Introduction

Over the course of four months I successfully manufactured and assembled a fully operational electric scooter without the use of welding and under a $200 budget. This was a personal project fueled by my own problem of transportation between classes to be able to save time traveling from place to place on campus. My learning goals for this project included understanding the design, fabrication and assembly processes that Mechanical Engineers experience when completing a project. This included knowledge of Solid Works, the Lathe, Bridgeport Mill, Band Saw, Waterjet, Drill Press and proper Engineering Design which accounted for the manufacturability of each part.

Key concepts

Key concepts this project included started with the Design Process. I did extensive research on each part of commercial electric scooters to understand how they worked and made my own design decisions to implement aspects of those features into a 3D model on Solid Works. This process took about two months and contained multiple iterations to achieve a model which accounted for the proper load amount which the scooter would be required to carry. Due to not having access to a welding shop, I needed to find a way to make the scooter frame with as little material as possible to account for the budget and strain on the motor, but in such a way that there would be little to no shear stress on the bolt fasteners I would be using to put it together, My goal was to create a model which put the majority of the load directly onto the frame. Due to some parts being pre-existing or cut from other objects the design needed to seamlessly integrate both the newly made and pre-existing parts together in a way that was structurally sound.

The next concept I focused on was learning the proper machining techniques necessary to create each part I intended to manufacture. I learned how to use several machines and wrote down a manufacturing plan for each part I intended to create. I learned how to use each machine to a high enough skill level where I never needed to recreate a part to not waste any money in my budget.

Another concept involved in this project was learning how to purchase, program, and wire electronics that could effectively spin a 500W DC motor. This involved creating wiring diagrams and navigating product data and manuals to create and program an effective electrical system. This system has the capability to be turned on and off by a key while using the twist of a throttle to control voltage allowed to the motor from the lithium ion battery.

Also, proper calculations needed to be performed to know what motor would be strong enough to move the scooter, what gear ratio was needed for the motor to spin the wheel below the speed limit of 20mph, what diameter bolts would be able to resist the braking force, and what thickness the floor plate needed to be to be able to hold my weight.
Additionally, this project honed my skills in project management. Having to balance a full time internship, college football training and work on this project around the limited open hour

availability of the fabrication shop at my school called for my skills in organization, time management and information gathering to increase exponentially. With only about an hour and a half a day for four days a week to work in the shop after work, I needed to have a plan each day for the operations I was going to perform in the shop to stay on track. So, I created a Notion page which put each part in order of when it would be fabricated and how many shop days it would take to make it to serve as a schedule I could stick to that prioritized the most technically challenging parts to fabricate as the first priority. I also had to time the purchasing of materials to deliver exactly when needed to not extend the lead time of completion.

Bill of materials

(green: available in shop, red: unavailable in shop, yellow, not enough available in shop)

ITEM NO.	Raw Material	DESCRIPTION	QTY.	Material In Shop	Manufacturing Plan	Phase
1	12" Long .86" Diameter Alluminum Rod	Handle Bar - no additional features	1		Lathe will be used if alluminum raw material provided is thicker than .86"	4
2	19" Long 1-1/2" Diameter Alluminum Rod	Steer rod - hollowed threaded cylindrical cut 1" diameter 6" deep up throgh the bottom of the rod. Hole .86" diameter through the side of the rod near the top.	1		Lathe will be used to create a hole penetrating up through the bottom of the rod that is threaded and if the alluminum raw material is too thi	3
3		Bike Steering Mechanism(**Made**)	1			
4	6" long .63" Diameter Alluminum Rod	Front Axle - middle section kept .63"diameter 3.2" long, from the mid section to each end the axle will have .39" diameter sections that are threaded.	1		Lathe will be used to make fabricate the correct diameter thicknesses and threading of the alluminum rod at the proper distances along it	2
5		Pipe Frame (**Made**)	1			
6	1/4" Thick 4" x 14" Alluminum Plate	Movement Blocker - 1/8" thick, 4 through holes total, two of them are 1.315" diameter 12.25" apart and the other two are centered near the middle of the plate face and are 1.5" in diameter and 1.75" apart	1		Water Jet will be used for the four holes in the plate at the appropriate diameters and distances as per the part drawing on solidworks.	1
7	1/4" Thick 16" x 32" Alluminum Plate	Floor Plate - rectangular through hole at the back middle of the plate 6" x 8"	1		Water Jet will be used for the one rectangular hole at the back middle of plate as per drawing on solid works	1
8	1/2" Thick 5" x 3" Alluminum Plate	Back Axle Holder (Gearside) - 1.315" through hole on the top middle of the back face of the holder and .39" diameter through hole threaded near the bottom of the skinny face	1		Water Jet will be used to cut the shape and top hole of the part and CNC or Drill will be used to make the axle hole that is threaded	2
9	16" long .63" Diameter Alluminum Rod	Back Axle - mid section .63" and 3.2" long smooth, then from that mid section to each end .39" diameter and threaded	1		Lathe will be used to make fabricate the correct diameter thicknesses and threading of the alluminum rod at the proper distances along it	2
10	6 X 1/8" Thick Alluminnum Plates	Battery Box -	1		Water Jet will be used to cut the shape of the box and the metal sheet bender will be used if nessesary to overlap metal sheets to make box	4
11	1.5" Thick 2" x 9" Alluminum Block	Folding Mechanism Top - 3" x 1" block of alluminum with two 1" by 3.5" prongs with .5" bolt holes(2 each) attached to a rod 1" diameter 4" long with a through hole .75" in diameter, end of rod cut at 45 degree angle to fit with bike part	1		CNC	3
12		Front Wheel (**Made**)	1			
13	1/2" Thick 6" x 4.15" Alluminum Plate	Back Axle Holder (Breakside) - has a through hole 1.315" diameter at the top right and a threaded hole through the skinny side .39" diameter	1		Water Jet will be used to cut the shape and top hole of the part and CNC or Drill will be used to make the axle hole that is threaded	2
14	1" Thick 6" x 3.5" Alluminum Plate	Folding Mechanism Bottom - 1" diameter rod with a through hole through the bottom .75" diameter with a semicircular block at the top with three through holes .5" diameter that are 1.5" apart, end of rod cut at 45 degree angle to attatch to bike part	1		CNC	3
15		Back Wheel (**Made**)	1			
16	2.1" Thick 4.5" Diameter Alluminum Cylinder	Wheel Hub Gearside - 4.5" diameter cylinder of alluminum 1.6" thick with a semicircular cut revolved around the sides to allow the wheel to fit around it, with a .63" diameter hole through the center and 8 other .25" threaded holes for bolts on the on the larger surface.	1		Lathe will be used to create proper thicknesses of the alluminum cylinder and axle hole. And Mill will be used to make gear connection holes	2
17	2.2" Thick 4.5" Diameter Alluminum Cylinder	Wheel Hub Breakside - 4.5" diameter cylinder of alluminum 1.6" thick with a semicircular cut revolved around the sides to allow the wheel to fit around it, with a .63" diameter hole through the center, has a jut out 1.95" diameter extrusion with 5 screw holes in it for the break disk and 4 other .25" threaded holes for bolts on the on the larger surface.	1		Lathe will be used to create proper thicknesses of the alluminum cylinder and axle hole. And Mill will be used to make break connection hole	2
18	1" Thick 1.75" x 3"	Break Mount - elbow style joint with 2 plate surfaces 3" x 1", one of those plates has two .25" holes for bolts to attach to the breakside back axle holer and the other has two .75" long jut out cylinders that are .5" diameter with .38" threaded holes through the middle to mount break caliper on.	1		Lathe will be used to make the cylindrical jut outs and Mill will be used to make the alluminum plates according to solid works dimensions	3
19		Caliper (**Made**)	1			
20		Break Disk (**Made**)	1			
21		Gear (**Made**)	1			
22	1/2" Thick 3" x 3" Plate of Alluminum	Under Support - 3" diameter semi circle cylinder with 1.315" diameter hole cut in a semicircle in the top center with a cut .5" away from the bottom that goes .34"" into the 3" diameter alluminum semi circle cylinder that is revolved around the center point of the 3" diameter circle and stops .5" away from the end. It has holes on the side ends .25" diameter.	9		CNC machine will be used to cut the shape and thickness of all 9 parts out of an alluminum block and to make the holes in them	1
23		Motor (**Made**)	1			

Methods

My methods for design and assembly were thought of in four phases. I thought of the basic frame body, floor plate, and undersupports as phase one due to their importance and ease of manufacturing. Phase 2 included the manufacturing of the back wheel accessories that would mount the brake disk, gear hub, and wheel to the body. Phase 3 included creating the collapsable shaft up to the handlebars of the scooter. Phase four included mounting of the electronics and braking components.

Results

The Electric Scooter can fully support my weight and roll forwards and backwards with ease. The steering mechanism works well to provide the rider with maximum control of the vehicle. Through this project I learned skills in design, manufacturing, the mechanical engineering process, electrical systems, load analysis, gearing, material selection, and project organization.

Future

In this project I could've created a system that could fold rather than collapse but was limited to due constraints. I plan to improve this project by adding a phone holder, water bottle holder and stereo system. This project has helped me learn about my style of design and consider how manufacturing is important when designing a project and allowed me to see through the perspective of all roles when completing this electric scooter.