CNC Machining

For Prototyping Hardware

Hosted by
Andrew Hudak
Fictiv

and
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Swope Design Solutions

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Webinars

Your Hosts

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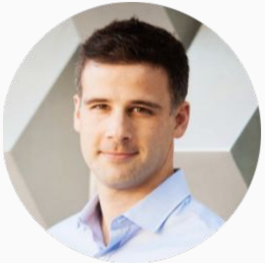

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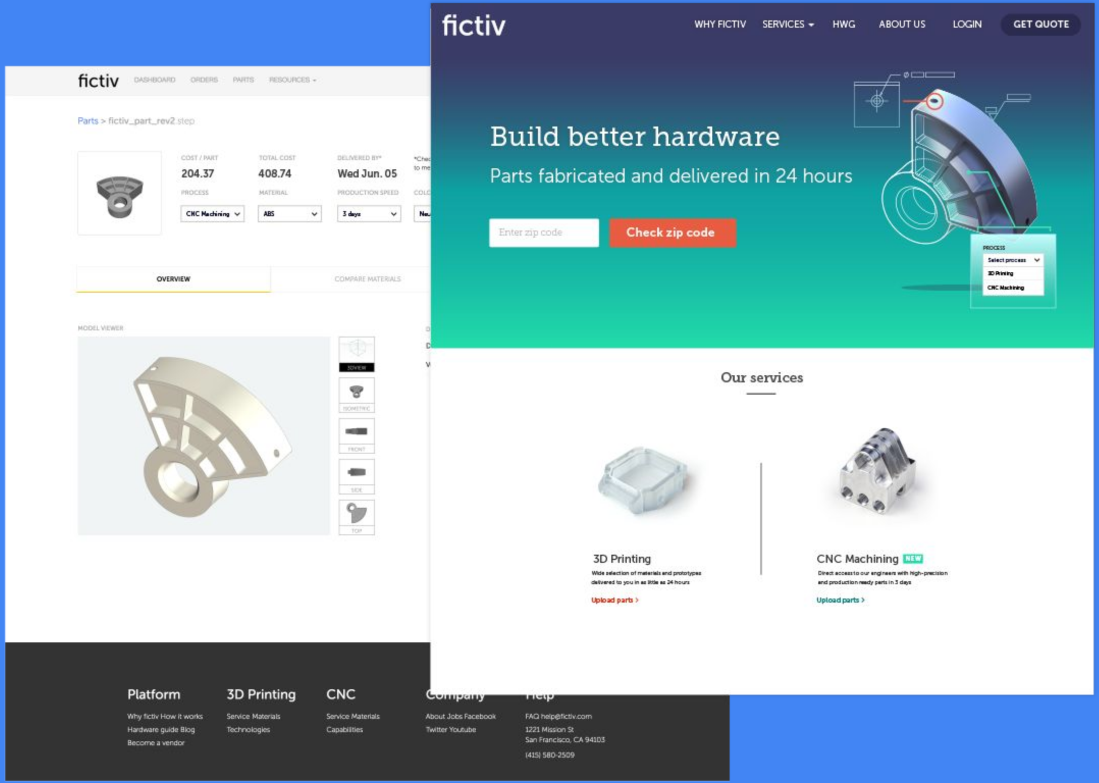
Fictiv’s manufacturing platform is the most efficient way to fabricate parts. Powered by a distributed network, we offer **3D printed parts in 24 hours**, and **CNC machined parts in 3 days**.

Our online interface makes it easy to get instant quotes, review manufacturing feedback, and manage orders - all through a single service.

In addition, Fictiv organizes a large knowledge base of curated content and community events centered around design, engineering, and manufacturing.



About

Swope Design Solutions is a Mechanical Engineering and Product Design firm that specializes in consumer products, medical devices, and robotics. From prototyping to production, we have a combined expertise in all areas of a product life cycle.

Process

Our process couples engineers who have a wide breadth of design experience with in-house capabilities and equipment to effectively and efficiently converge on solutions to our client's biggest problems. Many engineering firms are too large to rapidly converge on solutions and others too small to have sufficient in-house capabilities. At SDS, we strike the perfect balance between the two creating an ideal problem solving environment.

CONCEPT DEVELOPMENT

- Research & Development
  - IP Generation
  - Advanced Materials
  - Process Development
  - Feasibility Studies
  - Rapid Prototyping
- Product Design
  - Proof of Concept
  - Minimum Viable Product
  - Injection Molded Part Design
  - Electronics Integration
  - Enclosure Design
  - Mechanism Design
- CAD/CAE
  - SolidWorks
  - HSMWorks
  - FEA
- Machining Processes
- Industrial Design Integration

DESIGN FOR OVERSEAS OR DOMESTIC PRODUCTION

- Design For Manufacturing
  - Silicone Molding
  - Injection Molding
  - Tooling Design
  - Finishing Processes
- Design For Assembly
  - Assembly Fixture Design

TESTING

- Root Cause Analysis
- Performance Testing
  - Cycle Testing
  - Drop Testing
  - Pressure Testing
- Quality Assurance

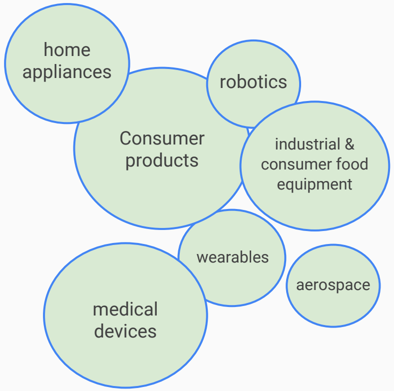
LOW VOLUME PRODUCTION

- CNC Part Production
- Silicone Part Production

ON-SITE EQUIPMENT

- HAAS VF2 SS 5 Axis CNC Mill
- Hardinge Lathe
- Bridgeport Mill
- Laserstar Laser Welder
- Silicone Transfer Press
- 3D Printing - Stratasys UPrint FDM
- Force testing equipment
- 6 Axis UR10 Industrial Robot
- UV Curing Station
- EFD Dispensing Equipment

INDUSTRIES



Overview

- What is CNC Machining?
- CNC in the PD cycle / When to Transition
- Communicating Design Intent
- Design Considerations & Pitfalls
- Machine Planning & Programming
- Question & Answer

What is CNC Machining?

- CNC Machining is a high-precision, subtractive manufacturing process
- Uses cutting tools to remove material from stock material (commonly plastic/metal), creating a part
- Machine controlled using computer coding language known as G-code
- Webinar Focus: CNC Milling
  - Rotating cutting tool, stationary workpiece

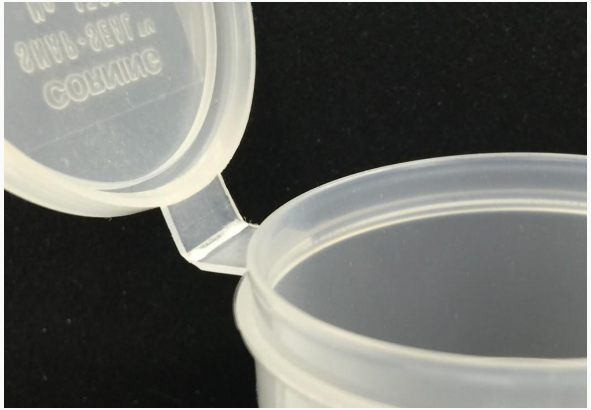
CNC in the PD Cycle

When to Transition

When to Transition to CNC

All prototypes are built to answer questions. When you need to address questions that no longer make sense being answered using 3D printing, it is time to transition to CNC machining in the PD cycle. Some examples include:

- Designs that require mechanical or physical properties not available with 3DP materials



Living Hinges

Testing and documentation for regulatory bodies

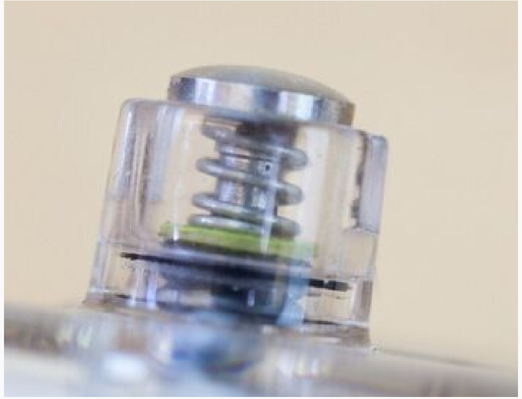
Prototypes for user testing with safety implications (food contact, etc)

When to Transition to CNC

- Designs that require mechanical or physical properties not available with 3DP materials

Evaluate adhesive or other assembly process performance

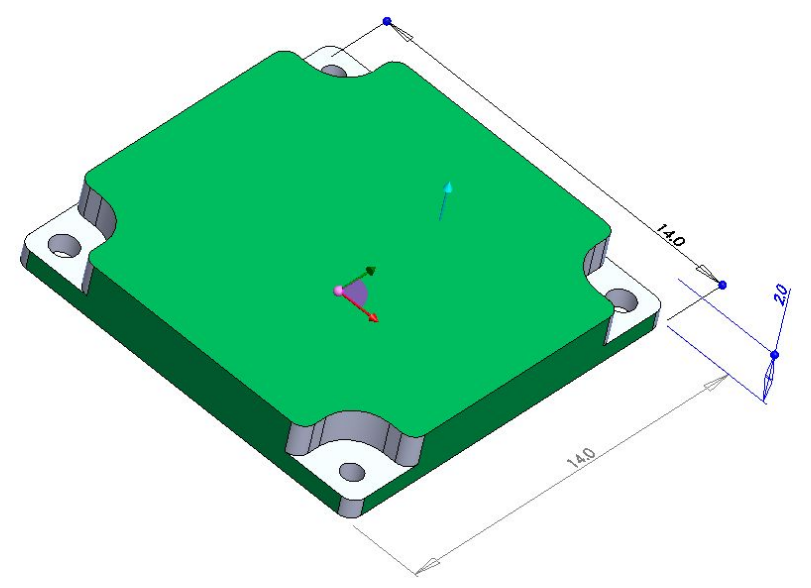
Simulate injection molded parts and materials

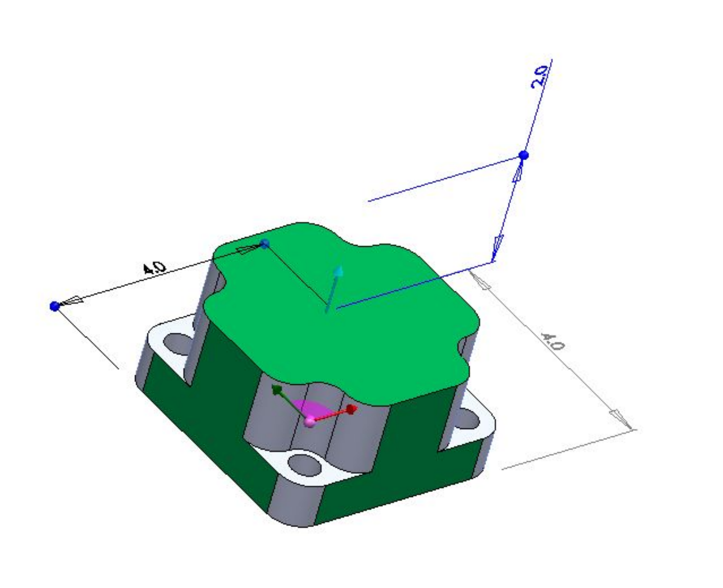


Evaluate mechanism performance

When to Transition to CNC

- Designs that offer cost savings with CNC
  - Often a project requires quantities, sizes, and/or part geometries that are *less* expensive with CNC machining
    - With subtractive processes, subtracting less is more cost effective.
    - With additive processes, adding less is more cost effective.





Communicating Design Intent

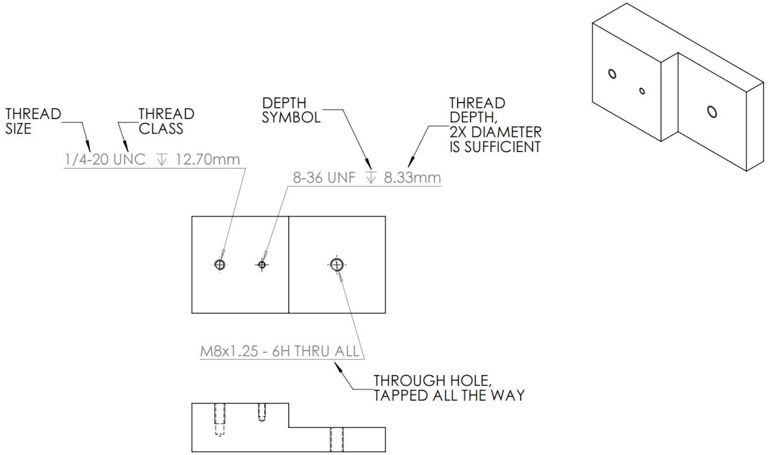
Communicating Design Intent

Whether or not you are working directly with a machinist, efficiently expressing the most critical aspects of your design is especially important. Overall things to keep in mind:

- Certain features are more important than others; prioritize them
- Communicating intent in your design will save time, money, and confusion
- Additional documentation/clarity is never a bad idea and in some cases is required

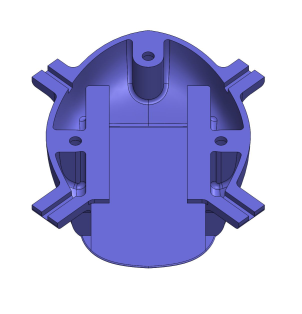
Communicating Design Intent - Hole Tapping

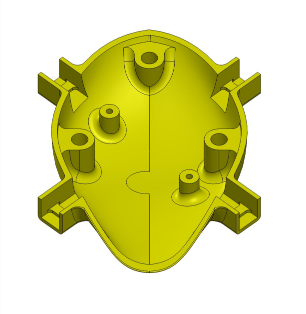
- Definition:
  - Holes to be threaded with a tap or other thread-milling operation
- CAD communication:
  - Pre-tap hole sizes
- Best practices:
  - Include a drawing containing hole callouts
  - Give verbal/email notice of tapping needs
- Avoid:
  - Cosmetic threads included in model
    - Memory intensive
    - CAM packages have standard tapping operations
    - Exceptions: threading with custom geometry or pitch

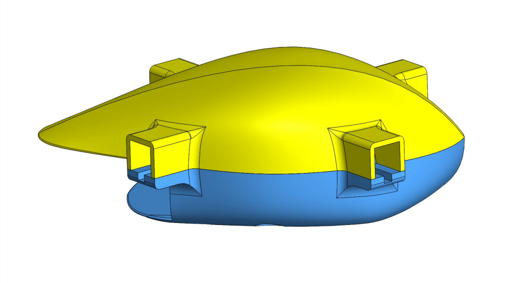


Communicating Design Intent - Mating Parts

- Definition:
  - Multiple parts intended to fit together in an assembly
- CAD communication:
  - Sometimes assumed from geometry
  - Clearer if mating parts are being examined simultaneously
- Best practices:
  - Give verbal/email notice of your mating/assembly needs and which fits are critical
  - Keep tolerance bands in mind!
  - Include an assembly drawing with your part files

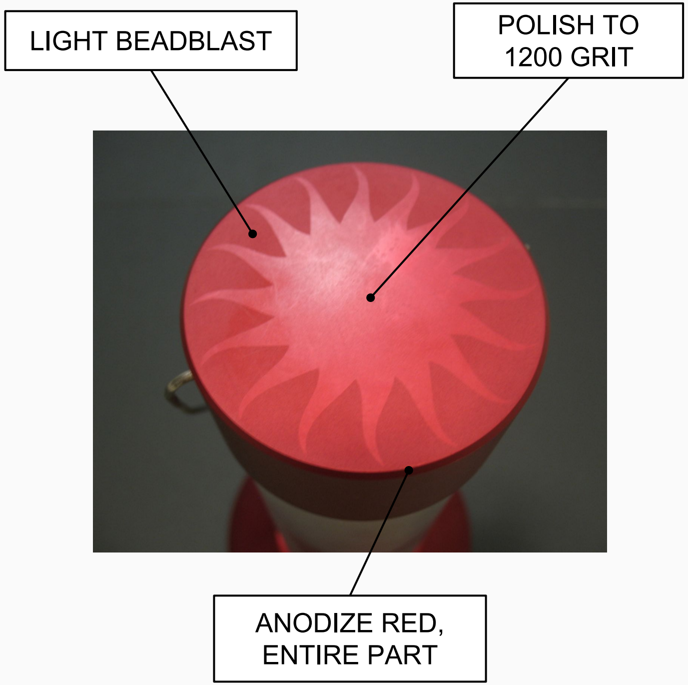






Communicating Design Intent - Cosmetic & Special-finish Surfaces

- Definition:
    - Surfaces needing different finishes than as-machined
        - Optical clarity
        - Sealing surfaces
        - Mold texturing
        - Post-process (beadblast, anodize)
- CAD communication:
    - Sometimes assumed from geometry
- Best practices:
    - Include a drawing containing surface callouts with your part file
    - Give verbal/email notice of finishing needs

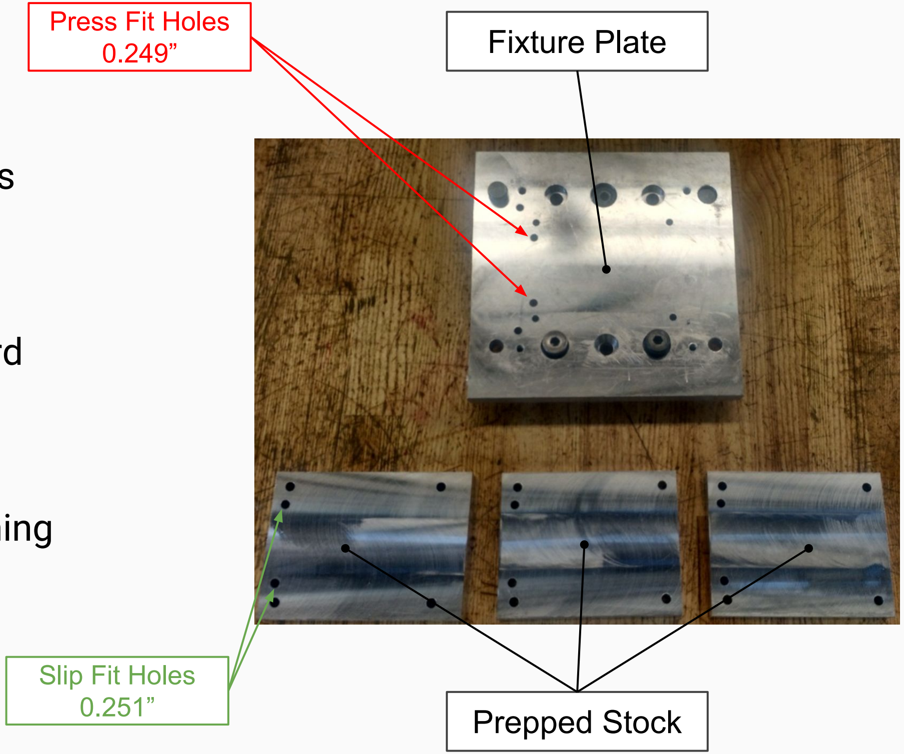


Communicating Design Intent - Press/Slip Fits

- Definition:
  - Holes needing tight-tolerance diameters for pin/shaft insertion and removal

- CAD communication:
  - Hole diameters just over/under standard sizes

- Best practices:
  - Include a drawing containing hole reaming callouts
  - Give verbal/email clarity on fit needs



Design Considerations & Pitfalls

Design Considerations & Pitfalls

When it comes to CNC machining, simplicity is key. Complex parts with intricate features can become expensive quickly. Here is a list of considerations to make when creating parts using this process

- Tolerances
- Internal Radii
- Pocket Aspect Ratios
- Hole Depth
- Undercuts
- Organic Geometry / Draft

Design Considerations & Pitfalls - Tolerances

- **Tolerances:** the permissible dimensional variances your part's design can tolerate

- A tighter tolerance means less variation in part geometry; a looser tolerance means more variation

- **Rule of Thumb**
    - Tighter tolerances = higher cost

      Go as loose as possible without losing functionality (ISO 2768 is a good standard for prototyping)

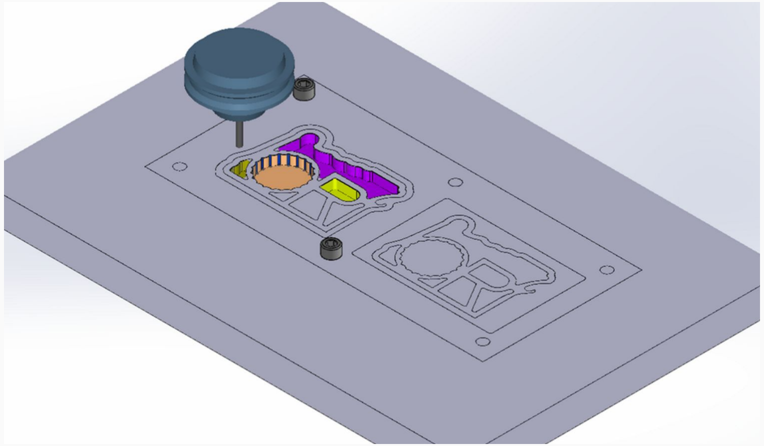
ISO 2768 TOLERANCES

LINEAR DIMENSION (mm)	TOLERANCE (mm)	TOLERANCE (in)
0.5 < dimension ≤ 3.0	±0.10	±0.004
3.0 < dimension ≤ 6.0	±0.10	±0.004
6.0 < dimension ≤ 30	±0.20	±0.008
30 < dimension ≤ 120	±0.30	±0.012
120 < dimension ≤ 400	±0.50	±0.020
400 < dimension ≤ 1000	±0.80	±0.031
1000 < dimension ≤ 2000	±1.20	±0.047
2000 < dimension ≤ 4000	±2.00	±0.079
Angular Dimensions: ±0.5°		
Surface Roughness: 1.6μm Ra (64.3 RMS, micro-inches)		

Design Considerations & Pitfalls - Internal Radii

- **Internal Radii:** rounded vertical edges in part pockets and other internal features
- CNC endmills are round, rotating tools and cannot cut sharp internal corners - radiused fillets must be added
- **Rule of Thumb**
  - Smaller radii = smaller endmill
    Smaller endmill = slower machining

    Go as big as possible



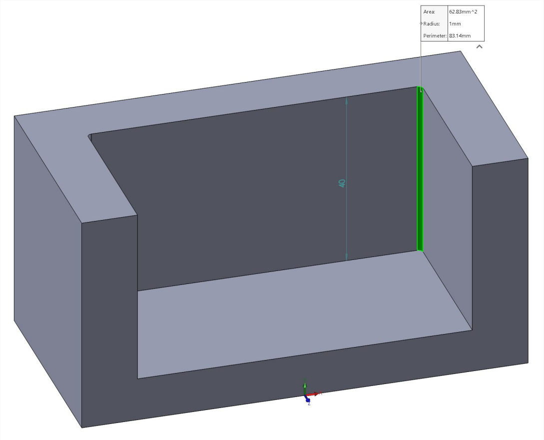
Design Considerations & Pitfalls - Pocket Aspect Ratios

- **Pocket Aspect Ratios:** the ratio between the depth of a pocket/slot and its width or smallest internal radius

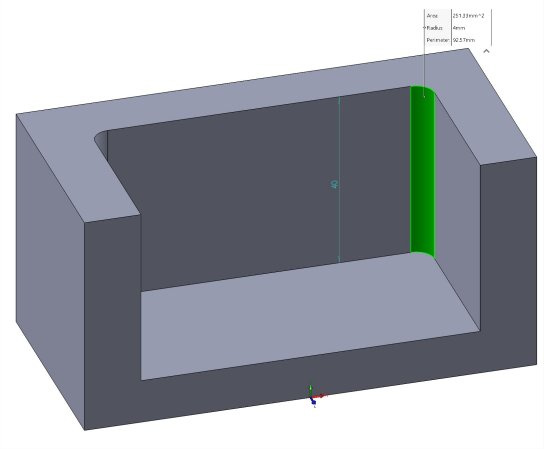
- Deeper pockets require longer tools which must machine slower to avoid chatter and vibration

- **Rule of Thumb**
  - Limit depth to 10x smallest internal radius (5x tool diameter/pocket width)

    Softer materials have more flexibility than harder ones



40x
NO!



10x
OK

Design Considerations & Pitfalls - Hole Depth

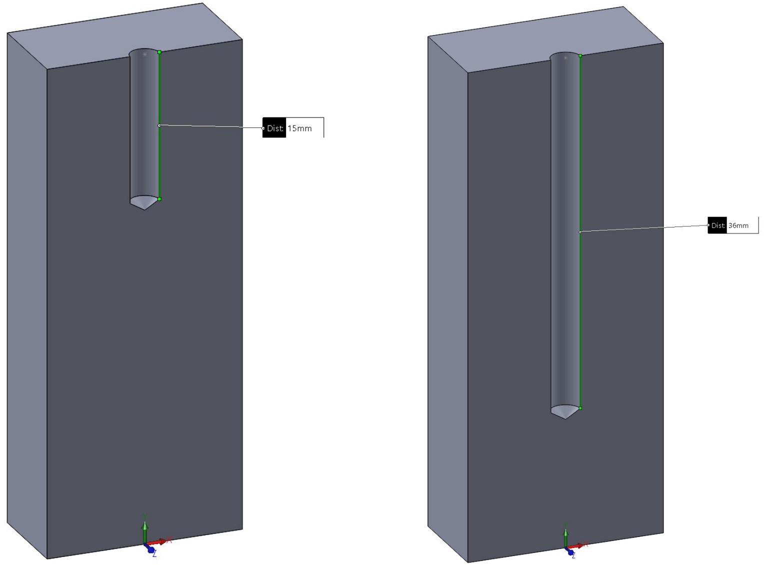
- **Hole Depth:** length of a drilled hole into a part

- Deep and skinny holes are slow and costly to drill and risk tool breakage and dimensional inaccuracy

- **Rule of Thumb**
  - 5x drill diameter is standard

    12x drill diameter absolute MAX (often more expensive)

3mm Hole



Standard

Absolute MAX

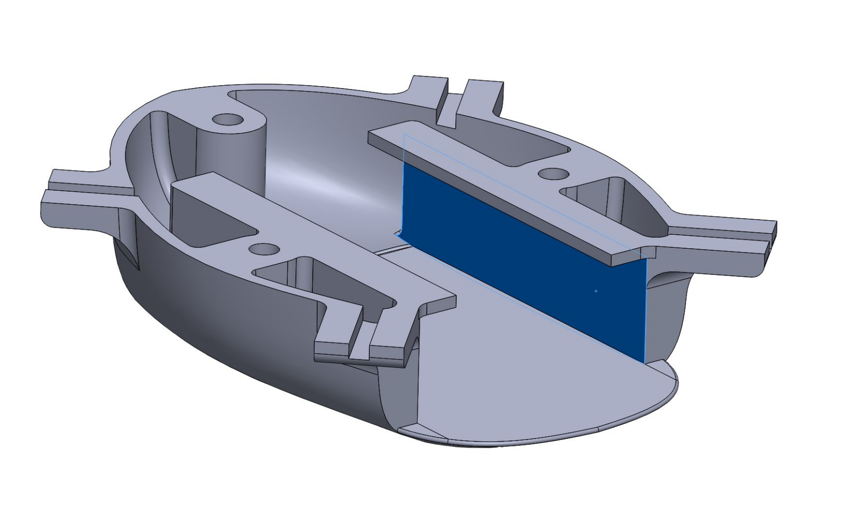
Design Considerations & Pitfalls - Undercuts

- **Undercuts:** Features only possible to create by milling underneath overhanging material

- Require special milling tools that may cost extra depending on feature geometry

- **Rule of Thumb**
    - Avoid whenever possible

      For o-ring grooves and keyways, stick to standard geometries



Design Considerations & Pitfalls - Organic Geometry / Draft

- **Organic Geometry:** non-uniform or spline driven surfaces and features

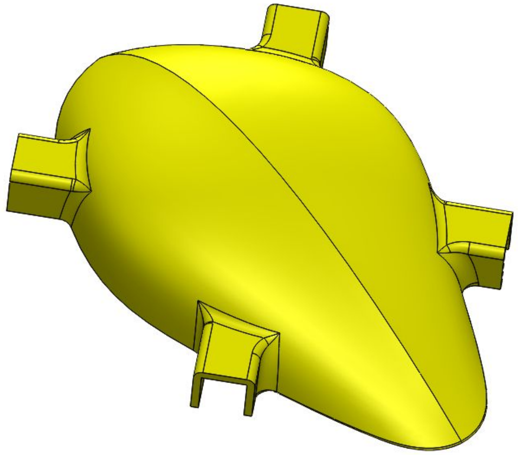
- **Draft:** angled walls usually present on injection molded and cast parts

- Slow to machine and require use of ball endmills

- **Rule of Thumb**
  - Avoid whenever possible

    If you must include, keep topography changes gradual

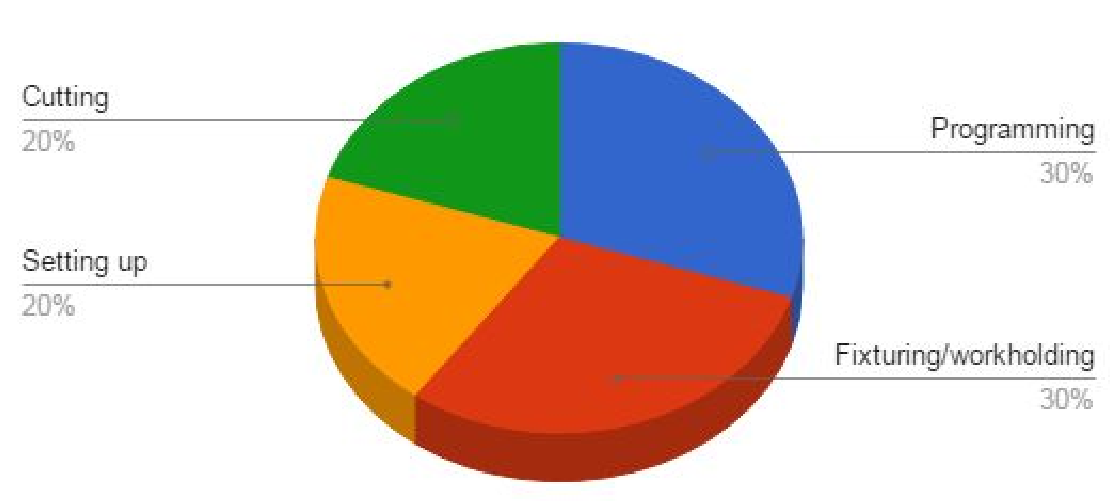
    Remove draft unless absolutely necessary to part function



Machine Planning & Programming

Machine Planning and Programming

Many designers and engineers have limited experience with CNC machines and may not know how the design they submit will influence cost, lead time, tolerances, surface finish, or other outputs. A typical CNC job consists of the following breakdown of time for getting 1 part made with a machine shop:



Machine Planning and Programming

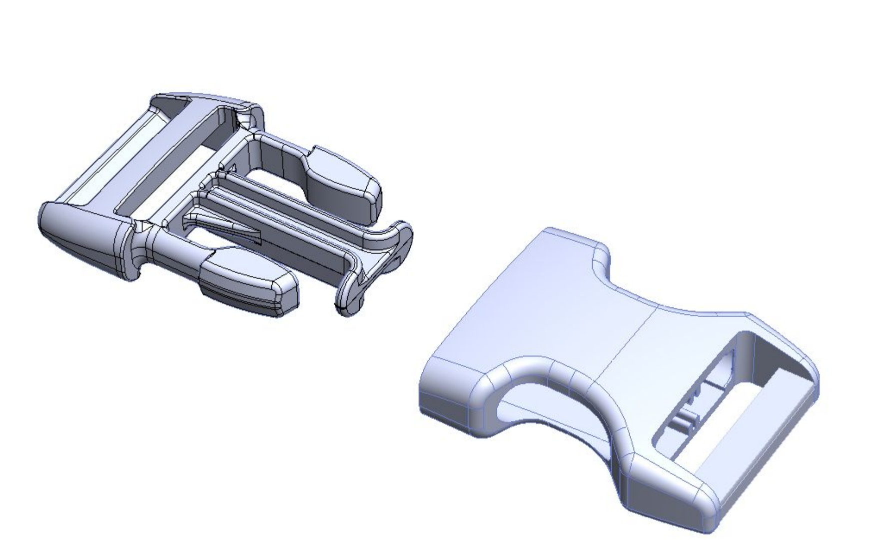
- Programming - 30%
  - Using your CAD model and the machine shop’s CAM software to create computer code for the CNC to machine the part.
- Fixturing/workholding - 30%
  - Designing, programming, and building the part(s) to hold the part that you are machining.
- Setting up - 20%
  - Loading tools
  - Loading stock
  - Cutting test part(s)
- Cutting - 20%
  - Actually cutting the desired part.

Machine Planning and Programming

Looking at the breakdown, here are some ways to reduce cost and save time:

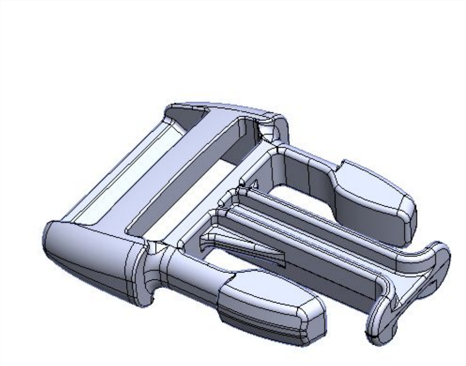
- Programming - 30%
  - Simplify part geometry as much as possible. No fillets, no chamfers, no undercuts, minimize number of setups.
- Fixturing/workholding - 30%
  - Design the part so that it may be fabricated using a 6" standard vise, if possible. Minimize the number of setups to achieve desired function.
- Setting up - 20%
  - Minimize the number of setups and number of tools needed to cut the part. If there are 12 different size holes, all under 2mm, the machinist will likely need to set up 12 drills in the machine (roughly 4 mins per drill). The same logic applies for taps, reamed holes, etc...
  - Minimize tight tolerance features. These features often need to get 'dialed in' through a test part or two before the machine can run a part that meets specification.
- Cutting - 20%
  - Use easily machinable plastics, aluminums, and brass to minimize machine time. Make pockets, holes, and internal radii as large as reasonably possible

Example of Moving from 3D Printing to CNC Machining

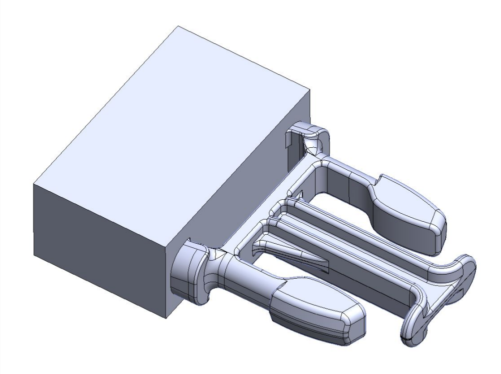


- “Clear” buckle design with flexing fingers.
- 3D Print to verify overall function.
- Need to perform cycle testing with final production material, Polycarbonate.
- Injection molding tooling cost > $10,000.
- CNC machine parts to perform testing prior to investing in tooling.

Example of Moving from 3D Printing to CNC Machining

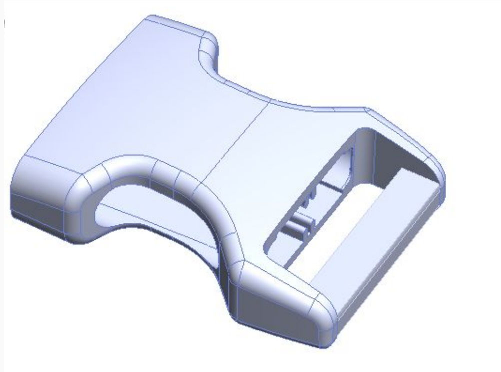


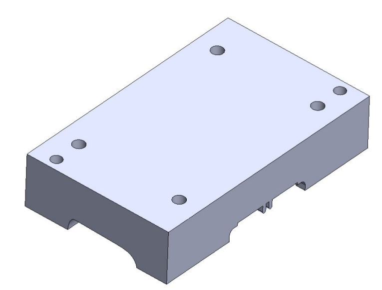
Challenging to fixture for machining.

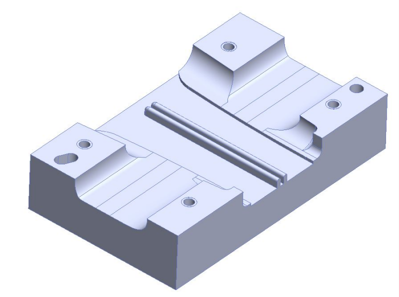


Far easier to fixture, yet still preserves the functionality that we wish to test.

Example of Moving from 3D Printing to CNC Machining







- Very difficult to machine, if not impossible.

- Part broken into two pieces.
- Exterior geometry simplified.
- Interior geometry remains unchanged.
- Simple to machine from standard stock.
- Allows testing of desired functionality.

Thanks For Listening!

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