A close-up photograph of a metallic surface, likely aluminum, featuring diagonal brushed lines. A circular feature, possibly a rivet or a hole, is visible on the left side. The lighting creates highlights and shadows across the surface.

# **2D – 2.5D Manufacturing**

# Milling

- High tolerance
- Moderate throughput
- Significant tooling costs / wear of tools

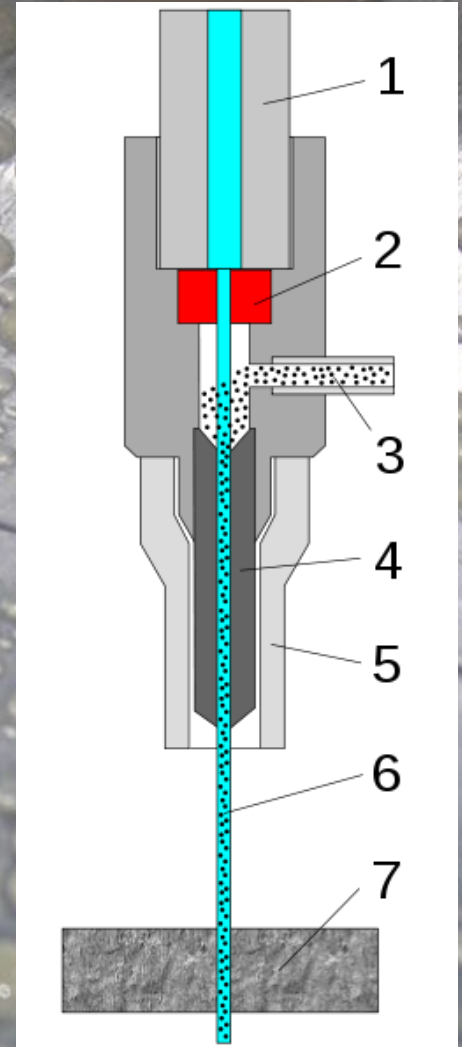
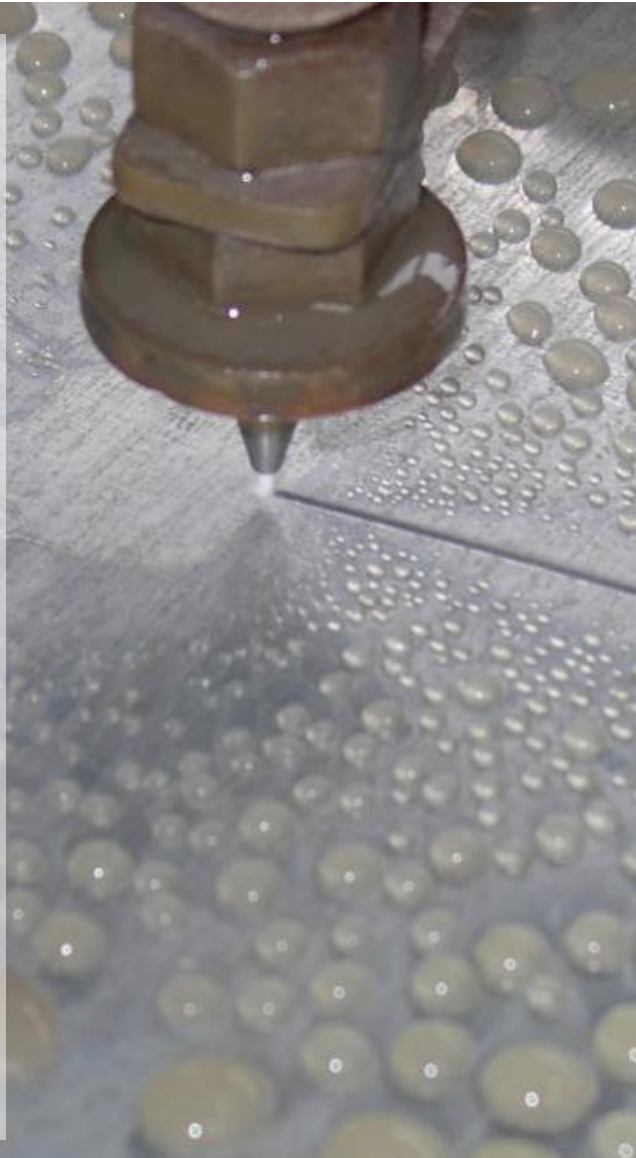


# Milling



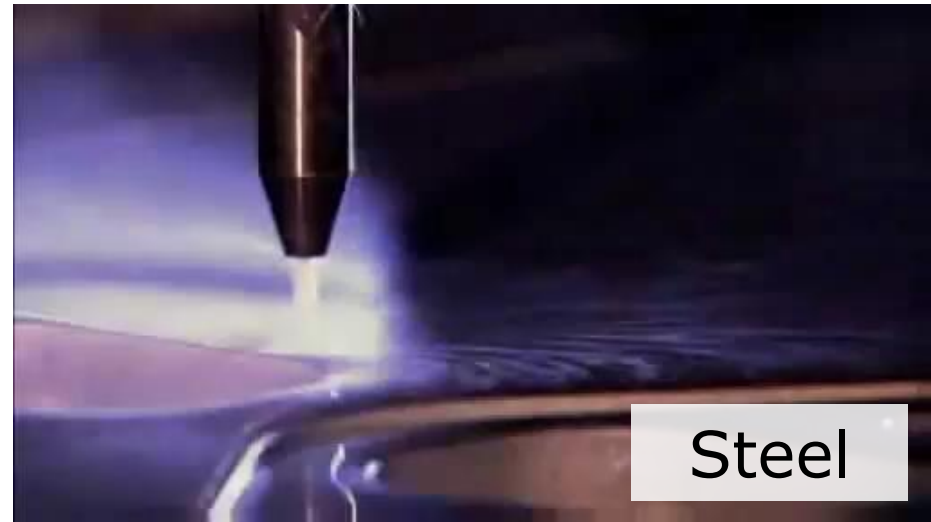
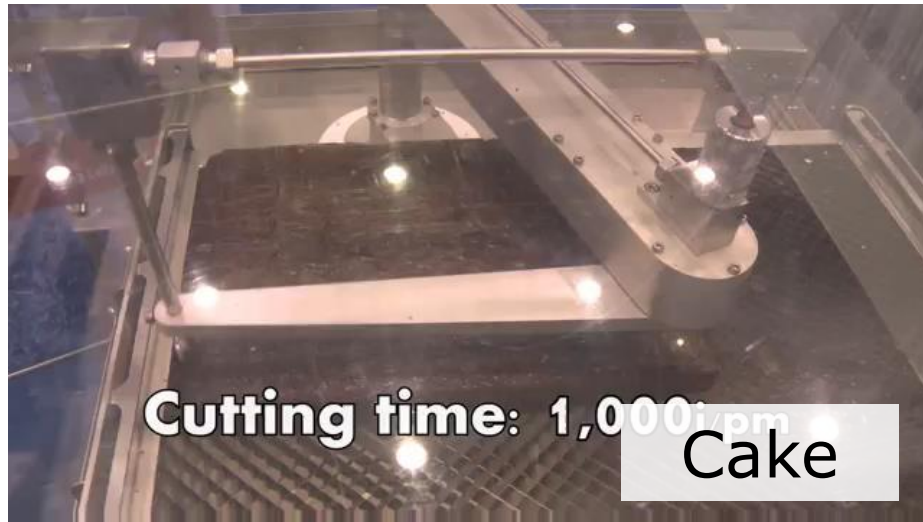
# Water Jet Cutting

- 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



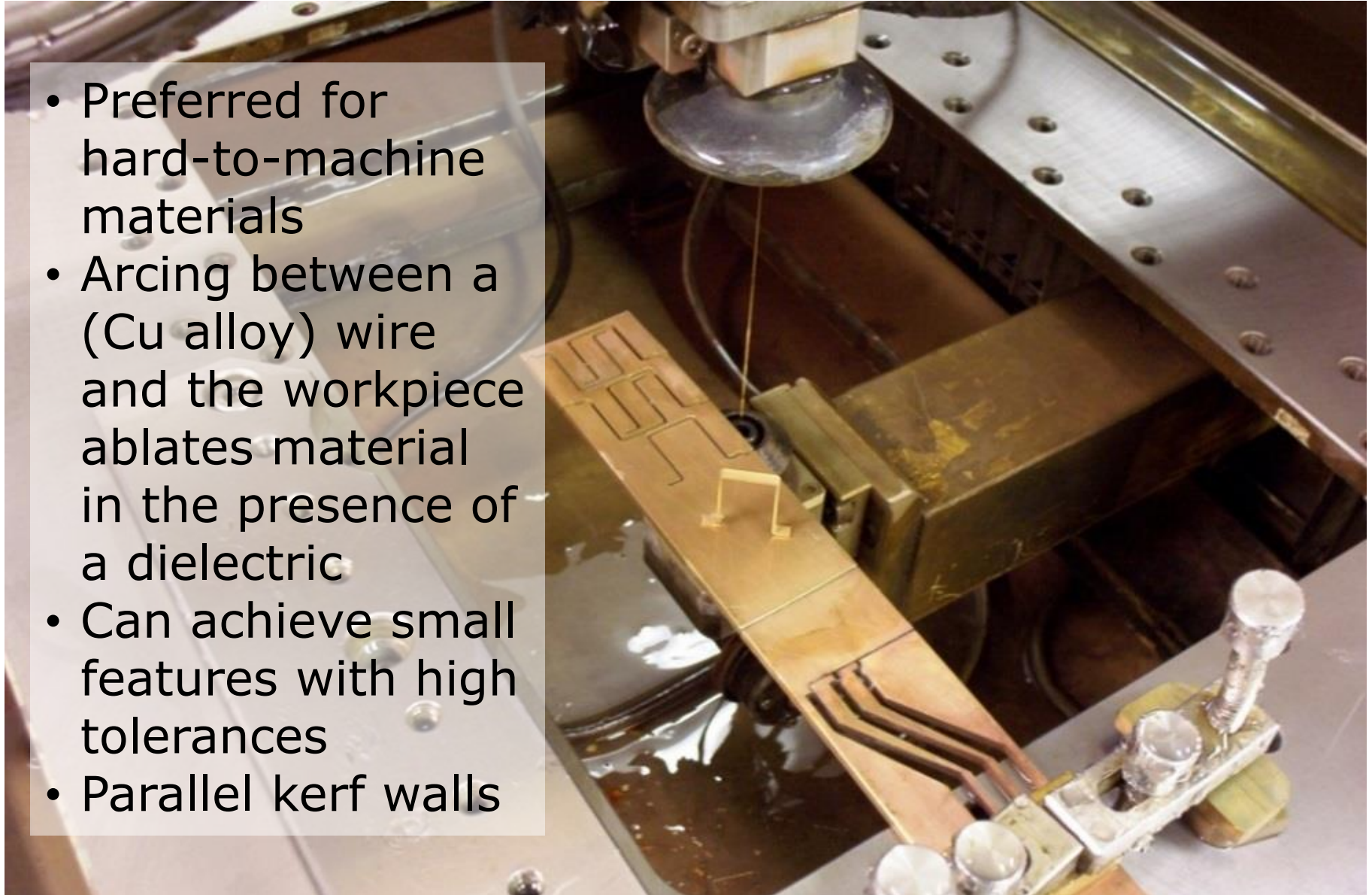


# Water Jet Cutting



# 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)

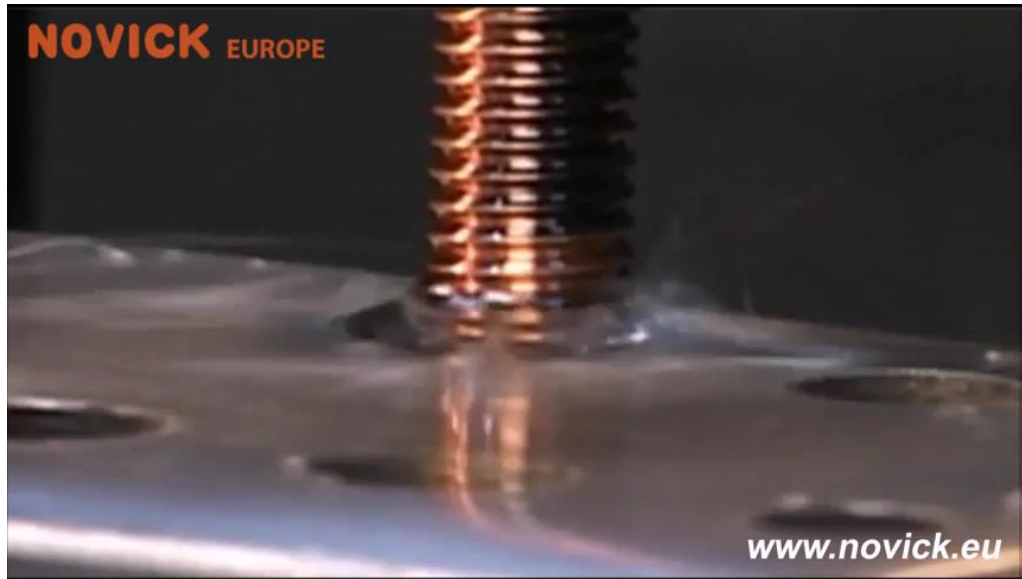


***CARL SOMMER***  
PRESIDENT OF RELIABLE EDM

Wire EDM



# Electrical Discharge Machining (EDM)



Die Sinking EDM

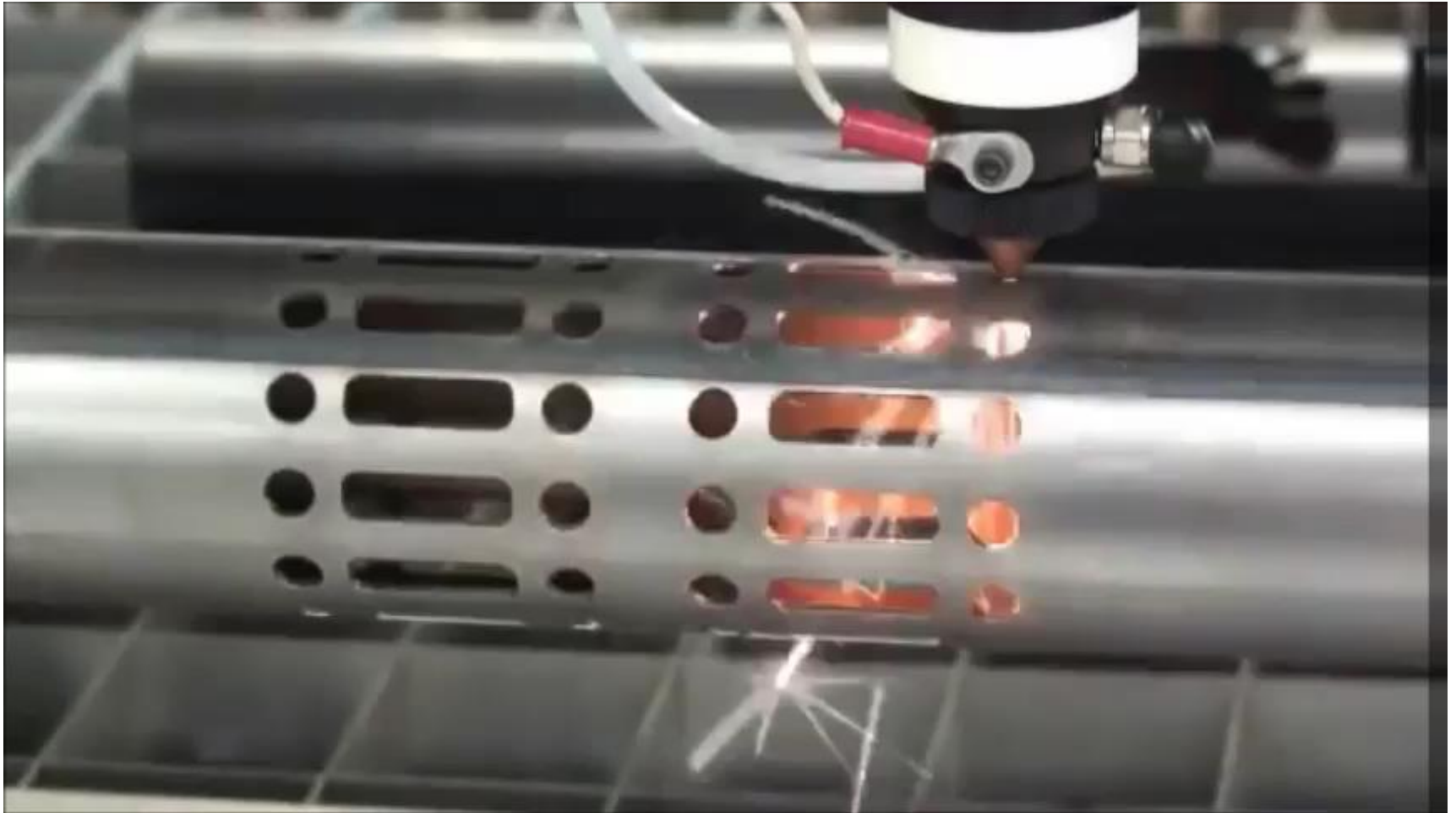


# Laser Cutting

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



# Laser Cutting



# Laser Cutting



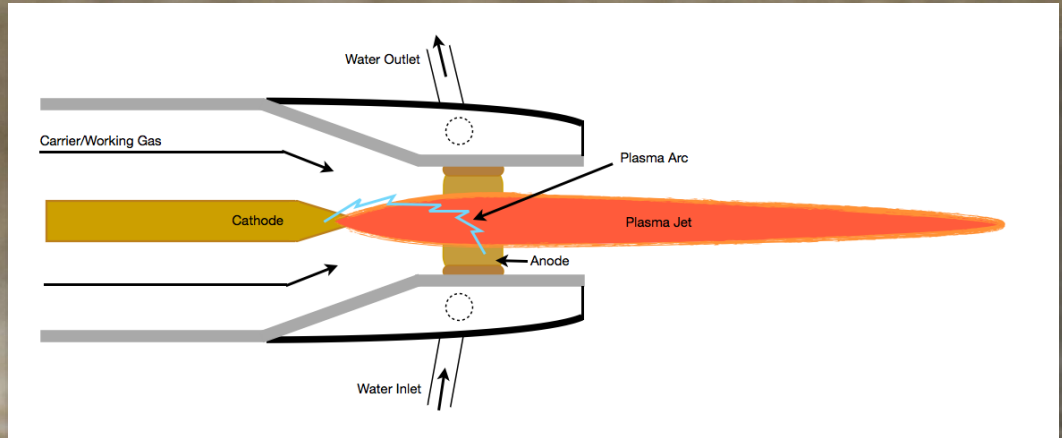
TruLaser Cell 8030: High productive laser cutting





# 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



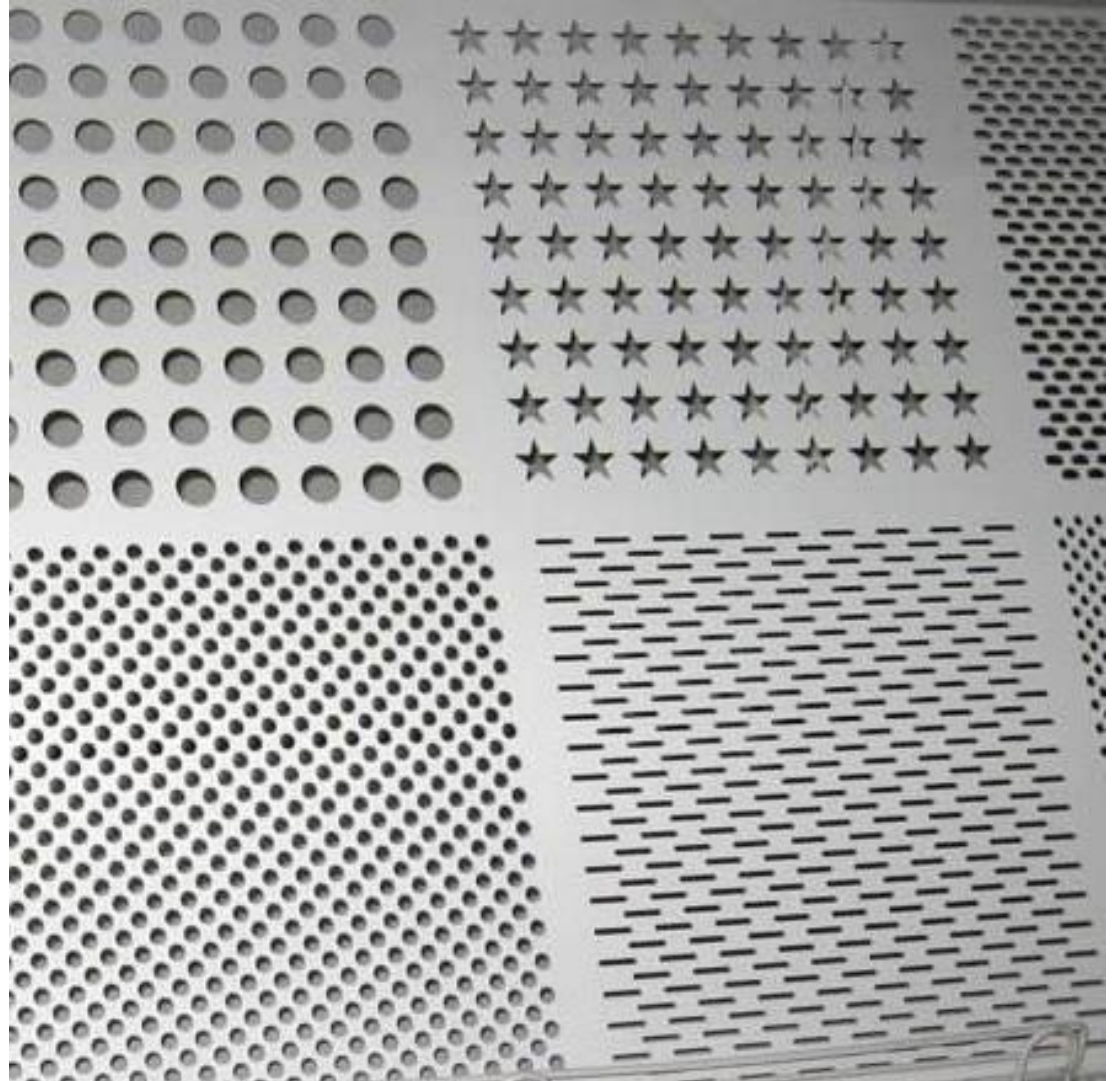
# Plasma Cutting



CNC-based

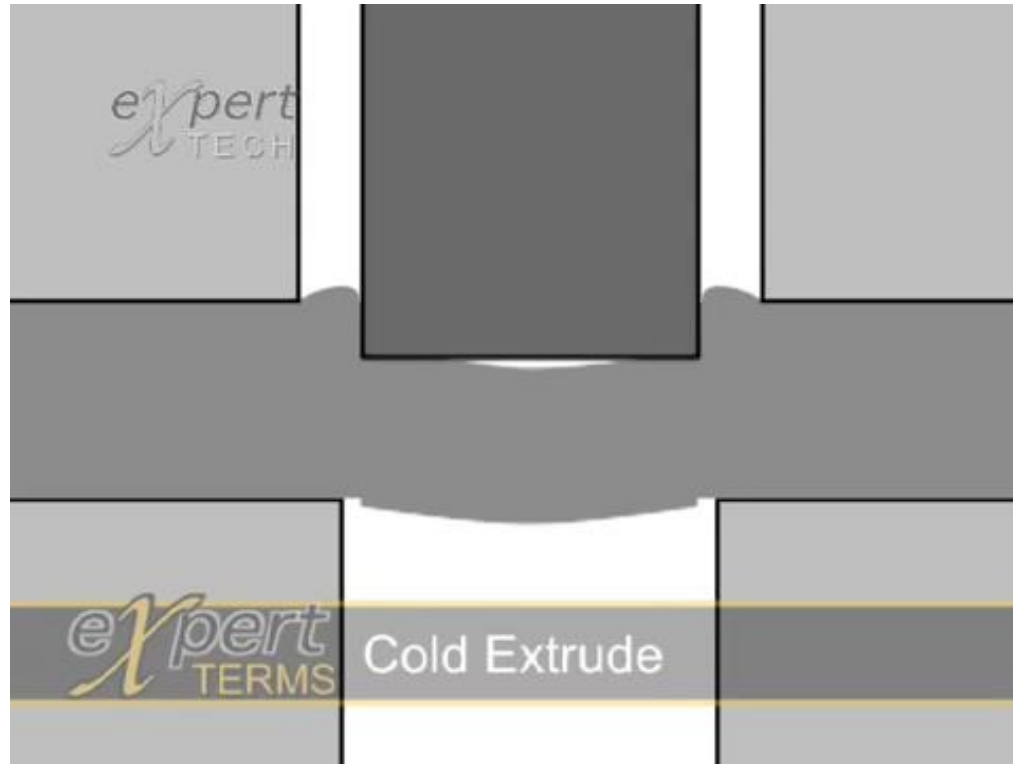
# Stamping / Die Cutting

- 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

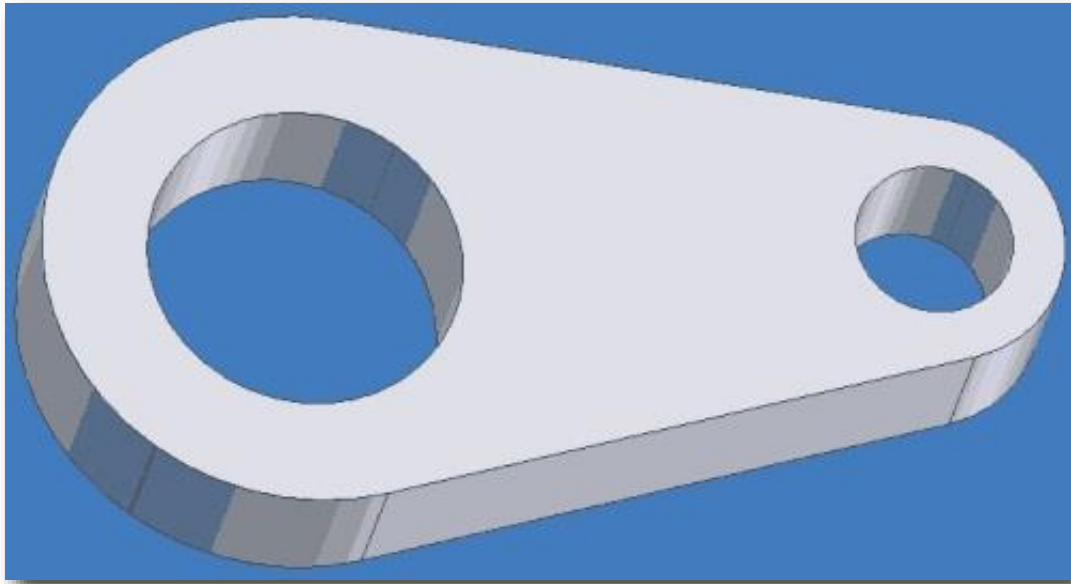


# Summary

Method	Materials	Kerf (in. x 0.001)	Tolerance (in. x 0.001)	Throughput	Direction of forces
CNC Milling	Most materials	Tool diameter	1	Moderate	XYZ
Stamping	Thin metals and plastics	n/a	10	High	Z
EDM	Conductive materials	4 - 14	0.2	Low	Minimal
Laser	Plastics, woods, metals (non flammable)	6	2	Moderate	Minimal
Water Jet	Most materials	20	1 - 8	Moderate	Z

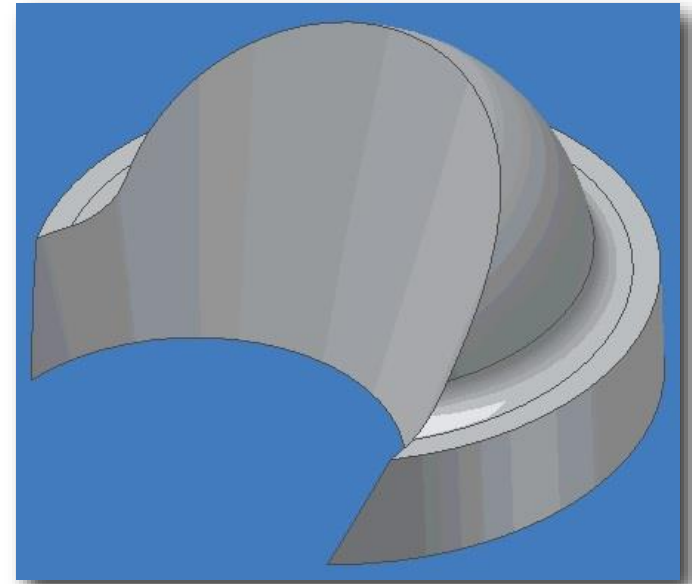
# 2.5D to 3D

2.5 D



Computerized control  
over x/y axes

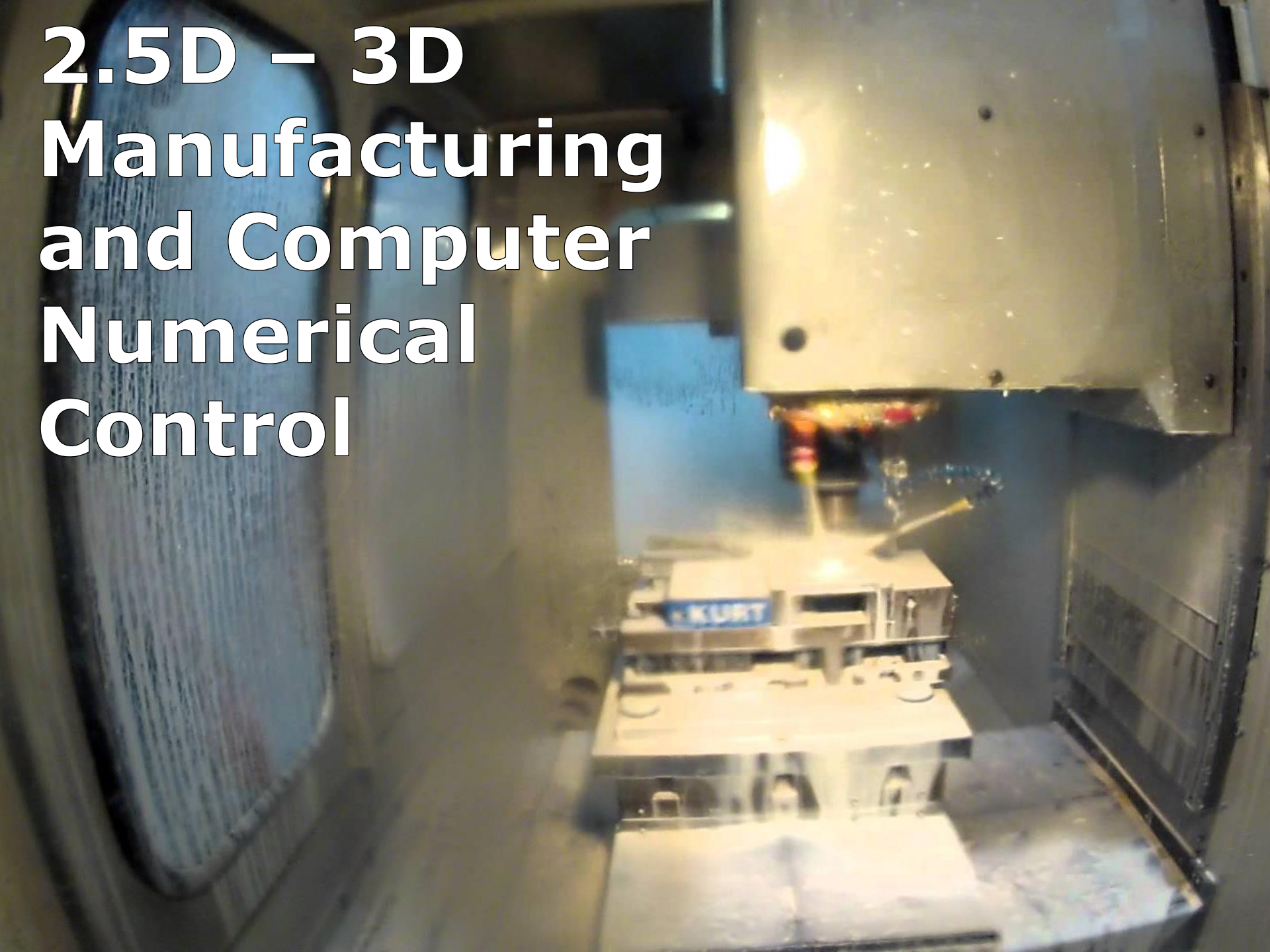
3D



Multi-axis  
programming



# 2.5D – 3D Manufacturing and Computer Numerical Control



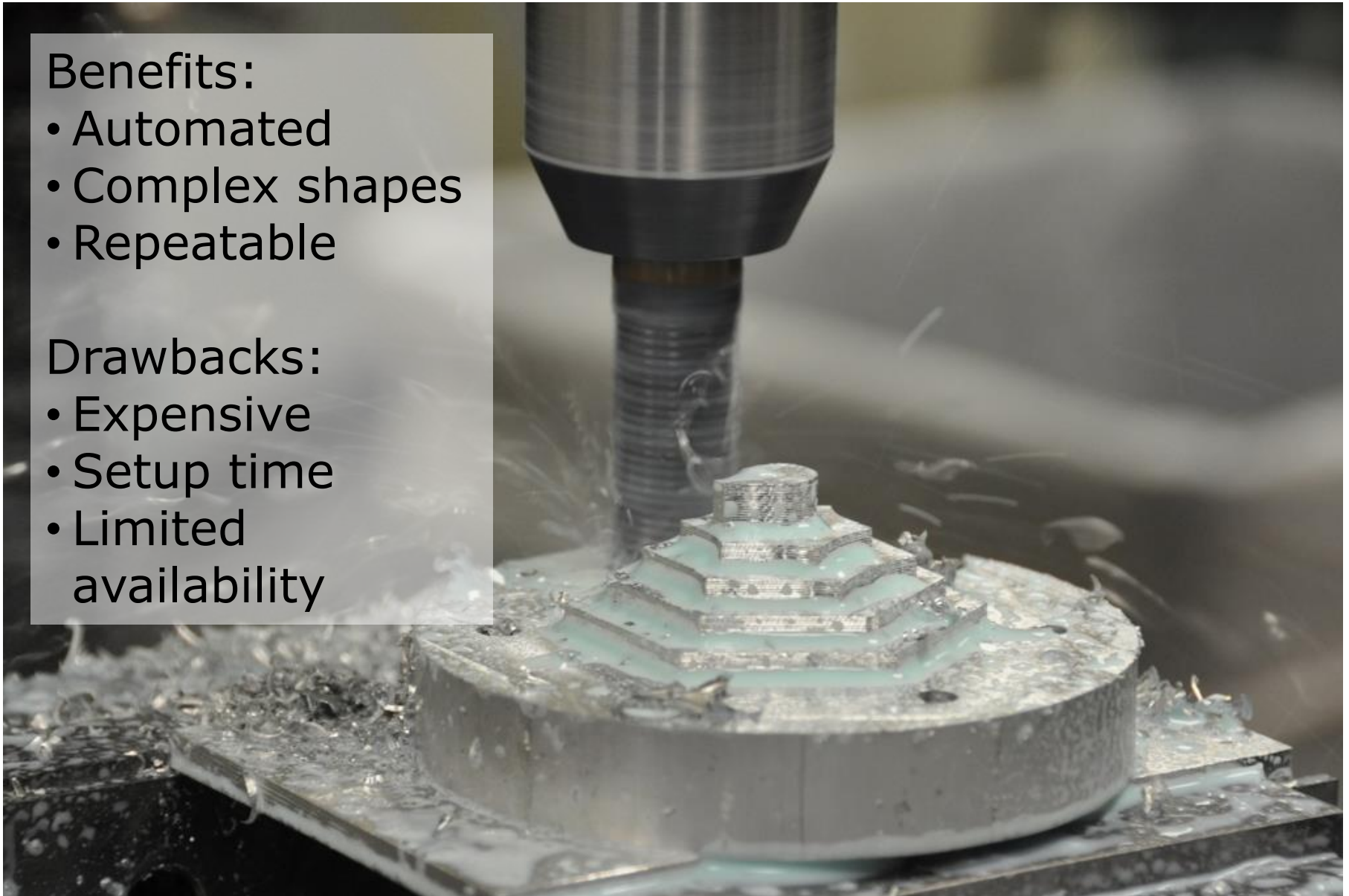
# CNC Machining

## Benefits:

- Automated
- Complex shapes
- Repeatable

## Drawbacks:

- Expensive
- Setup time
- Limited availability





# CNC at UPenn

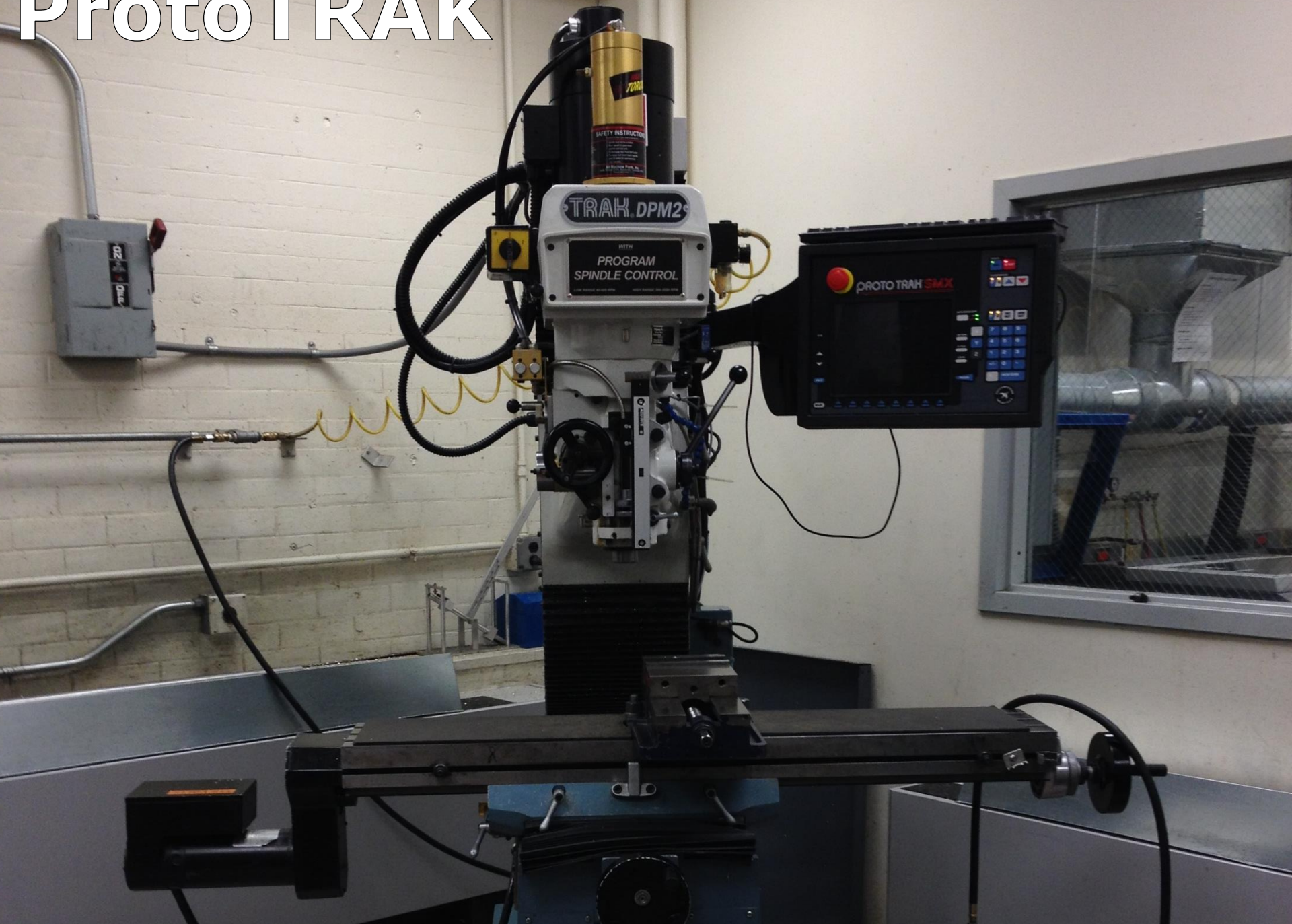
## Machining Center



## ProtoTRAK (retrofit mill)



# ProtoTRAK





# ProtoTRAK

## ProtoTRAK Controller (DRO mode)

### 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

PT4SX Offline

PROG P/N 0 2 AXIS INCH

**EVENT 0**

PROGRAM NAME 0  
SCALE 1.000  
AUXILIARY FUNCTION NO  
EVENT COMMENTS NO  
MULTIPLE FIXTURES NO  
DIMENSION DEFINITION PART GEO

**EVENT 1**

Select an event.

F1 F2 F3 F4 F5 F6 F7 F8  
POSN DRILL BOLT HOLE MILL ARC POCKET PROFILE EN-GRAVE MORE

Mill: Straight line profiles (with connective radii)

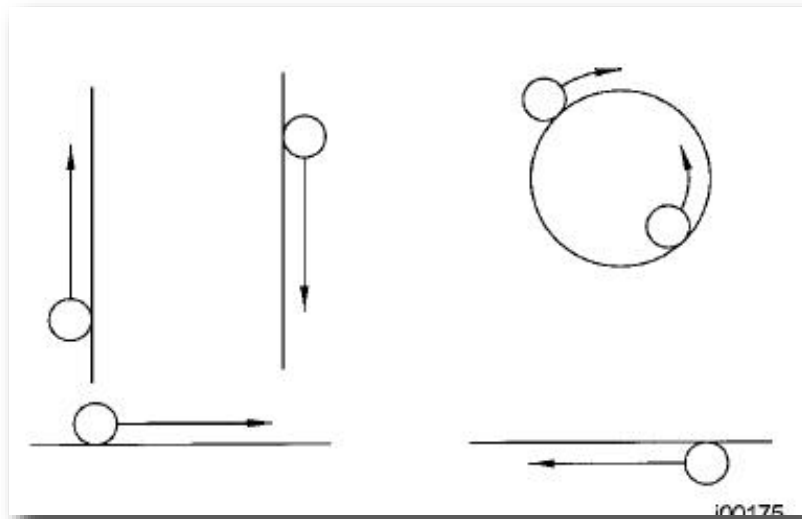
Arc: Specify beginning, end, and center of arc

Pocket: Interior circular, rectangular, or irregular pocket

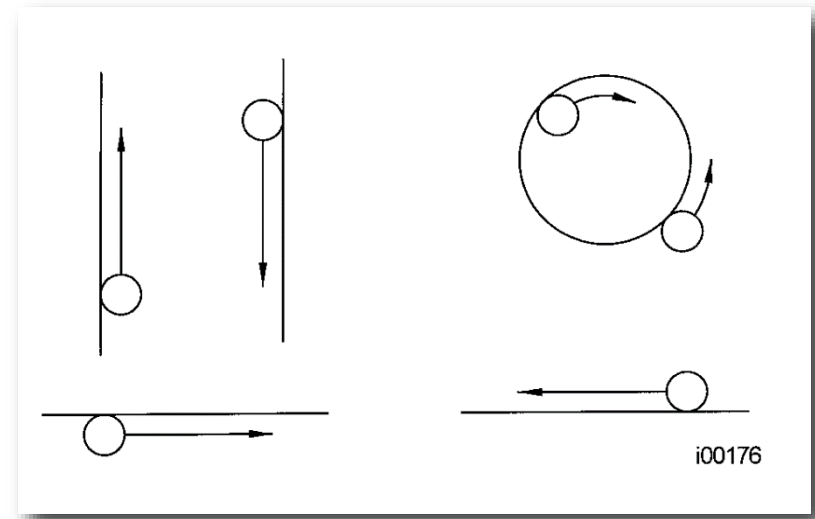
Profile: Exterior circular, rectangular, or irregular profile

# Milling Side

## Left



## Right





# ProtoTRAK Tips / Warnings

Always check Z!!

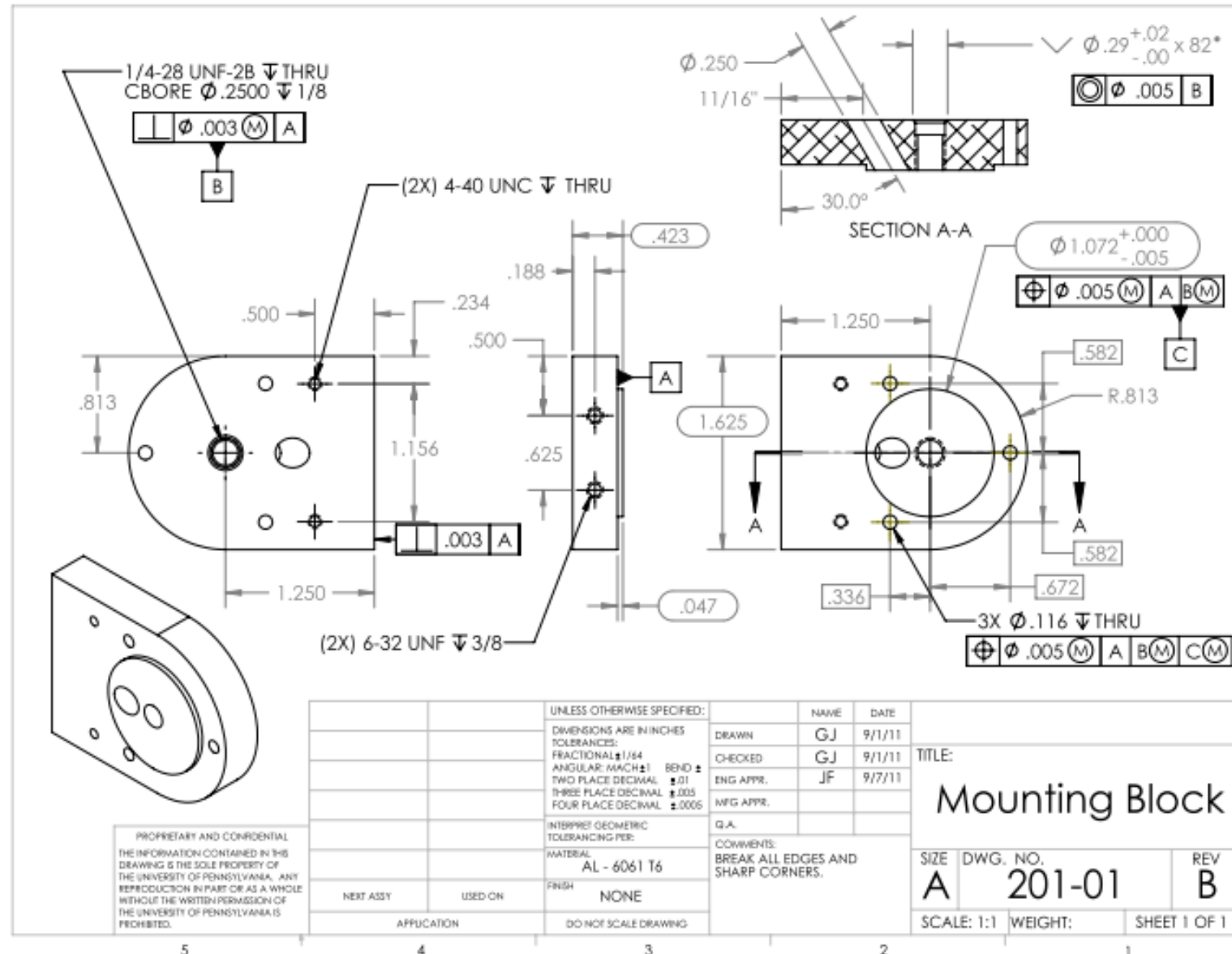
- Not doing so can cause flying metal, tool damage, machine damage, human damage
- Check Z whenever you start a milling event or move to a new milling event

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

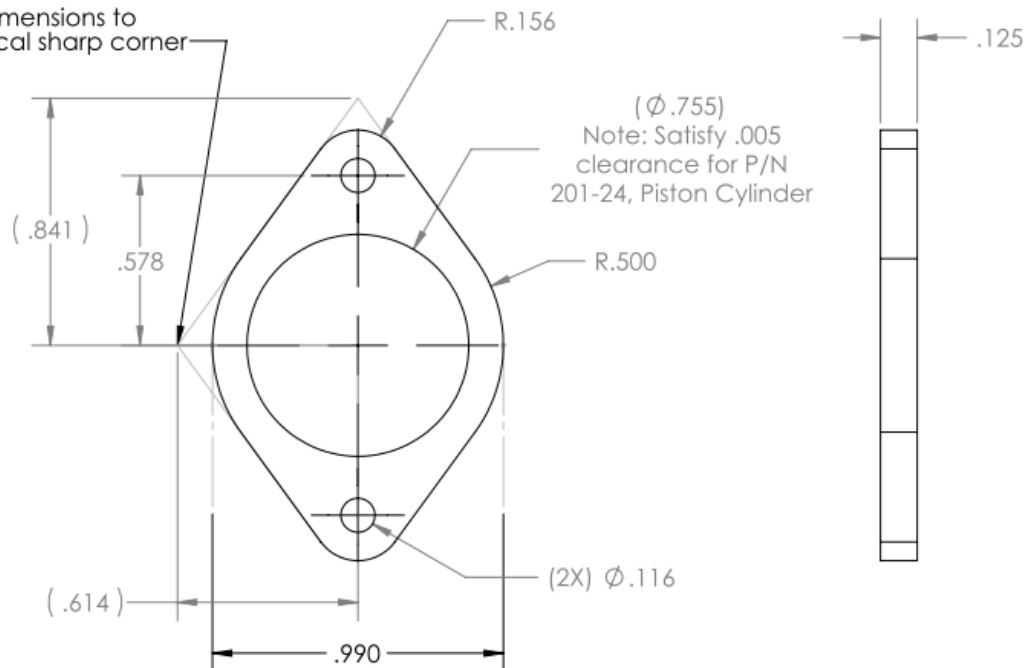
# Milling the Mounting Block



# Milling the Piston Flange

Note: For aid in CNC Programming

Note: Dimensions to theoretical sharp corner



PROPRIETARY AND CONFIDENTIAL  
THE INFORMATION CONTAINED IN THIS  
DRAWING IS THE SOLE PROPERTY OF  
THE UNIVERSITY OF PENNSYLVANIA. ANY  
REPRODUCTION IN PART OR AS A WHOLE  
WITHOUT THE WRITTEN PERMISSION OF  
THE UNIVERSITY OF PENNSYLVANIA IS  
PROHIBITED.

		UNLESS OTHERWISE SPECIFIED:	NAME	DATE	TITLE:  Piston Flange			
		DIMENSIONS ARE IN INCHES	DRAWN	CX				1/30/10
		TOLERANCES:	CHECKED	GJ				8/1/11
		FRACTIONAL: ± 1/64	ENG APPR.	JF				8/7/11
		ANGULAR: MACH ± 1 BEND ±	MFG APPR.					
		TWO PLACE DECIMAL ± .01				SIZE A	DWG. NO. 201-02	REV B
		THREE PLACE DECIMAL ± .005	COMMENTS: BREAK ALL EDGES AND SHARP CORNERS.					
		FOUR PLACE DECIMAL ± .0005						
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			SCALE: 2:1		
		MATERIAL C360 Brass						
NEXT ASSY	USED ON	FINISH NONE				SHEET 1 OF 1		
APPLICATION		DO NOT SCALE DRAWING						

5

4

3

2

1