1.4 Targets and Metrics Summary

With developing a new product, it is important to better understand how the different functions can be achieved, and how to track their improvements. By understanding the metrics that these functions will be benchmarked, it will allow for the project's targets to be developed. To develop these targets, the team compared what the best machines from the different CNC styles on the market had to offer, and took a rough average of them. Aspects were also sourced, including core metrics for our goals of cutting aluminum, wood, and plastic. Consideration was given towards regulatory guidelines set by OSHA.

1.4.1 Derivation of Necessary Metrics

All of the major functions were broken down into their various minor functions earlier, but still required metrics on how to measure the different components to see how they will compare to other machines on the market, as well as seeing if it will meet our own goals. Below the major functions will be broken down, but in Table 5 all major and minor functions will be explained.

- Structure
    - Necessary Metrics: Forces within the system, displacement due to oscillations in the machine, size of the frame, and weight of the structure

These metrics are all focused on the structure of the machine being as compact as possible while still allowing for as much of the machine's vibrations to be dampened. This will be important in ensuring that there are no vibrations during manufacturing which will lead to defects.

- Movement System
    - Necessary Metrics: Forces within the system, displacement due to oscillations in the machine, accuracy to input from program, time to reach desired point, speed of the motions, and acceleration of the motions.

These metrics are focused on how effective the movement system will be at moving the required pieces, and how much they assist in damping vibrations. In addition to that, the speed and accuracy will be measured to see how the two are related and to find a balance when programming.

- Safety
    - Necessary Metrics: forces on the system, parts per million, and time to shut off

These metrics will make sure that the forces on the machine will not cross the material maximums and lead to a catastrophic failure. It also ensures that the enclosure of the machine will contain all particulates that will be created, making a safe work environment. And accessibility to the shut off button is important in case there is some error or accident.

- Operating System
    - Necessary Metrics: tolerances in length, tolerances in distance, force regulation

These metrics will make sure that the parts work with the operating system in the intended manner. The way that this is going to be tracked is by checking the inputted measurements, speeds, and force regulation, and see how the product turns out. This links in with

almost all of the major functions since it will control everything and be responsible for a majority of manufacturing errors if done incorrectly.

1.4.2 Discussion of Measurement

During development, the machine will be modeled in Solidworks which will allow for a material analysis of the different components. The simulation will run with a few different scenarios such as a low load, an average load, and a maximum possible load. These will help the team understand the limits of all of the parts and how to improve the design to meet the material versatility goals. Further calculations can be done by hand or through Matlab to double check the numbers from the Solidworks simulations.

Some components will need to be physically tested to see what impact they will have on the system. The main component that will be tested physically will be the spindle to see what forces can be expected to input into the cad program. This will require tests to see what forces are acting when the spindle is at various speeds with and without load. Another important system to test physically is the effectiveness of the enclosure for the machine. The goal is to have this machine be able to sit on a desk, and if it leaks particulates or fluids out of the enclosure, it will greatly damage the potential for the machines sales, so this will need to be tested physically. The final system that will be tested physically is the accuracy of the movement and measurement system. This is important to test physically since ideally it will be exactly accurate to what the program says, but this is simply not feasible. So, tolerances will need to be determined and the system will likely undergo multiple iterations to improve the tolerances.

1.4.3 Mission Critical Targets

The most important targets for the system are found below in Table 5. These targets should be met to have a successful CNC machine, regardless of the method used.

Table 5: Targets and Testing Metrics

Function	Metric	Target
Controls Vibration	Force, Oscillation and Position	Deviations less than 200 micron
Maintains axial stability/rigidity	Oscillation and Position	Axial drift less than 200 micron at stable load
Holds all machine components	Force and Size	Fit within cubic meter size specification and withstand 500 N of force
Holds workpiece securely	Force and Oscillation	Accurate within 200 microns and withstands 5000 N/mm^2
Provides Accuracy	Length	Within 200 microns
Accelerates to position	meters/second^2	0.350 m/s^2
Stops at position	Length and velocity	Within 100 microns
Decelerates to stop	meters/second^2	5 m/s^2
Access to emergency stop	time	0.5 seconds
Encloses machine	Parts per Million	50 PPM
Recognizes position	Distance and Position	Within 100 microns
Controls cutting speed/force	Revolutions per minute / Force	15000 rpm/60 kg/mm^2
Controls internal temperature	Temperature	660 Celsius at contact of material