1.5 Concept Generation

To ensure that the product the team will develop will satisfy all of the proper needs, a large variety of ideas and concepts will be generated. From this, some will be honest solutions and others might be anti-problems to help get a better understanding of the different options that can be explored. Different problems that need to be solved range from size, to speed, material variety, and cost.

1.5.1 Concept Generation Tools.

There will be a variety of sources utilized to help determine the different methods that the design of the machine will follow. Some of the methods that will be used are biomimicry, anti-problems, morphological charts, and crap shoots. These will all be ways that concepts can be generated and lead to exploration of different options that can be offered.

1.5.2 Biomimicry.

There are a few different examples of animals that dig, cut, extrude, or do similar actions to milling or 3D printing in a way that could be beneficial to look at for the design of a machine.

1. Woodpecker
2. Carpenter Ants
3. Termite
4. Groundhog/Meerkat

5. Mole
6. Bees/Wasps
7. Silk Worms
8. Spiders

The first five different animals on this list would mimic milling to some extent as they are all known to cut through or eat materials. The last three are similar to 3D printers since they build structures and almost extrude material in a similar fashion.

1.5.3 Crap Shoot.

Table 6: Crap Shoot

People	Common Activities	Potential resources
Industrial designers	Visualizing	Quality materials
Engineers	Prototyping	Stable environment
Hobbyists	Designing	Inexpensive utilities
Machinists	Manufacturing	Dedicated space
Educators	One-off items	Dedicated time
Medical researchers	Iterations	Marketplace connection

1.5.4 Anti-Problem.

Anti-Problems help the team better understand the problem that they are trying to solve by analyzing how not to go about making a successful product. These problems consist of completing an operation that is almost the opposite of what needs to actually be done, or will make the machine less desirable to the end user, and these problems are as follows:

Problem 1: How do we increase the tolerances of the machine?

Solutions: decrease vibrational damping, make the frame flimsy, all moving parts will not have a means to lock or maintain their position, use cheap parts with poor tolerances

Problem 2: How do we increase the difficulty of operation?

Solutions: Full user input in G-Code, user programs machine by hand, manual operation of machine instead of CNC, no user manual, pay for CAM and pilot software

Problem 3: How do we make the machine more dangerous?

Solutions: Make the emergency stop inaccessible, no enclosure to protect from shrapnel, no filters to treat the air coming out of the machine, no coolant to prevent overheating

1.5.5 Morphological Chart.

Table 7: Morphological Chart

Method	Drive Method	Damping Method	Manufacturing Implementation	Tool Change/ Head Change
Mill	Linear Actuator	Tension	Heat Treatment	User Based
3-D Printing	Cable Driven	Material Choice	Polish/Sand	Automatic
Combo (Mill x 3DP)	Robotic Arm	Destructive Interference	Chemical Treatment	None
Water Jet	Internal drive block		Quick Change Working Surface	
Plasma	Belt drive Block			
Laser	Hydraulic			
	Stepper			

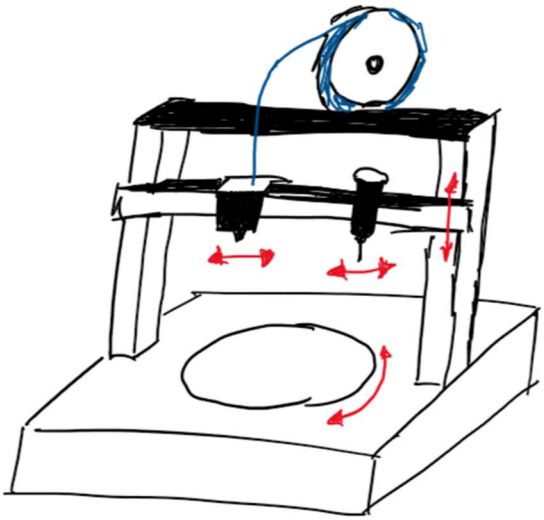
1.5.6 Medium Fidelity Concepts.

Medium fidelity concepts are ones that we believe could be successful, but might not be the best option. These were made by utilizing Table 6, as well as the list of 100 concepts found in Appendix E. With each of these concepts is the full description of what was chosen, how it will function, and a quick sketch to help envision what the product would look like.

1.5.6.1 Medium Fidelity Concept 1.

3 axis FDM printer with 4 axis mill belt driven using geometric designed damping utilizing a quick change work space and no tool-changer for milling parts.

This system consists of a quickly replaced head which switches between additive and subtractive manufacturing. Utilizing a 4th axis during the milling process allows the device to cut away supports after being manufactured and provide smoother surfaces and finer details in the model. Hypothetically this can be applied to SLS or SLM printing instead and offer metal solutions to manufacturing.

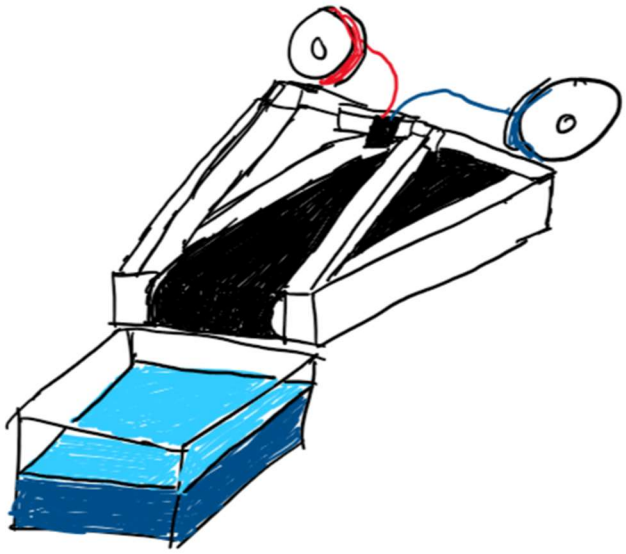


1.5.6.2 Medium Fidelity Concept 2.

3 axis FDM printer with conveyor belt motion during the printing process, with dual extruder head and water chamber for finishing.

This would allow for fast production and creation of FDM parts through continuous production. Currently, prints are left overnight and the printer is left inactive until it is removed

by a user. By incorporating a conveyor belt, the prints can be continuously pushed and prototypes could be created consecutively without human intervention. Utilizing a dual extruder head would allow for water soluble materials to be used as supports and can be removed from the conveyor belt and dropped into a water finishing chamber. This will create fully removed

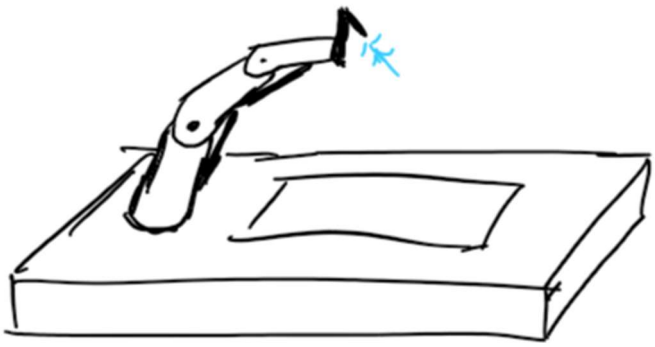


prototypes without any additional work from the user.

1.5.6.3 Medium Fidelity Concept 3.

5-axis waterjet with mobile robotic arm, uses geometric damping, water-only, no abrasive applications.

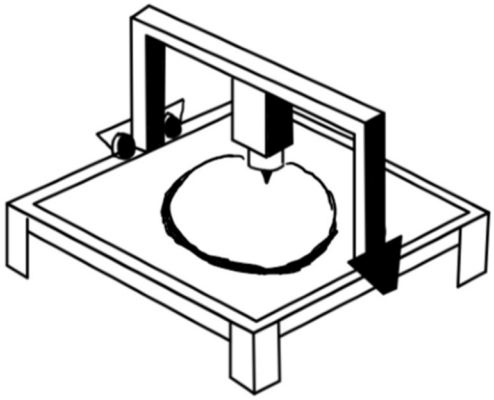
Using a water-only system would allow for easy maintenance and less concern about filtration during the process. However, this would limit the material selection that we use to softer materials such as foam or low-density plastics. This would be great for quick prototypes, but would limit the material versatility when compared with other methods.



1.5.6.4 Medium Fidelity Concept 4.

4 axis laser cutter with variable wattage laser head, externally driven linear actuator, tool changer to change the laser head between etching and cutting.

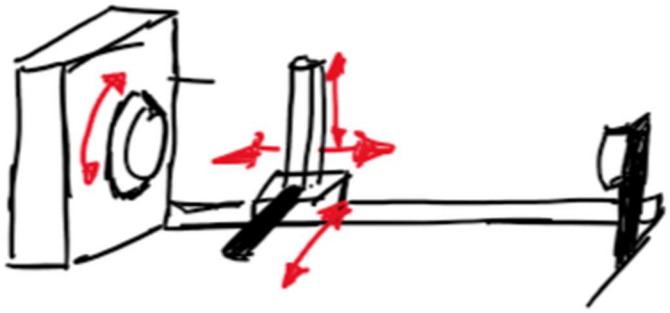
The variable wattage laser head would allow for power saving during cuts of softer materials, while still having the capability to cut stronger materials such as metal. In this system, it would be able to work with cuts of sheet metal or pipe by turning on the 4th axis, and create special geometries over a 3-axis cutter.



1.5.6.5 Medium Fidelity Concept 5.

4 axis lathe with laser etching module installed in a tool changer.

This would allow for powerful manufacturing turned parts with finishing designs applied directly to the system. Using a laser etcher during the turning process would form intricate designs or cuts to help with better visualization to industrial designers and engineers. Safety around lasers would have to be considered during the design process.\



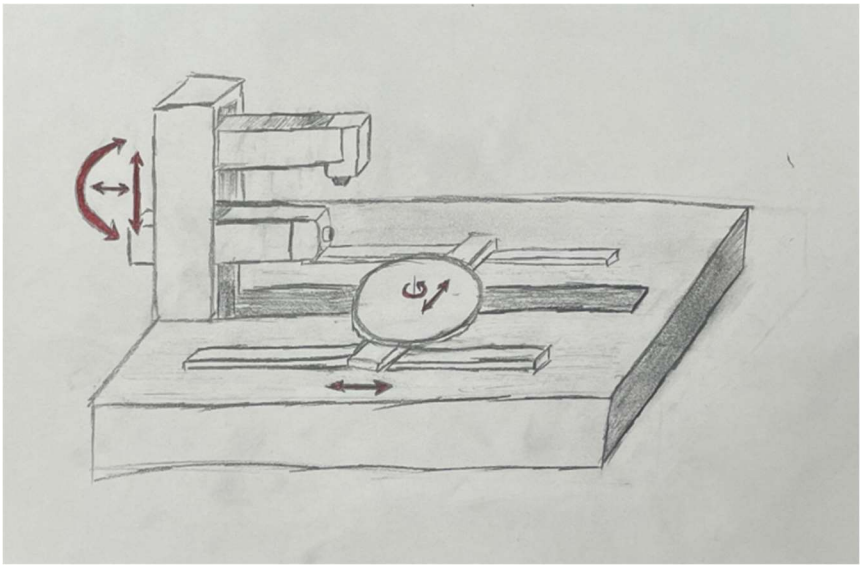
1.5.7 High Fidelity Concepts.

The high fidelity concepts that were generated are the designs that the team feels will be the most feasible to produce, as well as the ones that are most likely to succeed. These, like the medium fidelity ones, were generated from information found in Table 6, as well as the 100 ideas found in Appendix E. With each concept there is a description as made from the table, an explanation of how it would work, and a more detailed drawing of what the final product would look like.

1.5.7.1 High Fidelity Concept 1.

5-Axis Mill With External Linear Actuation, Using Material Selection for Damping, With Polishing Post-Processing, and an Automated Tool Changer

This machine is a true five-axis milling machine where the spindle is able to move along one axis and also rotate. The baseplate will make up the rest of the five axes where it is able to translate along two axes and rotate about the vertical one. This will be a bit of a challenge to make it fully sturdy and damp all vibrations, but will allow for high quality parts to be machined in a proper five-axis method instead of a 3+2. It is pictured below, but does not show the enclosure or tool changer in order to focus on the actual design of the machine.

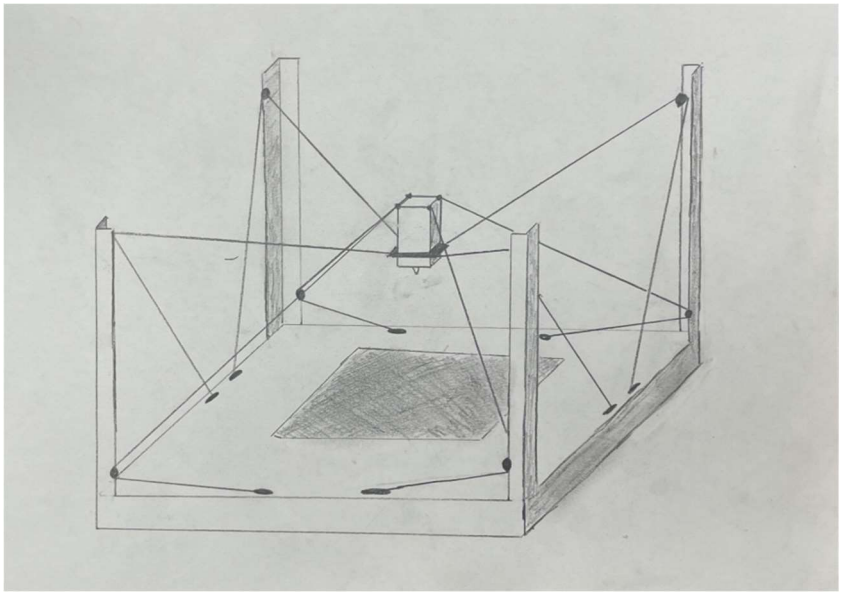


1.5.7.2 High Fidelity Concept 2.

5-Axis 3D printer With External Linear Actuation, Using Material Selection for Damping, With Polishing Post-Processing, and an Automated Tool Changer

This machine uses a complex pulley and winch system to move the extruder head around the workspace in a five-axis manner. The higher pulleys connect to the lower points on the

extruder, while the lower pulleys connect to the top points on the extruder. It's through a system known as tensegrity that it will retain its structure and remain movable. The way that the cables hold the extruder in tension will be almost rigid when needed. This model, however, will have the motors/servos for the winches hidden in the base of the machine for a cleaner look on the final product.



1.5.7.3 High Fidelity Concept 3.

5-Axis Water Jet using a Robotic Arm, Focused on Material Selection for Damping, with Sand Blasting Post-Processing, and Without a Tool Changer.

Using a Robotic arm for the Z-axis, Y-axis, A-axis, and B-axis while the moving platform holding the robotic arm controls the X-axis. Connected to the robotic arm is the nozzle for the water jet with all wiring and piping required for the water jet to be operational. This machine faces many difficulties mostly from the software side of the operation, requiring custom

CAM applications to process files. If a suitable robotic arm can be built to withstand the weight of all water jet components along with the forces of the nozzle this machine can have a chance of life.