2D – 2.5D Manufacturing
Milling

- High tolerance
- Moderate throughput
- Significant tooling costs / wear of tools
Milling
Water Jet Cutting

- Water + garnet abrasively cuts material with 60 ksi pressures
- Cold cutting of thick materials—no heat affected zone (HAZ) or discoloration
- No tooling costs
- Multi-axis control permits cut axes from normal
Water Jet Cutting

Cutting time: 1,000 rpm
Cake

Steel

5 Axis Control
Electrical Discharge Machining (EDM)

- Preferred for hard-to-machine materials
- Arcing between a (Cu alloy) wire and the workpiece ablates material in the presence of a dielectric
- Can achieve small features with high tolerances
- Parallel kerf walls
Electrical Discharge Machining (EDM)

Wire EDM
Electrical Discharge Machining (EDM)

Die Sinking EDM
Laser Cutting

- Can be used in low to high volume applications
- No tooling costs
- Reduced part stresses and minimal to moderate heating
Laser Cutting
Laser Cutting

TruLaser Cell 8030: High productive laser cutting
Plasma Cutting

- Inert gas blown from nozzle excited to plasma state via applied bias
- Cutting is achieved via melting – thus a HAZ is expected
- Rough finish unless optimized or thin
Plasma Cutting
Stamping / Die Cutting

- High throughput, parallel process
- High tooling costs and tool wear
- Higher quality edge finish (may) require secondary finishing to remove burrs / roughness
Stamping / Die Cutting
<table>
<thead>
<tr>
<th>Method</th>
<th>Materials</th>
<th>Kerf (in. x 0.001)</th>
<th>Tolerance (in. x 0.001)</th>
<th>Throughput</th>
<th>Direction of forces</th>
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<tr>
<td>CNC Milling</td>
<td>Most materials</td>
<td>Tool diameter</td>
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<td>Moderate</td>
<td>XYZ</td>
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<td>EDM</td>
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<td>Plastics, woods, metals (non flammable)</td>
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<tr>
<td>Water Jet</td>
<td>Most materials</td>
<td>20</td>
<td>1 - 8</td>
<td>Moderate</td>
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2.5D to 3D

2.5 D

Computerized control over x/y axes

3D

Multi-axis programming
2.5D – 3D Manufacturing and Computer Numerical Control
CNC Machining

Benefits:
• Automated
• Complex shapes
• Repeatable

Drawbacks:
• Expensive
• Setup time
• Limited availability
CNC at UPenn

Machining Center

ProtoTRAK (retrofit mill)
ProtoTRAK

Utility
- 3 axis digital readout
- Jog
- Power feed
- Cut arbitrary features in the x/y plane
Conversational Programming

You have experienced dxf conversion / importing into the ProtoTRAK software

• Simple geometries can also be programmed conversationally on the controller

• The basic procedure is:
  1) Enter header info
  2) Program “events”
  3) Execute
Conversational Programming

Mill: Straight line profiles (with connective radii)

Arc: Specify beginning, end, and center of arc

Pocket: Interior circular, rectangular, or irregular pocket

Profile: Exterior circular, rectangular, or irregular profile
Milling Side

Left

Right
ProtoTRAK Tips / Warnings

Always check Z!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

- Not doing so can cause flying metal, tool damage, machine damage, human damage
- Check Z whenever you start a milling event or move to a new milling event

Perform a test pass offset in Z from your part
- Do not perform a “trial run” as this can damage the machine

Oversize your tool (in the tool table) to allow for a finish pass
Milling the Mounting Block
Milling the Piston Flange

Note: For aid in CNC Programming

Note: Dimensions to theoretical sharp corner

(Ø .755) Note: Satisfy .005 clearance for P/N 201-24, Piston Cylinder

<table>
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<tr>
<th>UNLESS OTHERWISE SPECIFIED:</th>
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NEXT ASSEMBLY:

APPLICATION: DO NOT SCALE DRAWING

A 201-02 B

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