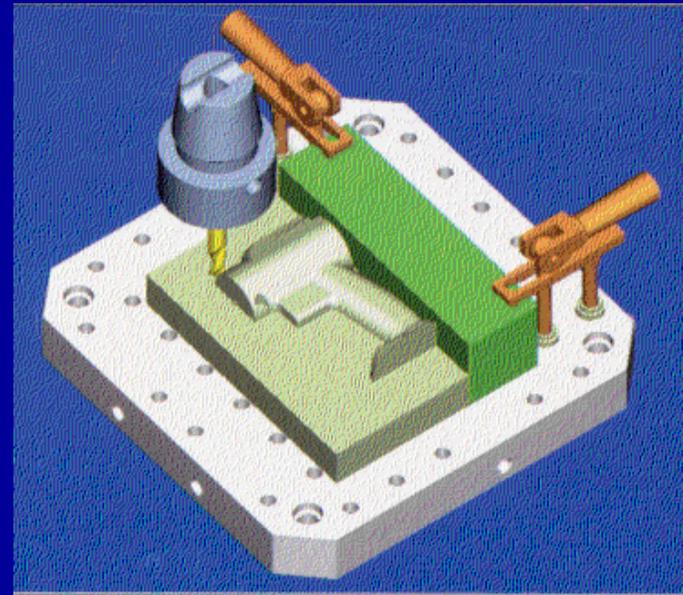
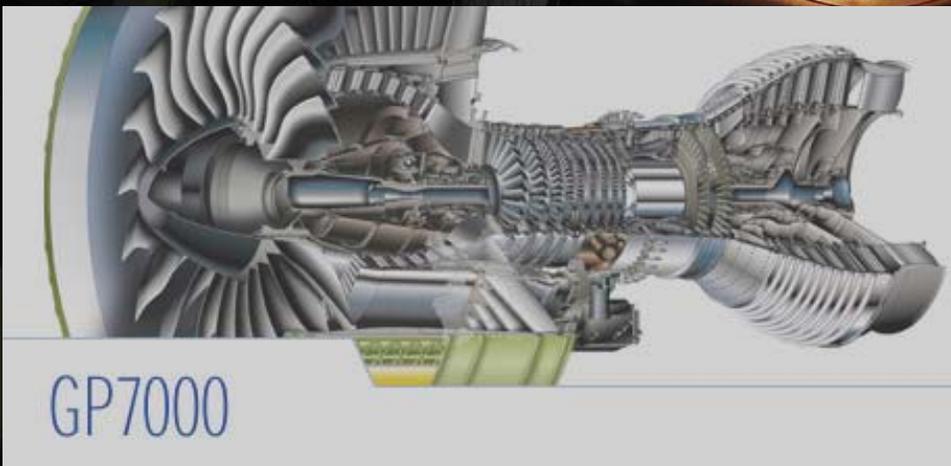


Computer Numerically Controlled (CNC) Machining and Tool Path Programming

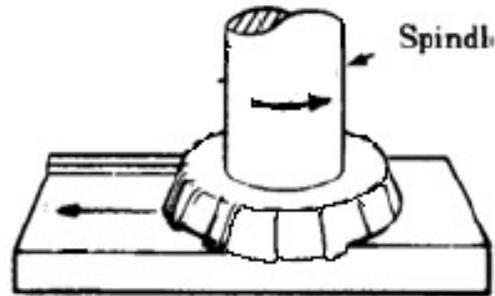


CNC Machining of Complex Surface Parts

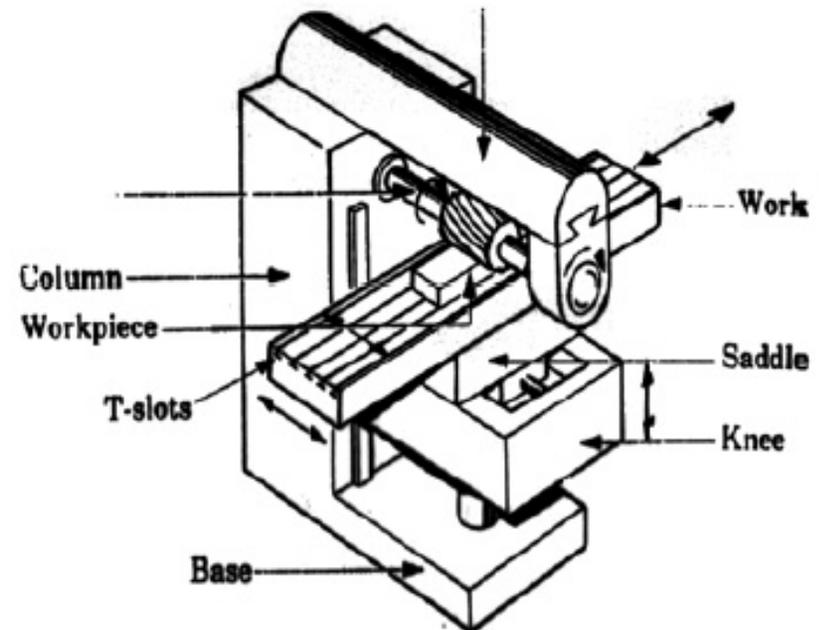
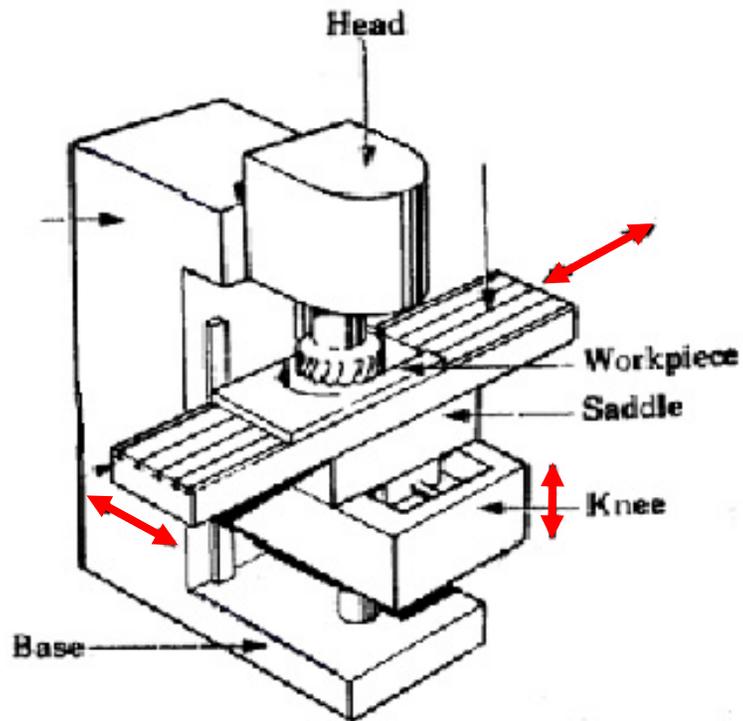
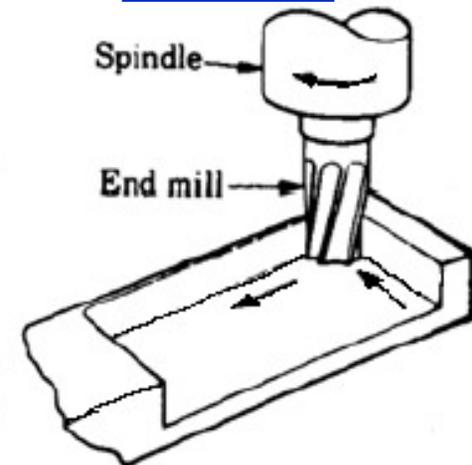


2 1/2 and 3 Axis Milling

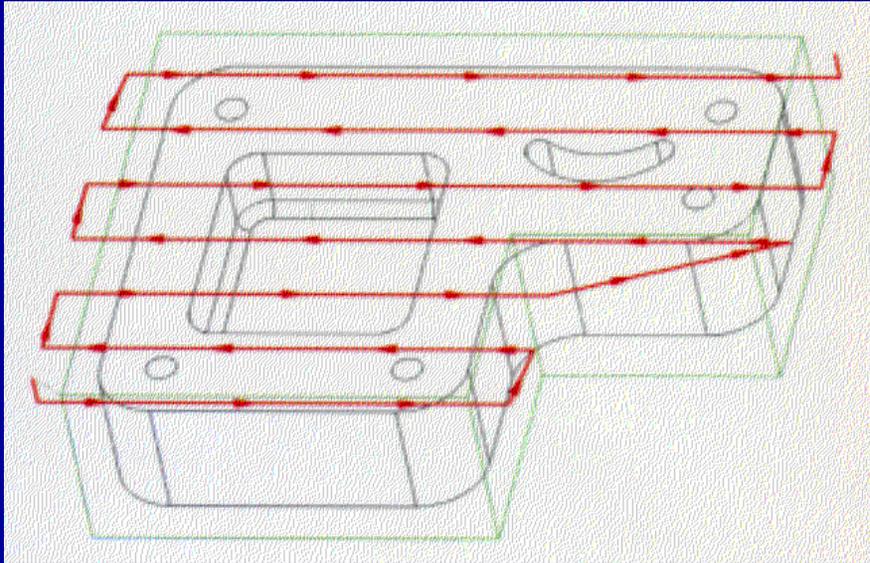
Face milling



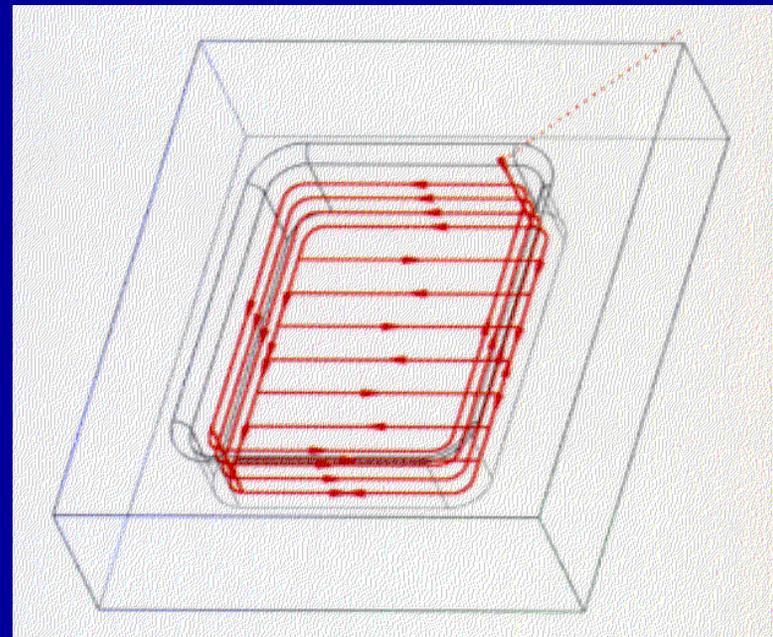
End milling



Face Milling



Pocketing



Three-Axis CNC Machines

- In 3-axis CNC vertical machine, the working table moves along x- and y-axis, and the tool along z-axis.
- In machining, tool orientation is fixed, either in vertical or horizontal direction.
- If all surfaces to be machined are accessible by the cutter in one setup, select a 3-axis CNC machine.

Synchronized Motions in 3 Axis



Five-Axis CNC Machines

- X-, Y-, and Z- Axis Motions and A- and B- axis Rotations (**Simultaneously**)
- Tool orientation can be changed simultaneously during machining.
- If some surface patches to be machined are not accessible by the cutter in one setup, consider to use a 5-axis CNC machine.



Five-Axis CNC Machines



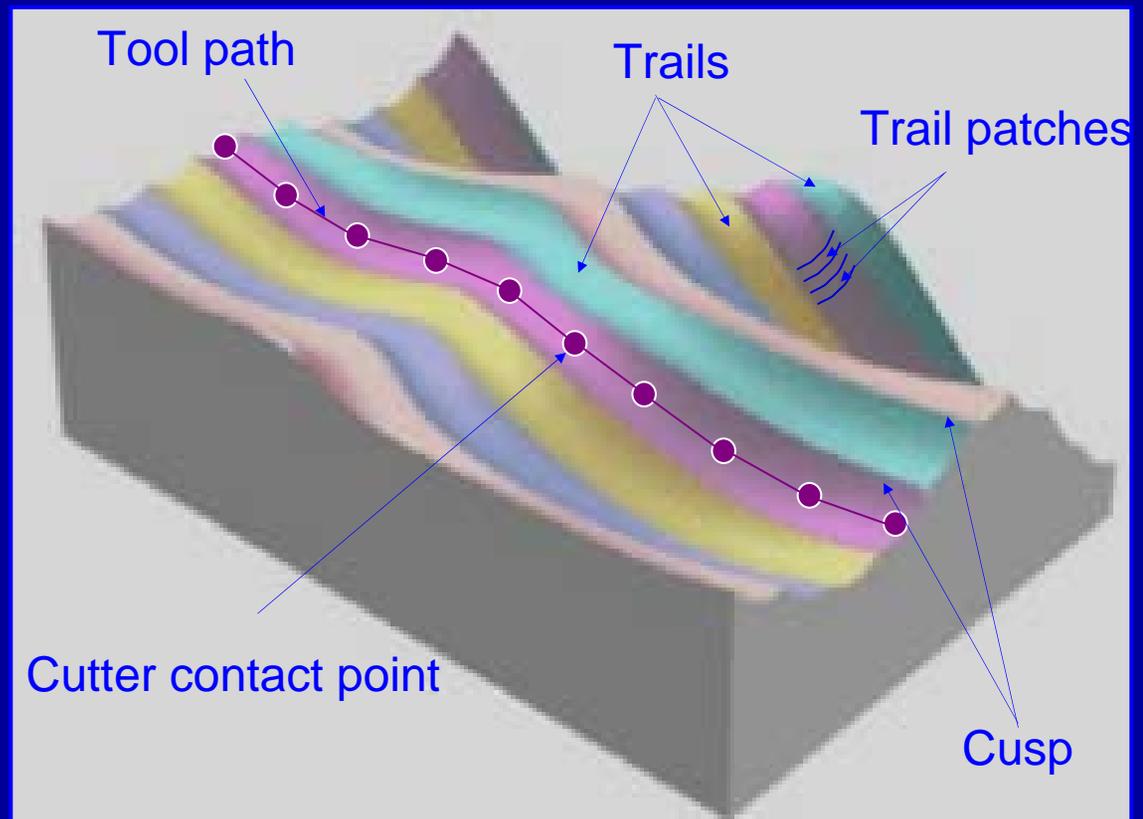
Five-Axis CNC Machining



Cincinnati V5-2000 5-Axis
CNC Machining Center

Machined Surface

- CAD Model of the Surface
- Tool Path Generation
- Simulation of Cutting
- Accuracy of the Machined Surface
- Over-cut and Over Cut Detection



Computer-Aided Manufacturing (CAM) CNC Tool Path Programming

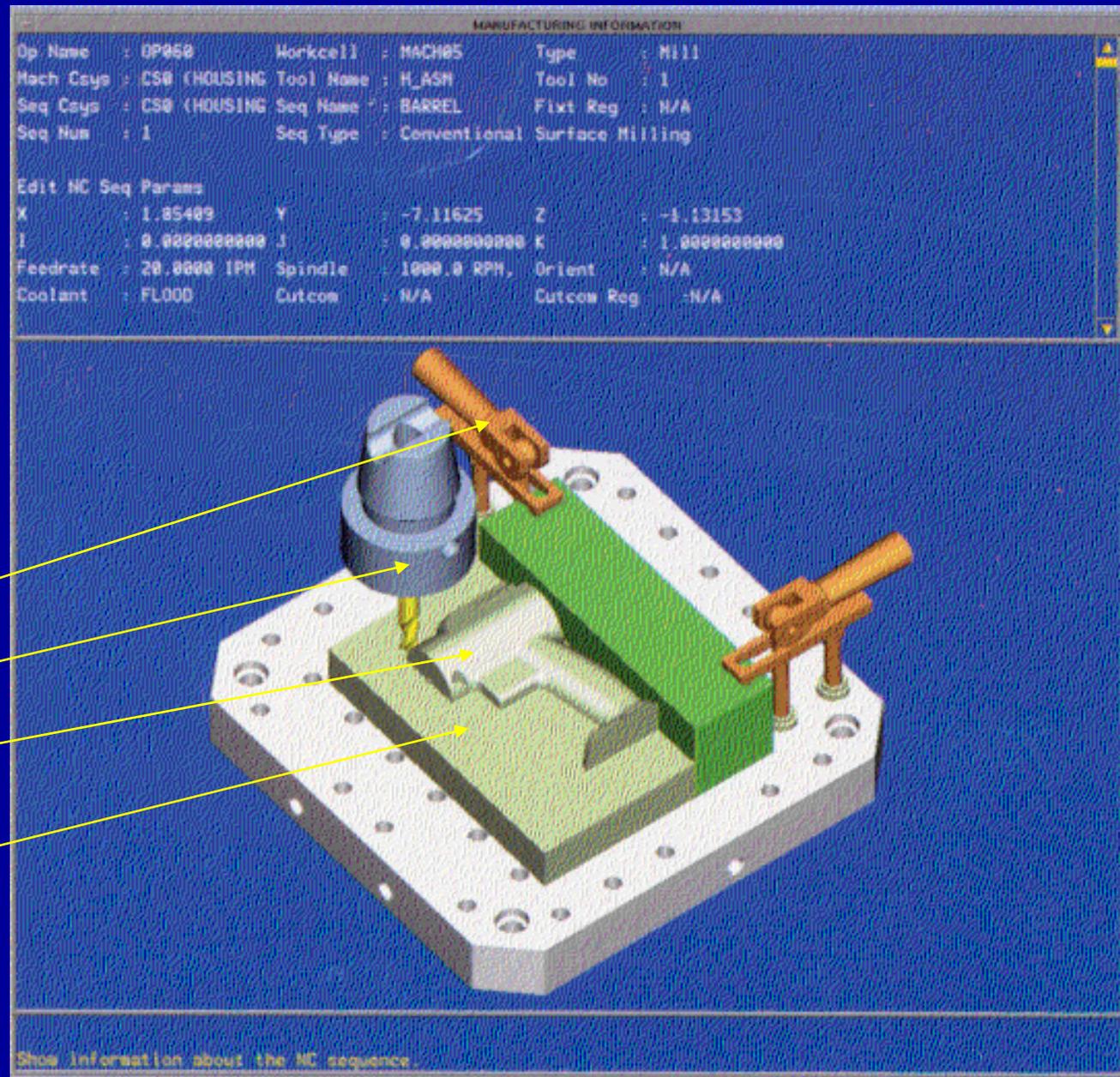
- ...
- Automatic **Tool Paths** Generation for CNC Machining from CAD Models
- Tool Path **Verification** and Graphical **Simulation** of CNC Machining
- CNC Post-Processor for Machine Dependant **G-code** Generation

Tool Path Generation, Machining Simulation

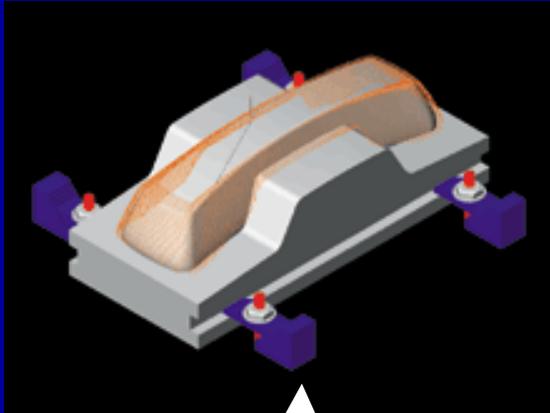
3-Axis Milling

- Fixture
- Cutter
- Part
- Workpiece

NC Sequence

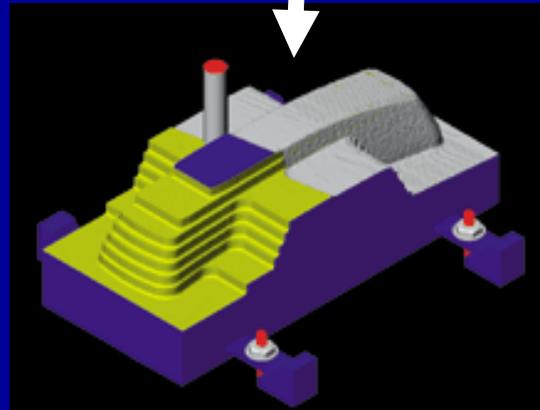


Tool Path Generation and Machining Simulation

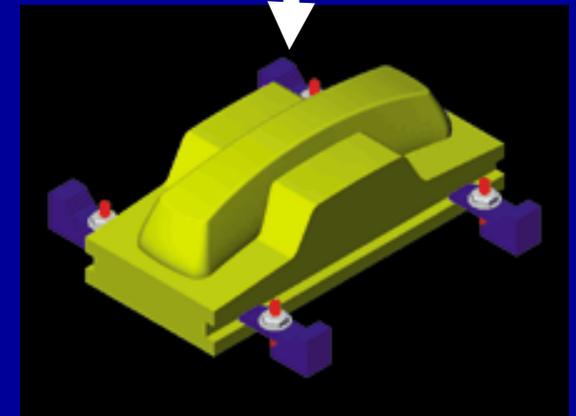


Generate 3-axis
CNC tool paths
for the mold of a
phone handset

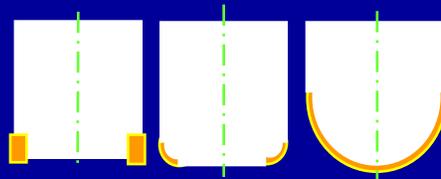
Verify the tool
paths and
simulate the
milling process



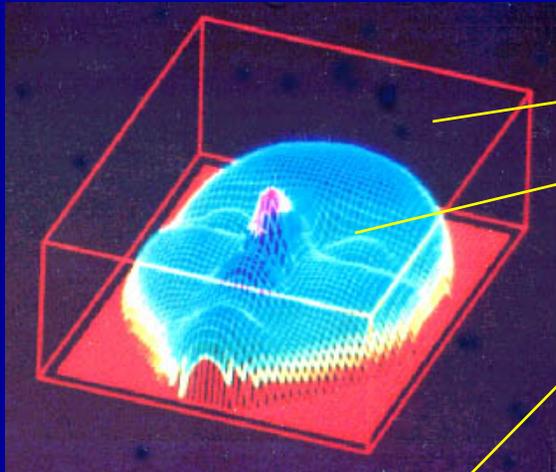
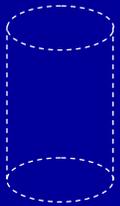
The digital result
of the virtual
CNC machining



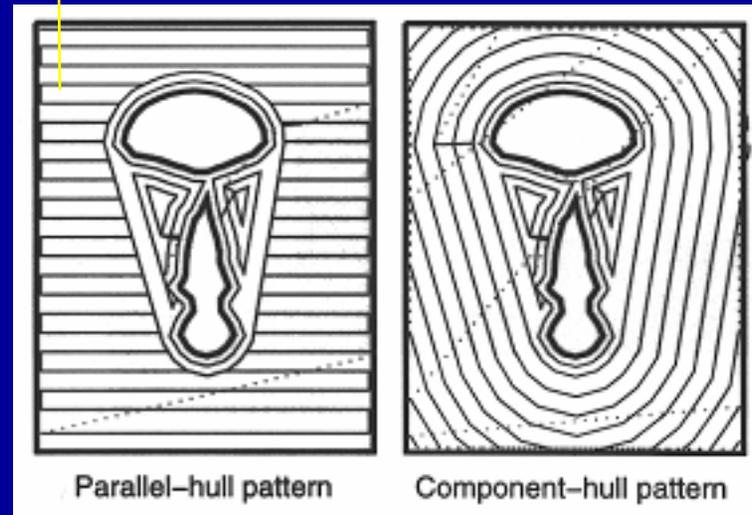
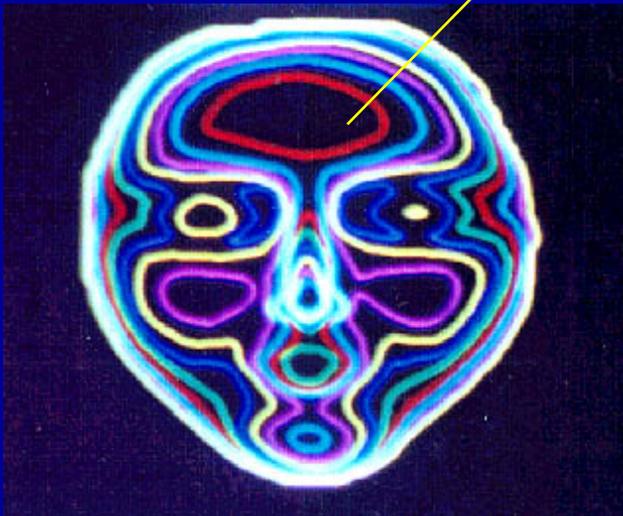
**Flat, Torus and
Ball End Mill**



2 1/2 Axis Rough Machining

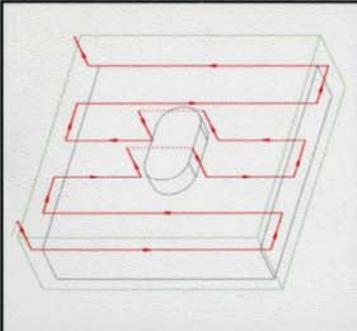


- Stock (or Workpiece in Pro/Mfg)
- Mechanical Part
- 2D Contours for Layered Machining
- Tool Path for Example 2D Layers

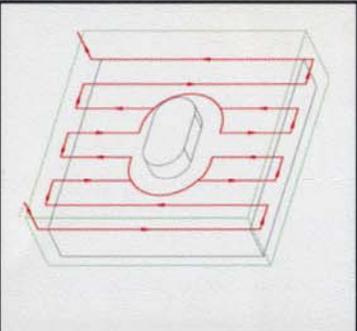


Parallel-hull pattern

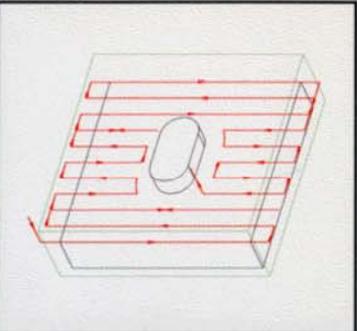
Component-hull pattern



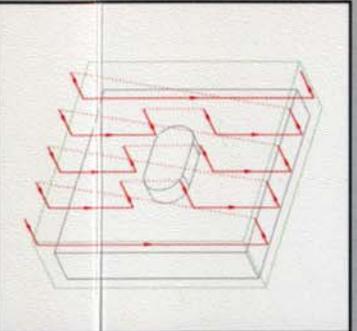
TYPE_1



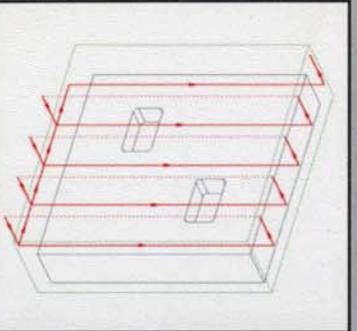
TYPE_2



TYPE_3

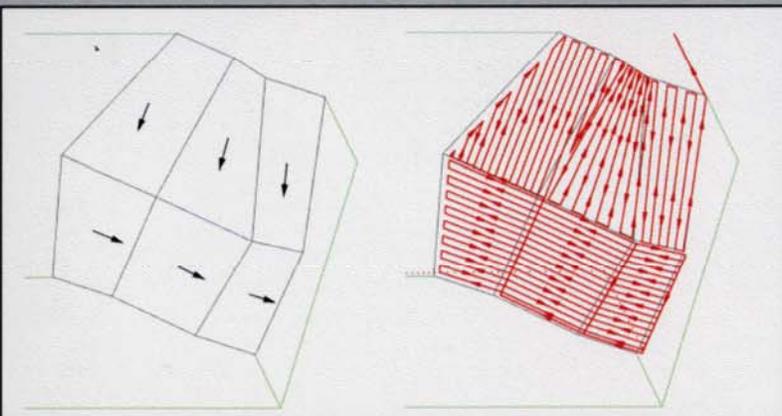


TYPE_ONE_DIR

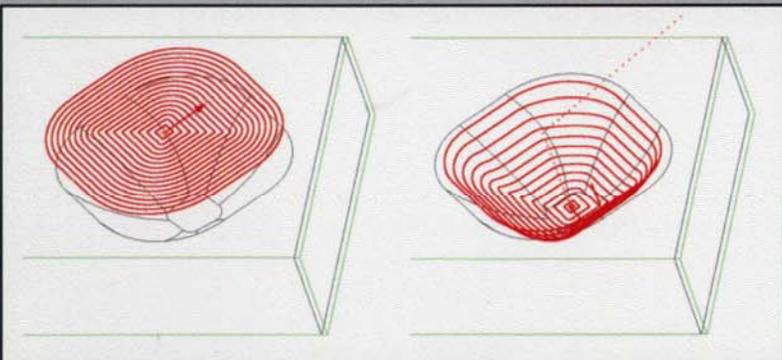


TYPE_1_CONNECT

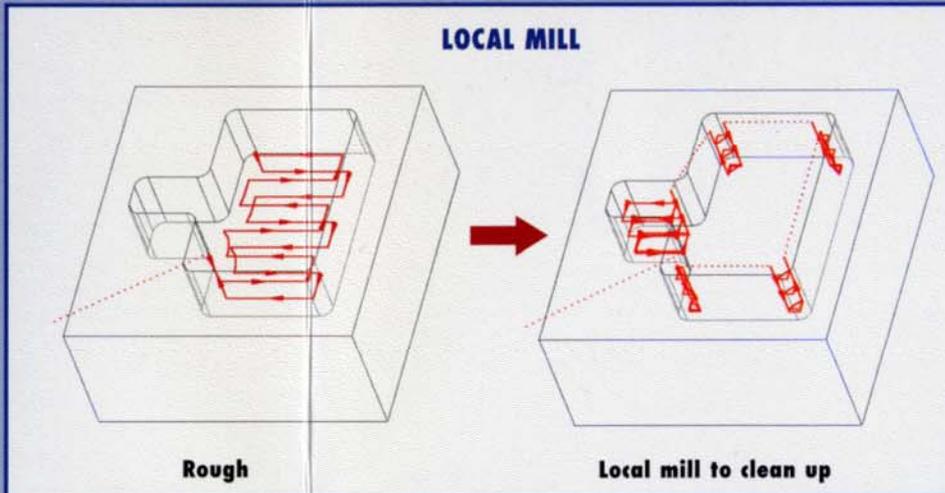
CONTOUR TYPES



SURF/SURF Follows natural contours



PROJECTED Projects contours onto surfaces

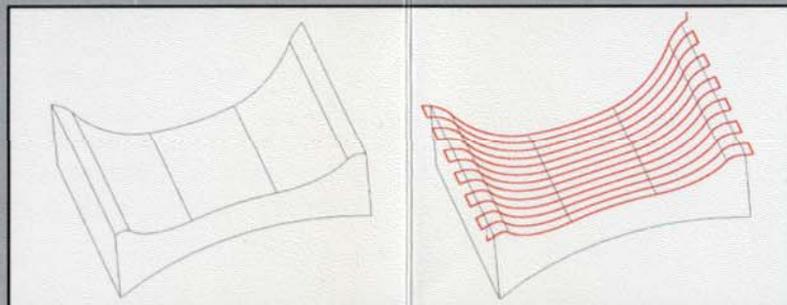


LOCAL MILL

Rough

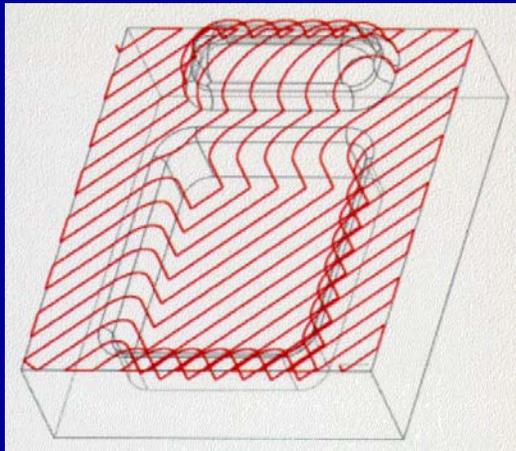
Local mill to clean up

Different Tool Path Patterns

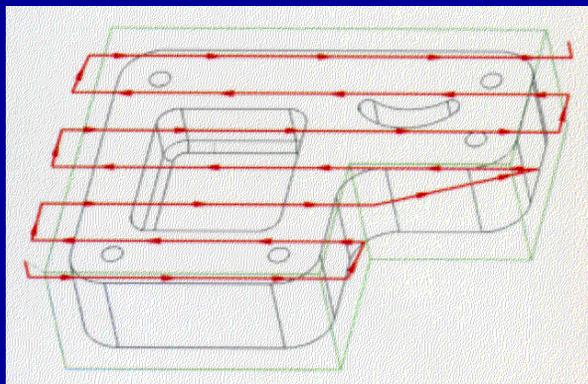


CUTLINE Follows user-specified contours or flowlines

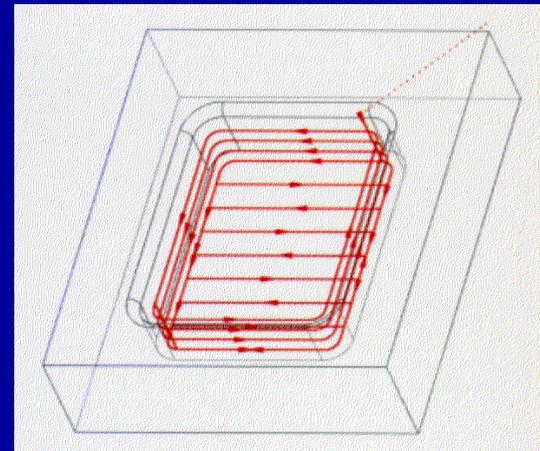
Conventional Surface



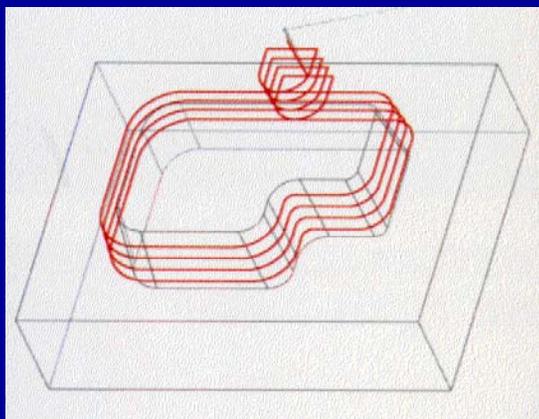
Face



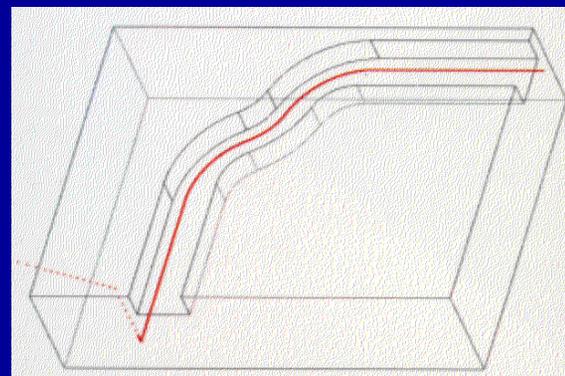
Pocket



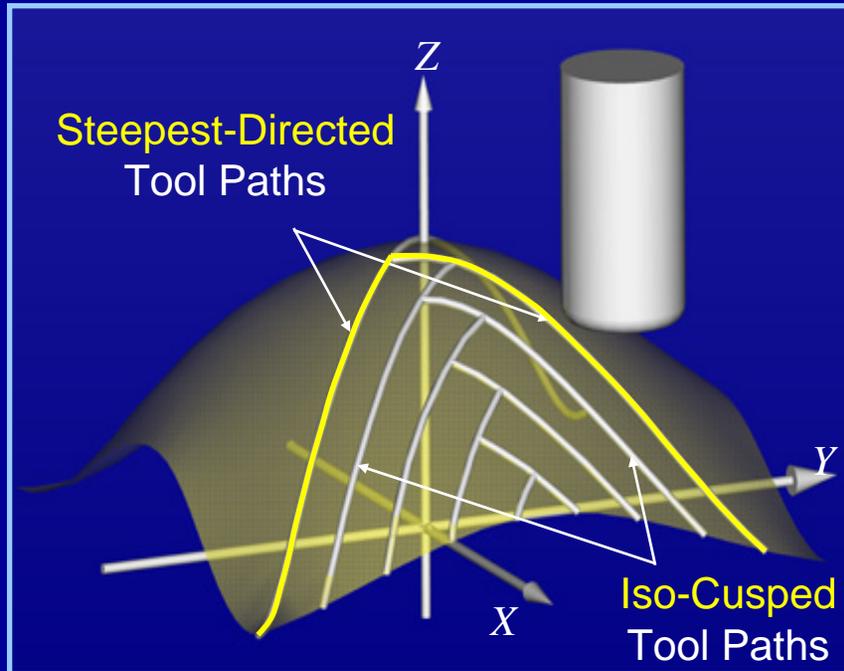
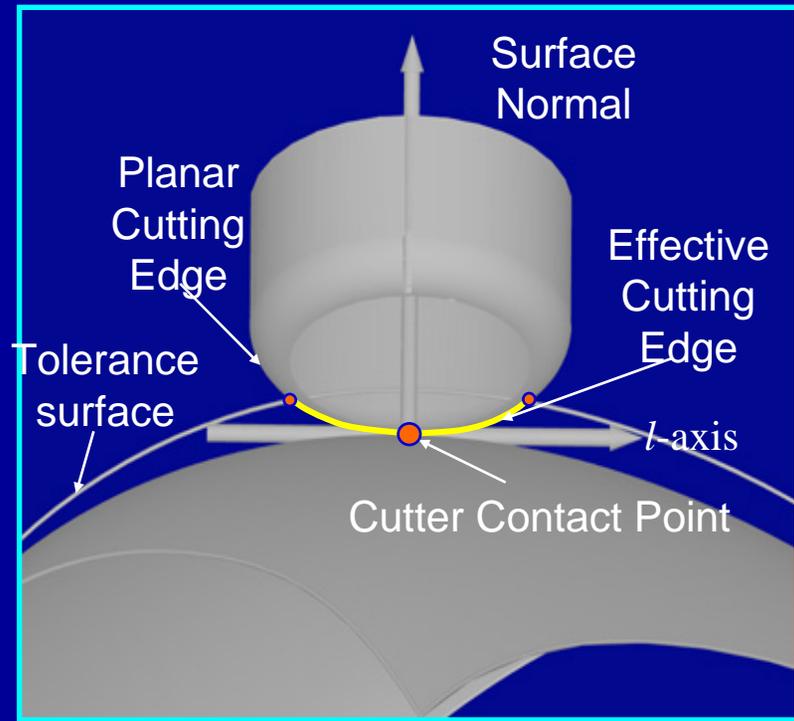
Profile



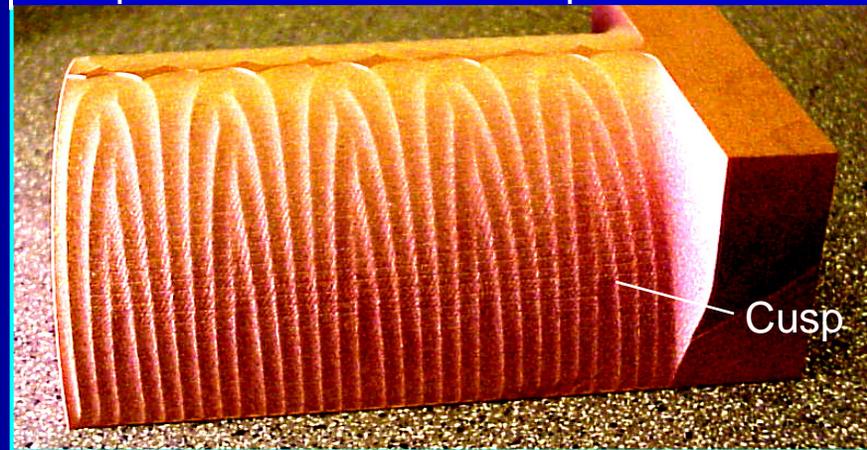
Trajectory



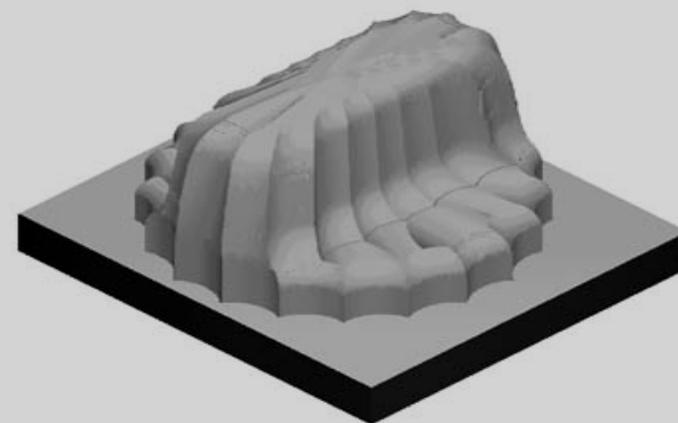
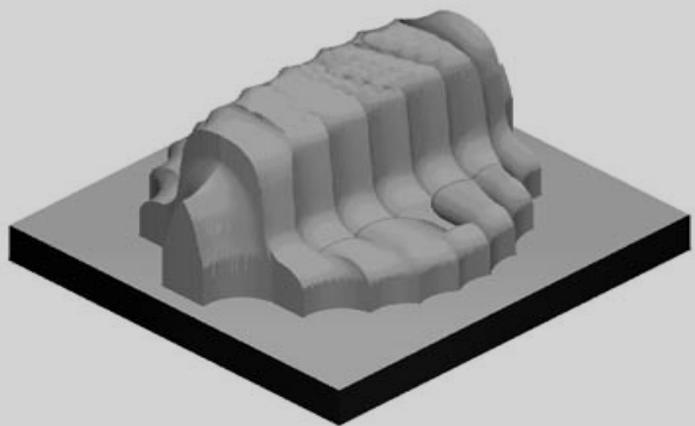
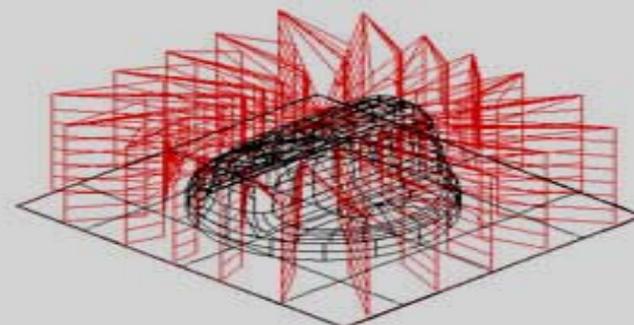
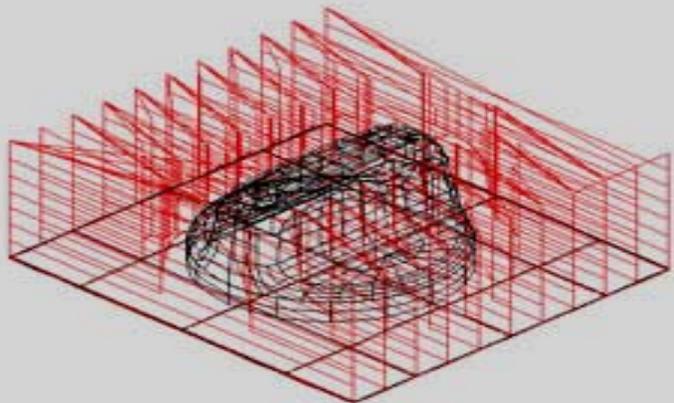
Cutter, Part Surface, Surface Normal, Tolerance Surface, Tool Path, Cusp



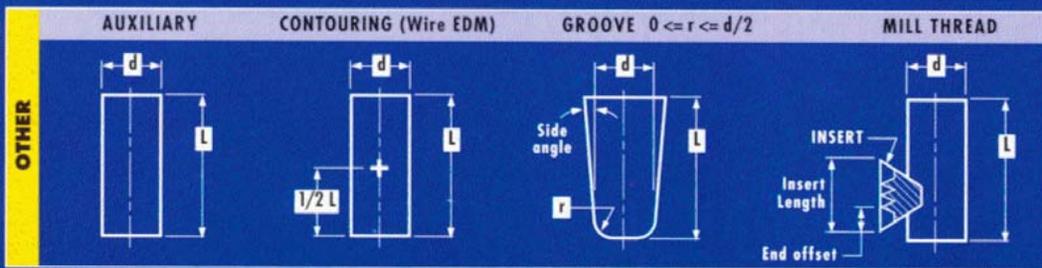
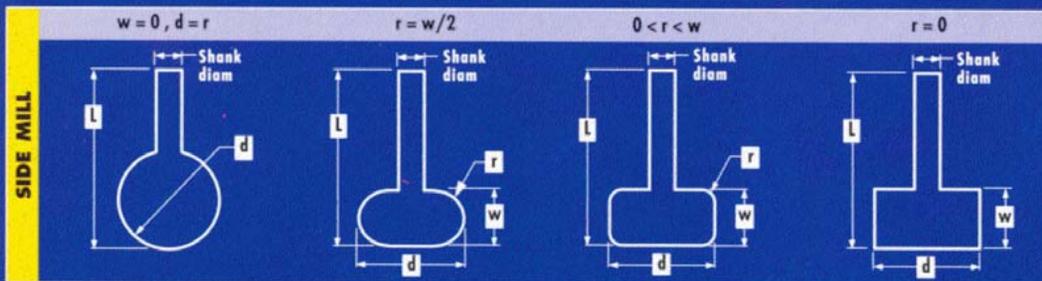
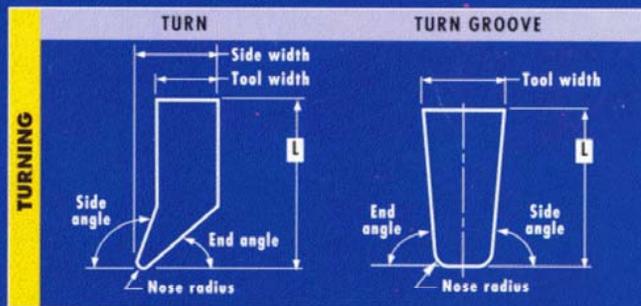
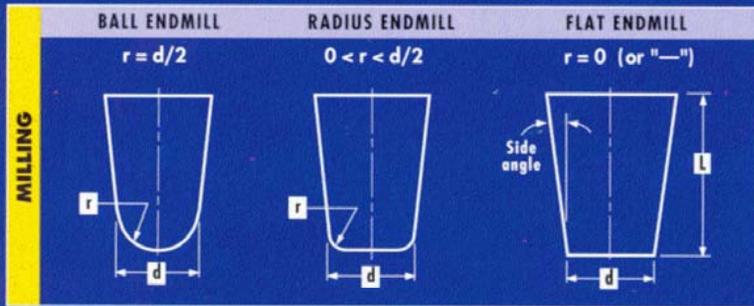
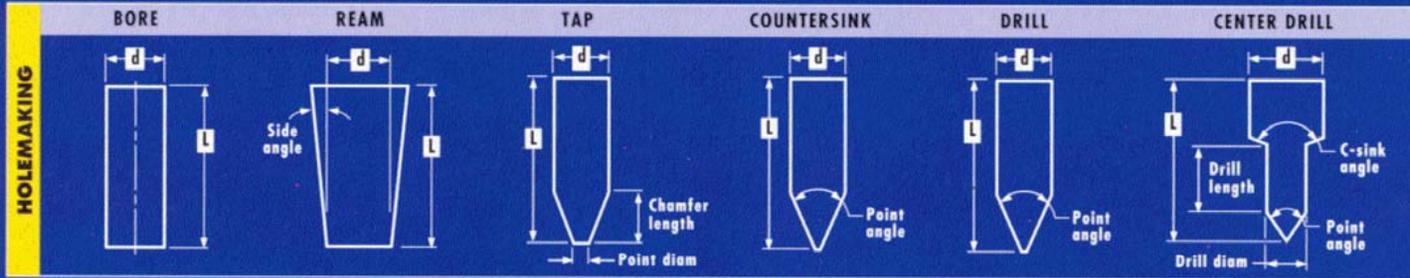
Steepest-Directed & Iso-Cusped Tool Paths



Parallel-Plane-Guided and Radial Tool Paths



Setting Up Tools



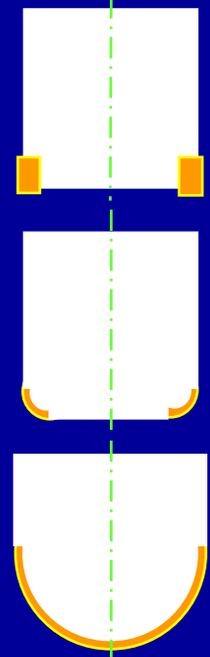
KEY

r	CORNER_RADIUS
d	CUTTER_DIAM
w	CUTTER_WIDTH
L	LENGTH

TOOL Parameters

- CHAMFER_LENGTH
- CORNER_RADIUS
- CSINK_ANGLE
- CUTTER_DIAM
- CUTTER_WIDTH
- DRILL_DIAMETER
- DRILL_LENGTH
- END_ANGLE
- END_OFFSET
- GAUGE_X_LENGTH

- GAUGE_Z_LENGTH
- HOLDER_TYPE
- INSERT_LENGTH
- LENGTH
- LENGTH_UNITS
- NOSE_RADIUS
- NUM_OF_TEETH
- POINT_ANGLE
- SHANK_DIAMETER
- SIDE_ANGLE
- SIDE_WIDTH
- TOOL_COMMENT
- TOOL_LID
- TOOL_MATERIAL
- TOOL_TYPE



Setting Up Machining Parameters

Goto Point

Specify Tool Motion Parameters:

Feed... FEEDRT / 20.000, IPM

Spindle... SPINDL / RPM, 1000.000, CM

Coolant... COOLNT / OFF

Cutcom... CUTCOM / OFF

Specify Target Goto Point: Specify Offset Values:

Specify Point ... Specify Offset ...

Specify Axes Tool Moves Along:

Simultaneous X Axis Y Axis Z Axis

Z First

Z Last

Define Tool Axis at Target Point:

Along Z axis

Use Previous

Specify New Axis Specify Axis ...

OK Preview Cancel

Sets speed and machine parameters.

Defines location to move tool.

Controls axes of motion.

Defines tool axis orientation for the motion.

Accepts/Previews/Cancel tool motion.

Pro/Mfg Menu System

MFG MDL

- Assemble
- Create
- Redefine
- Delete
- Replace
- Simplfd Rep
- Done/Return

MFG SETUP

- Workcell
- Tooling
- Fixture
- Operation
- Param Setup
- CL Setup
- Mfg Geometry
- PProcessor
- Done/Return

MACHINING

- Operation
- NC Sequence
- Matrl Remove
- CL Data
- Output Order
- Synchronize
- CL Command
- Mfg Setup
- Utilities
- Done/Return

CL DATA

- Input
- Output
- Edit
- Post Process
- NC Check
- Done/Return

PARAM SETUP

- Site
- Mach DB
- Peck Table
- Register

CL SETUP

- Tool Table
- PPRINT
- Feed Color
- NC Alias

MFG GEOMETRY

- Mill Volume
- Mill Surface
- Drill Group
- Datum Feats

MACH AUX

- Machining
- Auxiliary
- Volume
- Local Mill
- Conventl Srf
- Contour Srf
- Face
- Profile
- Pocketing
- Trajectory
- Holemaking
- Thread
- Grooving
- 3 Axis
- 4 Axis
- 5 Axis
- Done
- Quit

MACH AUX

- Machining
- Auxiliary
- Area
- Profile
- Groove
- Thread
- Holemaking
- Outside
- Inside
- Face
- HEAD 1
- HEAD 2
- Done
- Quit

MACH AUX

- Machining
- Auxiliary
- Contouring
- No Core
- Taper Angle
- XY-UV Type
- 4 Axis
- 2 Axis
- Done
- Quit

MILLING *2 1/2 to 5-axis machining performed on a mill type machining center.*

- Volume 2 1/2 axis roughing.
- Local Mill Removes leftover material from a previous toolpath.
- Conventl Srf Surface machining which follows planar slices across the part.
- Contour Srf Follows specified contours of type SURF, CUTLINE, or PROJECTED.
- Face 2 1/2 axis surface roughing.
- Profile Machines near-vertical surfaces with side of tool.
- Pocketing Machines walls & bottom surfaces. Used to clean up after volume mill.
- Trajectory Drives tool along edge or user-specified curve.
- Holemaking Drilling, boring, tapping, etc.
- Thread 3-axis helical milling.
- Grooving 3 to 5-axis milling, with the tool moving along a GROOVE cosmetic feat.

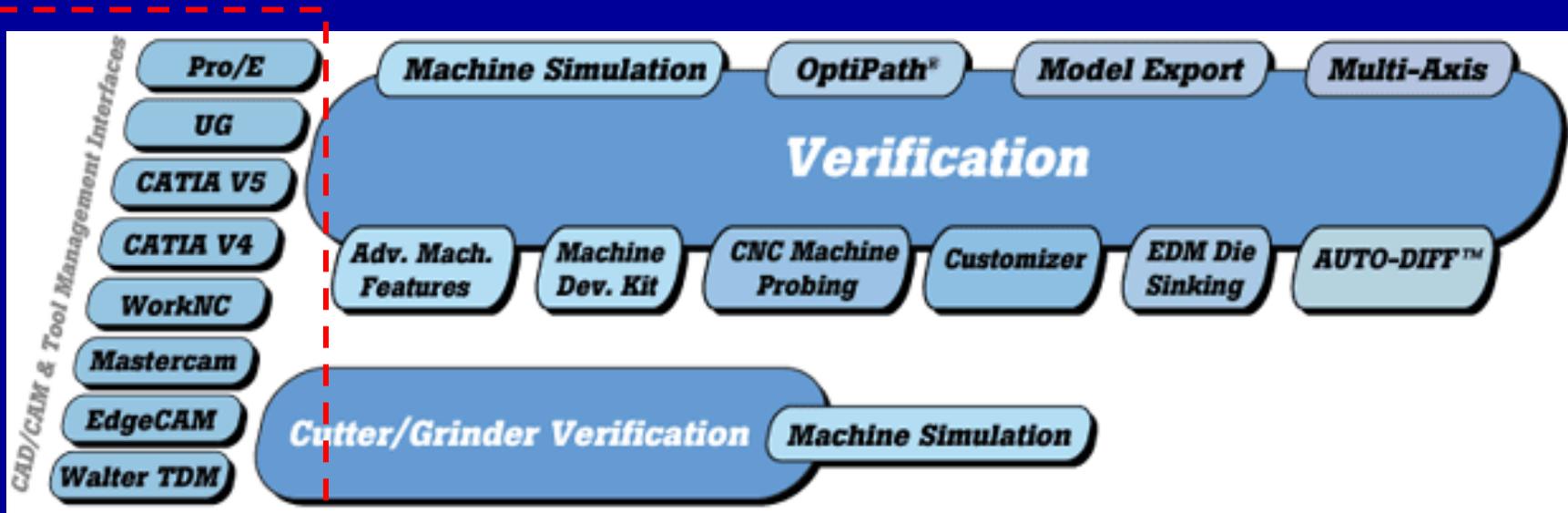
TURNING *Generally used on stock which is symmetric about the Z axis (i.e. stock with circular cross-sections throughout).*

- Area Used for rough-cut turning.
- Profile Follows a profile defined by surfaces of the part, datum curves, or by sketching.
- Groove Uses a peck-type motion to turn narrow grooves.
- Thread Defines the trajectory of the tool control point by sketching.
- Outside Machines the outside surfaces of the workpiece.
- Inside Machines the inside surfaces of the cored workpiece.
- Face Machines the workpiece surfaces perpendicular to the lathe axis.
- HEAD 1 Uses HEAD 1 turret (default for 2-axis workcell; optional for 4-axis).
- HEAD 2 Uses HEAD 2 turret (only applies to 4-axis workcell).

WIRE EDM *Used for any type of 2-axis contouring, including wire EDM, flame cut, waterjet, and laser.*

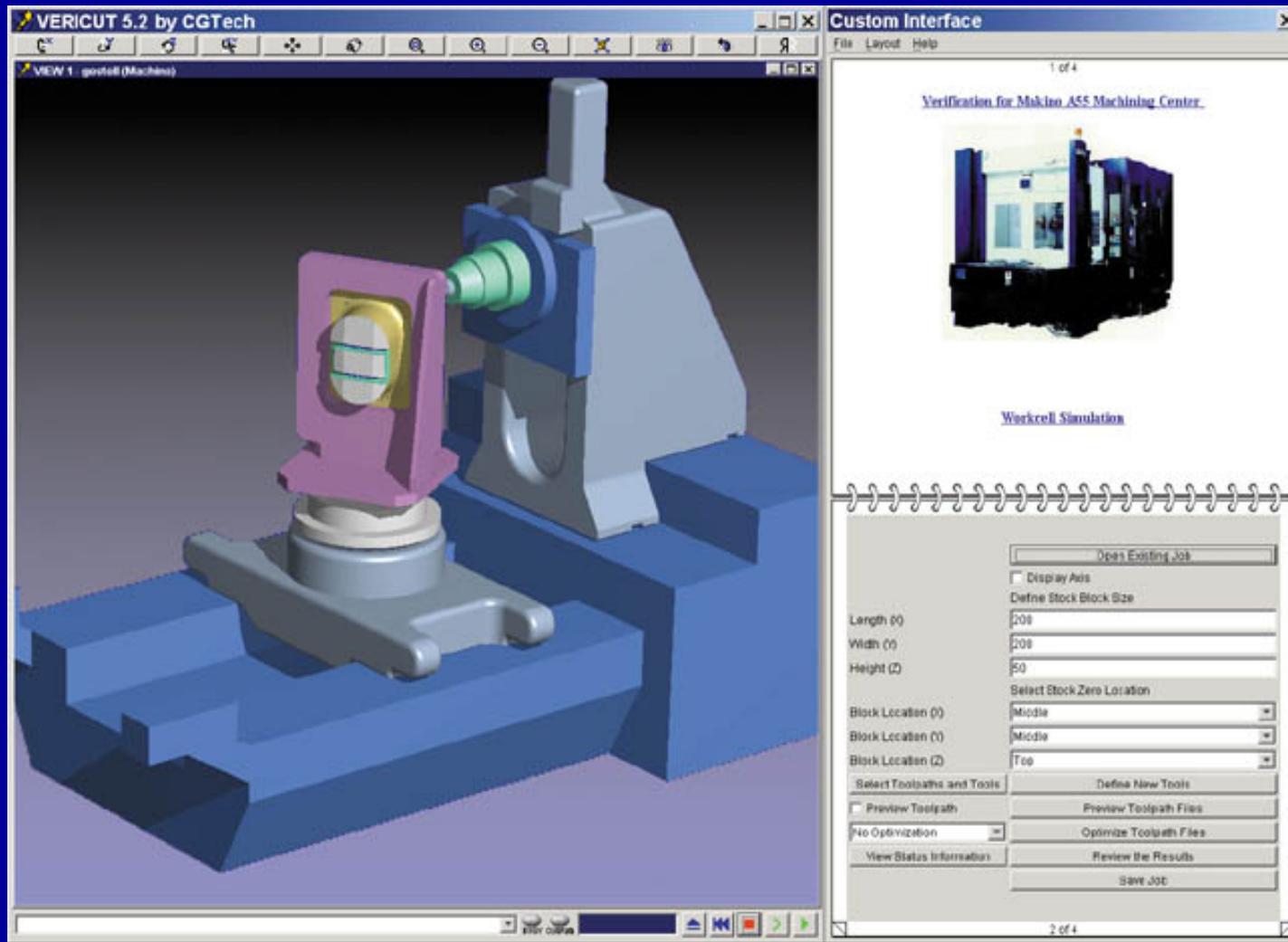
- Contouring Causes the WEDM tool to follow a specified trajectory.
- No Core Removes all material within a specified contour.
- Taper Angle CL Data output on XYZ/UV format.
- XY-UV Type CL Data output on HEAD1/HEAD2 format.

VERICUT Interface to Major CAD/CAM Systems



**Pro/E has licensed a CNC simulation module
from VERICUT
– with no machine tool modeling capability**

Simulation of CNC Machining (VERICUT)



Machining Simulation and Tool Path Verification

The screenshot displays the WorkNC software interface, which is used for machining simulation and tool path verification. The interface is divided into several sections:

- Workzone:** Shows the current job path and contents.
- Workzone Contents:** A table listing the operations in the job path.
- Buttons:** Includes buttons for 'New Toolpath...', 'Recalculate', 'Postprocessor...', 'Execute...', and 'Quit'.
- Run Status:** Shows the current status as 'Idle' and units as 'Metric'.
- VisuNC Graphics:** A 3D wireframe view of the part geometry and tool path. The tool path is shown in red, and the part geometry is in cyan. The coordinate system (X, Y, Z) is visible.
- Tool Path Verification:** The 3D view shows the tool path (red) and the part geometry (cyan) in a wireframe format. The tool path is a complex, multi-axis trajectory.

No.	Type:	Status:	Comments:
<input type="checkbox"/>	Part geometry	C+	
<input type="checkbox"/>	1 Contour roughing - block	C+ P-	Bull-nose (6.35,0.51)
<input type="checkbox"/>	2 Z-level finishing	C+ P-	Bull-nose (4.76,0.51)
<input checked="" type="checkbox"/>	3 Optimized Z-level finishing	C+ P-	Bull-nose (4.76,0.51)

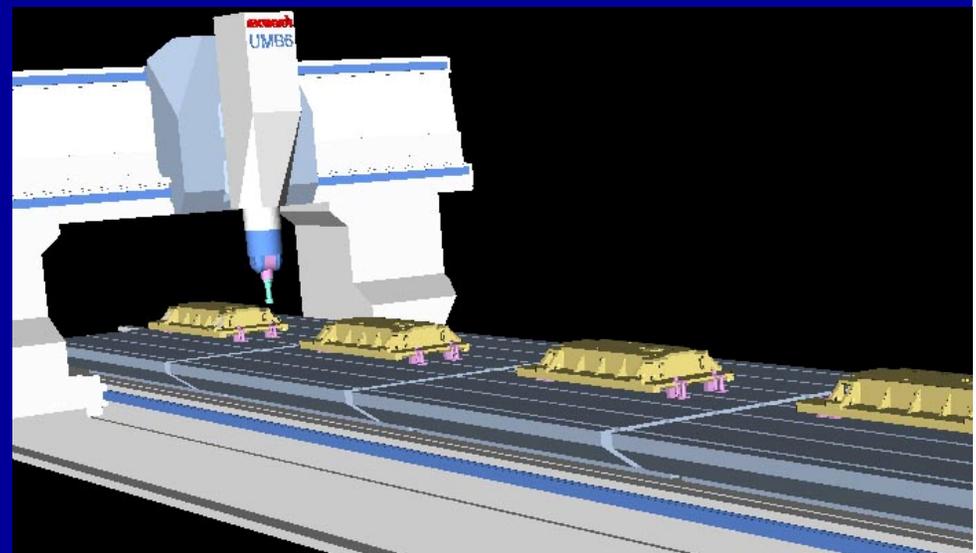
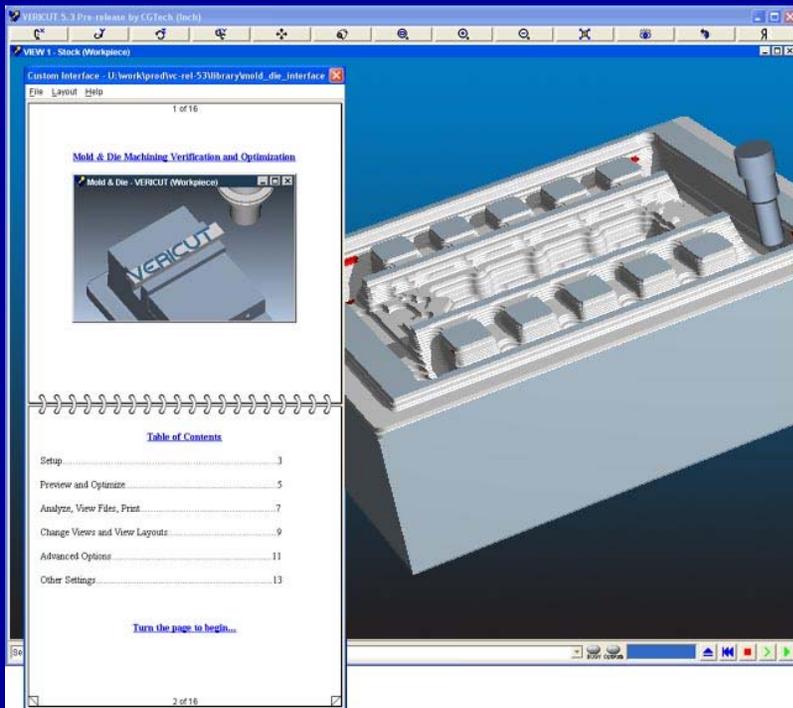
ROTATE: pick first point (left), new axis (right) or hit X, Y, Z, I...

Buttons: +x, +y, +z, -x, -y, -z, ISO, @ X, @ Y, @ Z, Save, Rest.

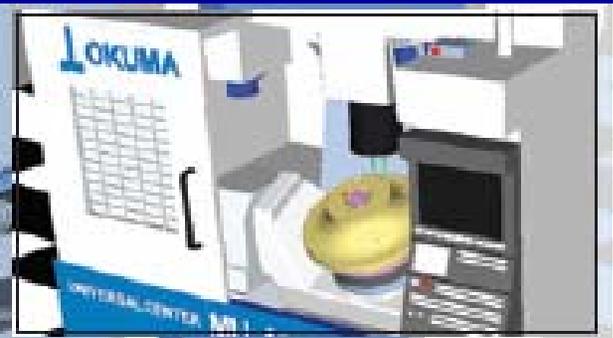
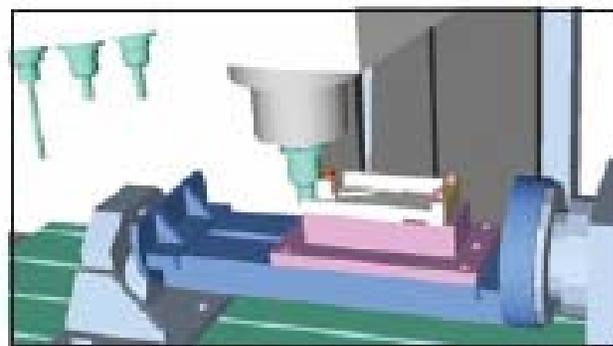
**5-Axis CNC
Milling Based
on a CAD
Model of Boat
Design**

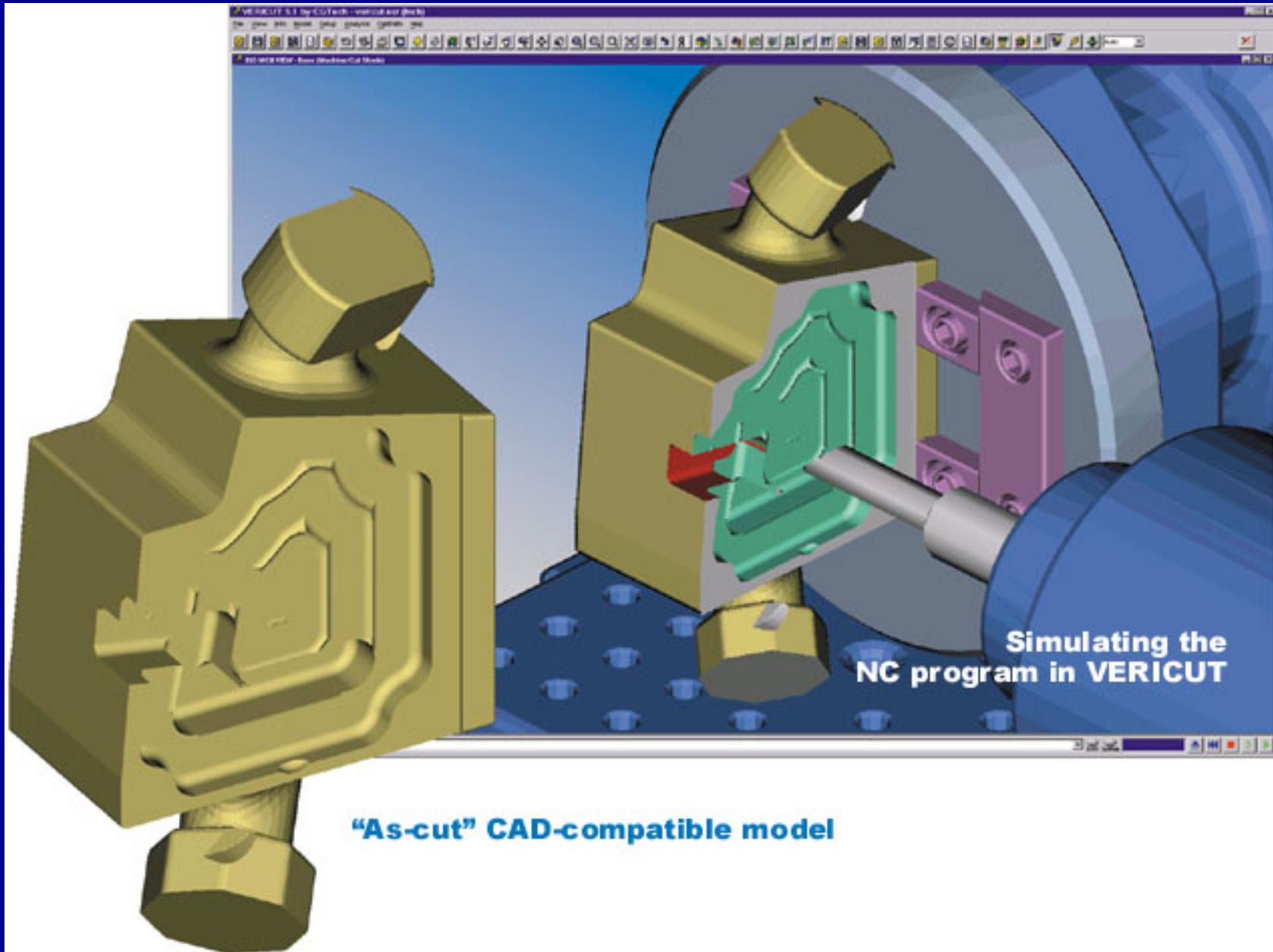


Different CNC Machines & Tasks



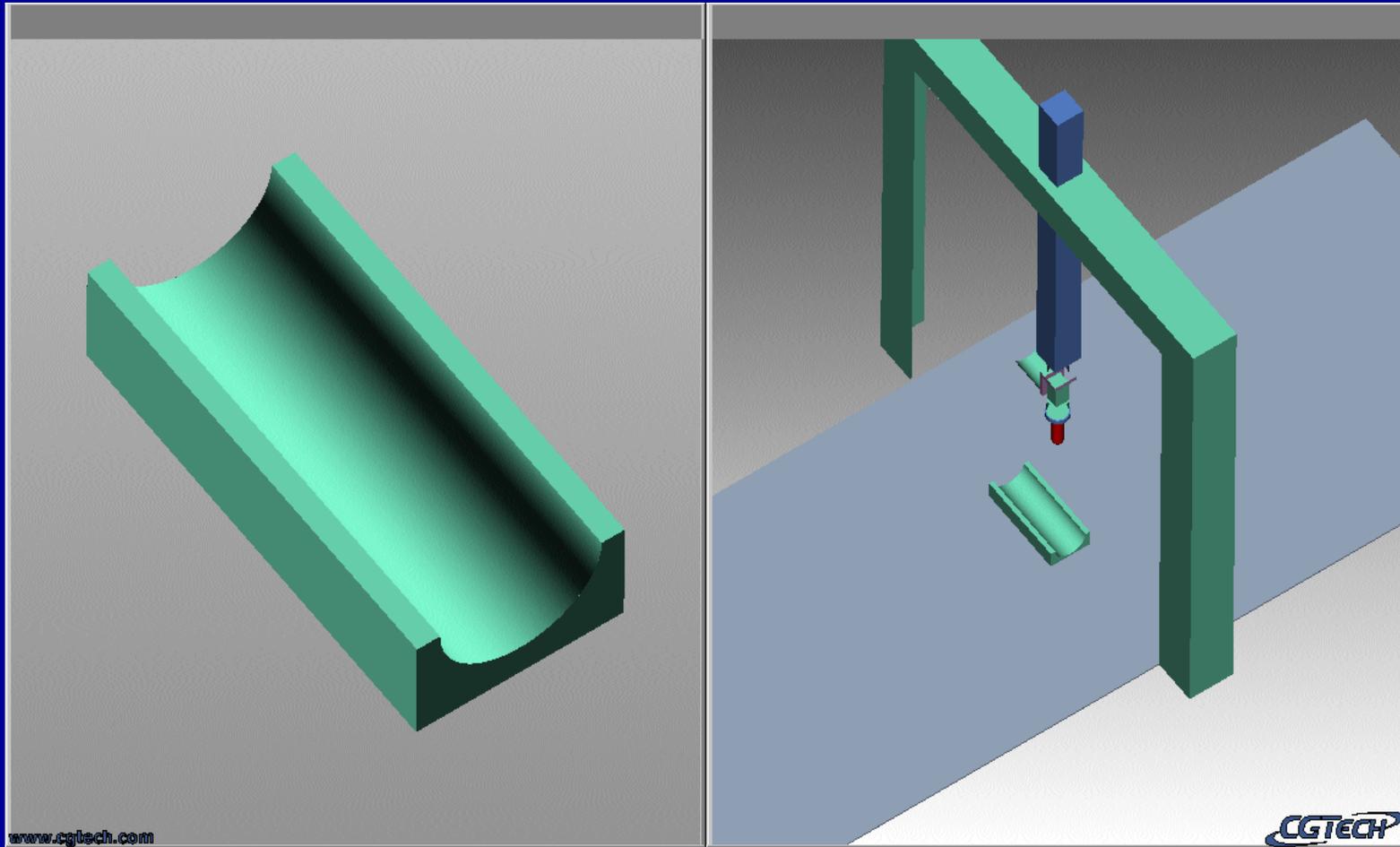
VERICUT CNC Machine Simulation



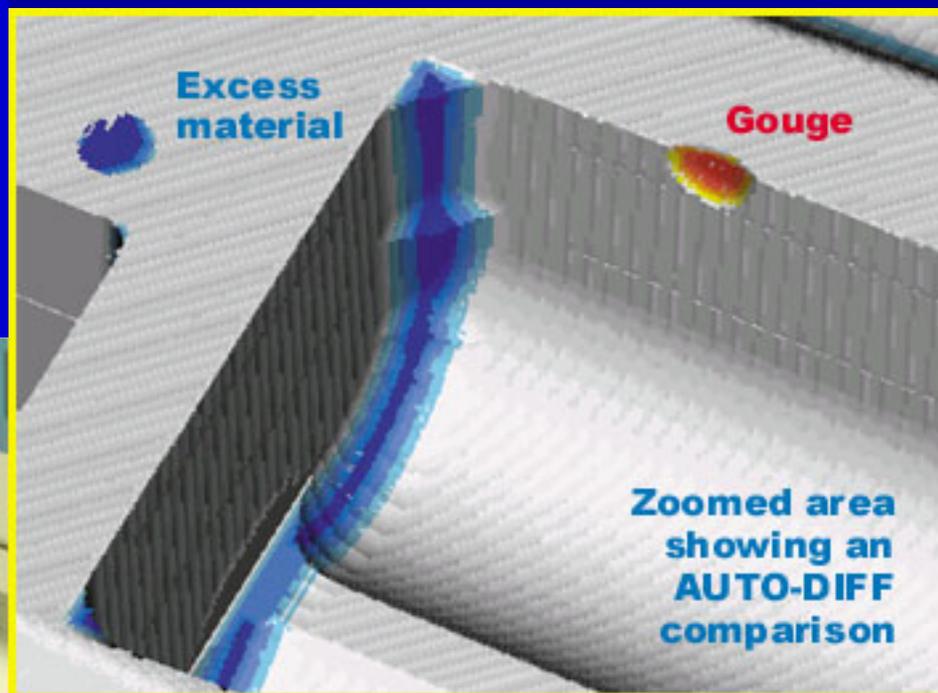


"As-cut" CAD-compatible model

CNC Milling Simulation - CUSP



Gouge Detection

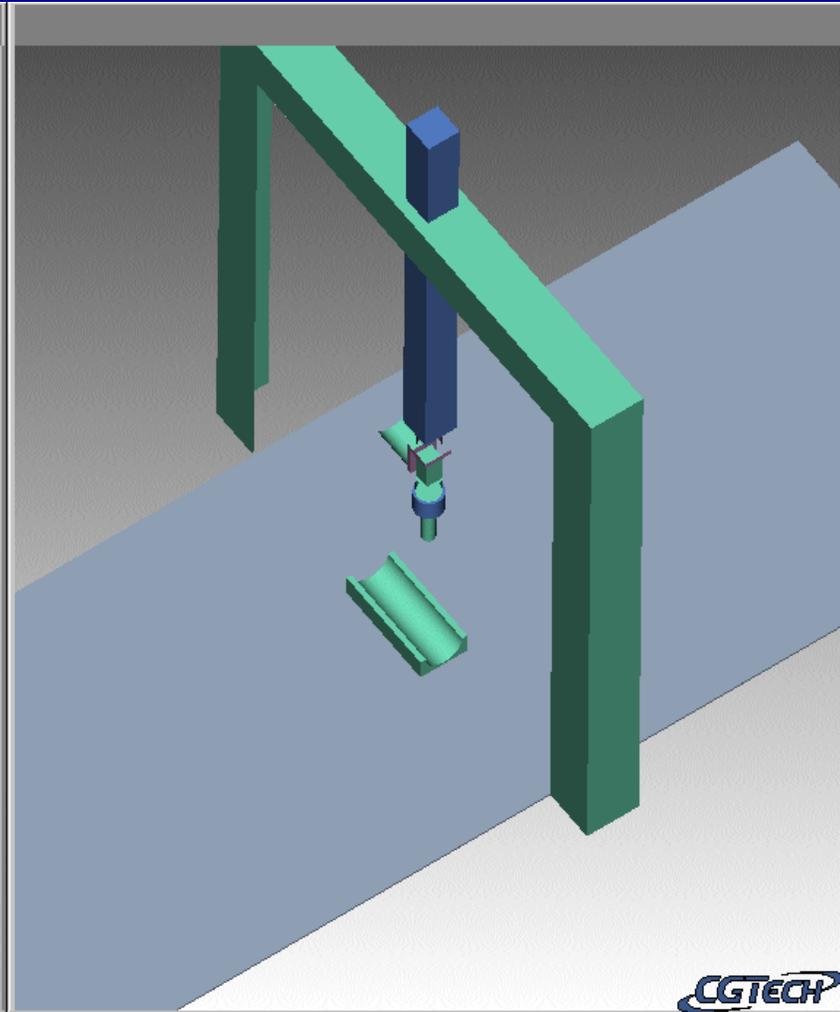
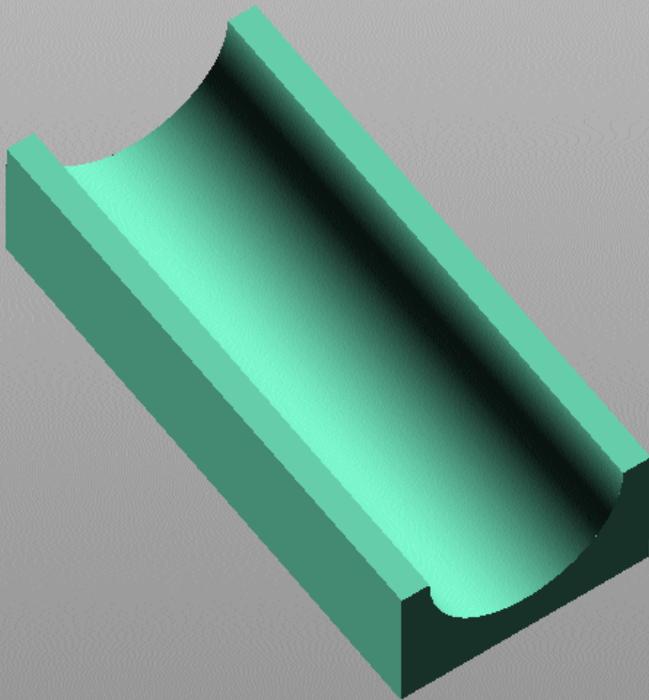


Part cut in VERICUT
from the NC program...

The main image shows a 3D model of a complex, curved part. The part is white with blue and orange highlights. A yellow box highlights a specific area on the part's surface. The part is shown in a perspective view, with a blue and green background.

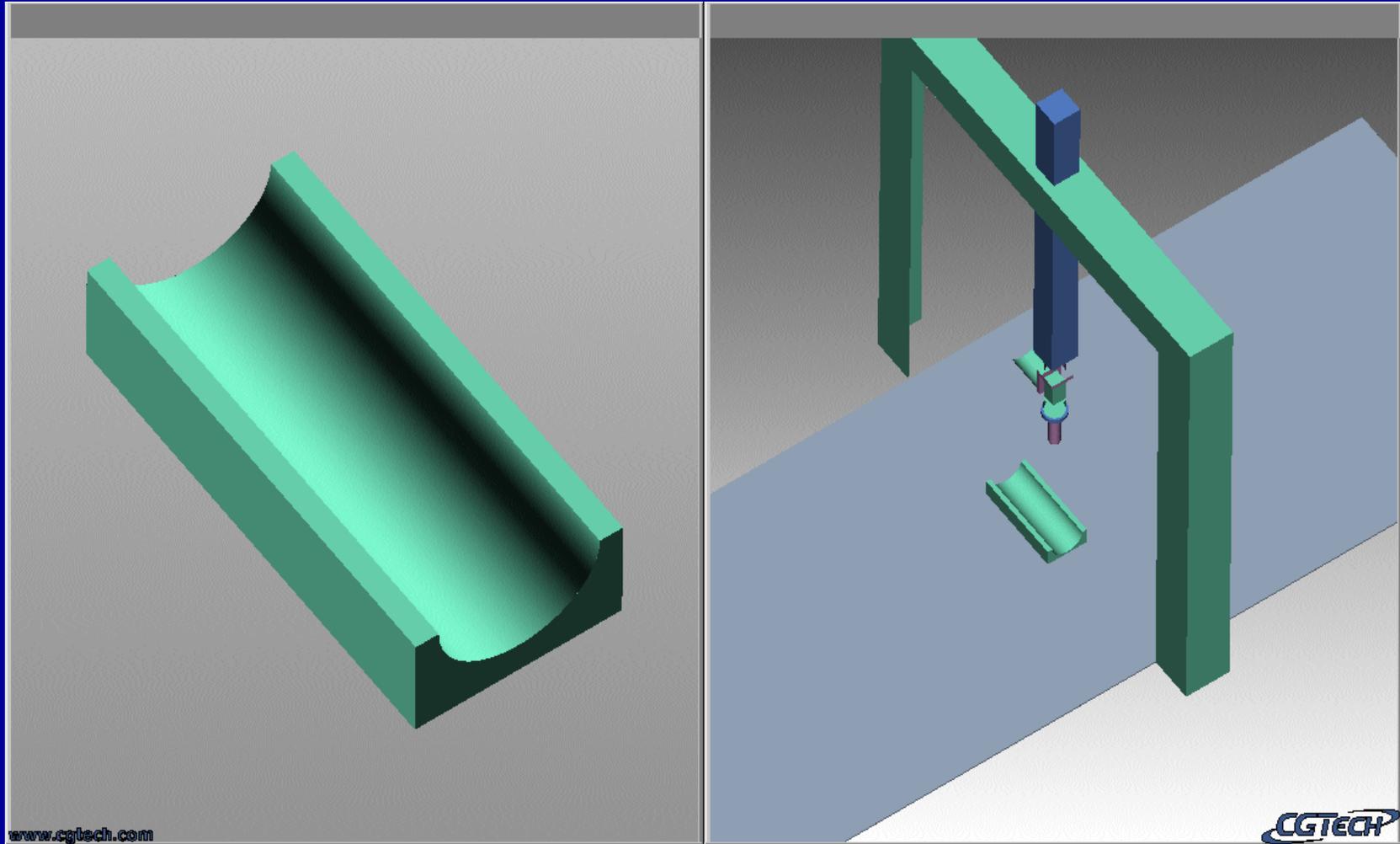
Collision and Gouge Detection

- Flat End Mill



Collision and Gouge Detection

- Torus End Mill



EDM CNC Simulation

