sure that PICKSTYLE is set to 1.
- 4 Enter `interfere` on the command line.
- 5 Select the diagonal brace and press ENTER. Select the dark green duct and press ENTER.



- 6 In the Interference Checking dialog box, clear the Delete Interference check box. Click Close.



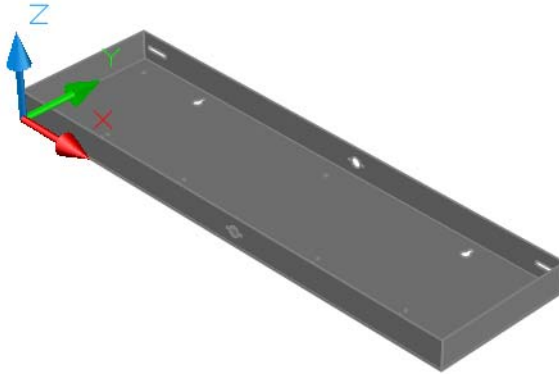
- 7 Change the visual style to 3D Wireframe.
- 8 Use 3D Orbit to view this typical problem area.
- 9 Close the drawing file.

Further Study in the User's Guide

Check for Interferences within a Solid Model

Create Files for Manufacturing

The information in a solid model can be extracted for manufacturing. The following aluminum case was modeled in AutoCAD. Then, a prototype of this case was manufactured in a few weeks without the use of any paper drawings.



Aluminum case manufactured from an AutoCAD drawing file

Starting with the solid model, the engineer followed these steps:

- In AutoCAD, the ACISOUT command was used to create an SAT file with the essential data of the case derived from the solid model. The ACIS file was sent by email to a manufacturing company.
- The manufacturing company imported the ACIS file into their metal-folding software, which added the required bend radii.
- Their software created an NC (numerical control) file that was sent to a flatbed laser cutting machine. The laser cutting machine cut out the part from an aluminum sheet.
- The part was folded into shape and given a powder coat.
- The engineer noticed some potential problems that required a new prototype.

Try It

- 1 In the `\Help\buildyourworld\` folder, open the drawing `75 Case.dwg`.
- 2 Use 3D Orbit to view the case from several angles.
- 3 Enter **acisout** on the command line and select the case to create an ACIS file.
- 4 Open and scan through the resulting SAT file in a text editor such as WordPad.
- 5 Close the text and drawing files.

Further Study in the User's Guide

Export ACIS Files

Make 3D Solids Transparent

Reducing the opacity of solid models is a useful tool both for presentation and modeling. You can control the transparency of 3D solids with the Opacity control in the Materials window. If a material is assigned to each 3D solid in a model, you can control the opacity of each 3D solid individually.

Try It

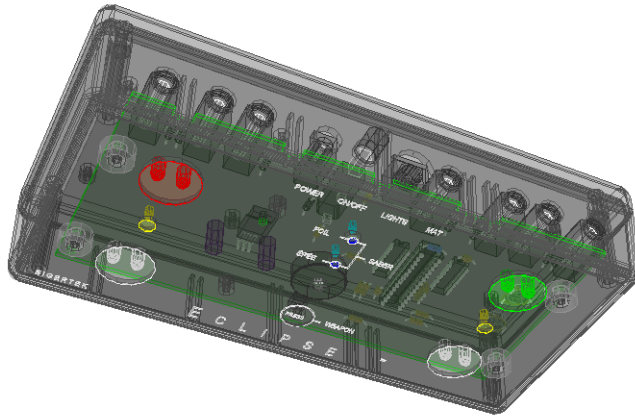
- 1 In the `\Help\buildyourworld` folder, open the drawing `73 Eclipse.dwg`, or in the `\Sample` folder, open the drawing `3D House.dwg`. If you chose the Eclipse drawing, turn on the 37 SPACER layer and insert the block 1PCBoard, as you did previously.
- 2 Enter **materials** on the command line or, on the dashboard, in the Materials control panel, click the Display Material Window button.
- 3 At the top of the Materials window, one or more materials are displayed on swatches. If you opened `3D House.dwg`, make sure that the current material is set to Roof. Click the blue-gray swatch that displays the Roof In Use tooltip.
- 4 On the Materials window, adjust the Opacity slider to a value of 24. If you are using `3D House.dwg`, click on other materials such as Interior Texture and Exterior Textures. On the Materials window, adjust the Opacity slider for each of these.

NOTE For best results, make sure that hardware acceleration is turned on. To access this setting, enter **3dconfig** on the command line. In the Adaptive Degeneration and Performance Tuning dialog box, click Manual Tune. In the Manual Performance Tuning dialog box, click Enable Hardware Acceleration.

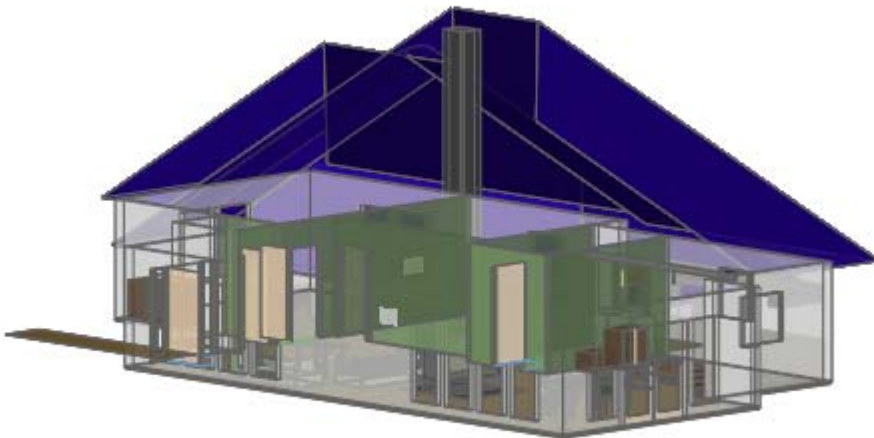
- 5 Using 3D Orbit, make sure that the current visual style is set to Realistic and rotate the model. Try entering **-shademode** on the command line and specifying Gouraud.

NOTE A faster method is available on the dashboard to set the opacity for all materials. Simply click the X-ray Mode button on the Visual Styles control panel.

- 6 Close the file.



73 Eclipse.dwg with opacity decreased



3D House.dwg with opacity decreased

Further Study in the User's Guide

Shade and Color Faces

Create and Modify Materials

Create Realistic Images for Presentation

With a powerful set of lights, cameras, materials, and texture maps, you can set up a virtual studio within a 3D solid model. For a quick rendering, use the RENDER command. The preset values will produce reasonable results.

Try It

- 1 In the AutoCAD \Sample folder, open the drawing *3D House.dwg*.
- 2 Turn off layer *A-Roof* and specify an interesting view, as shown in the illustration.
- 3 Enter **render** on the command line or, on the dashboard, on the Render control panel, click the Render button. Click Continue to ignore any missing texture maps.

The model is rendered in the Render window. From the Render window, you can save the resulting image in several formats by clicking File and then Save.

- 4 Close the file.



Further Study in the User's Guide

Create Realistic Images and Graphics

Final Thoughts

Solid modeling is fun and produces impressive, useful images and data. As you practice and experiment with solid modeling, you will develop your own preferred techniques. Nevertheless, if you focus on the following points, you will be successful and more efficient.

- Organize your work before you begin. Create a logical set of layers.
- Use precise and disciplined geometric logic when constructing solids to make sure that your models are correct.
- Always check your work at every step to reduce the likelihood of perpetuating modeling errors. View a model from several angles, and use the ID command to verify the coordinates of endpoints and the DIST command to verify lengths and distances.
- Retain reference geometry such as centerlines and profiles. Keep them separate on their own layer.
- Save models at intermediate stages with different file names, so you can easily go back and retrieve data.
- Use just enough detail in a solid model to accomplish your goals.
- Experiment and have fun!

