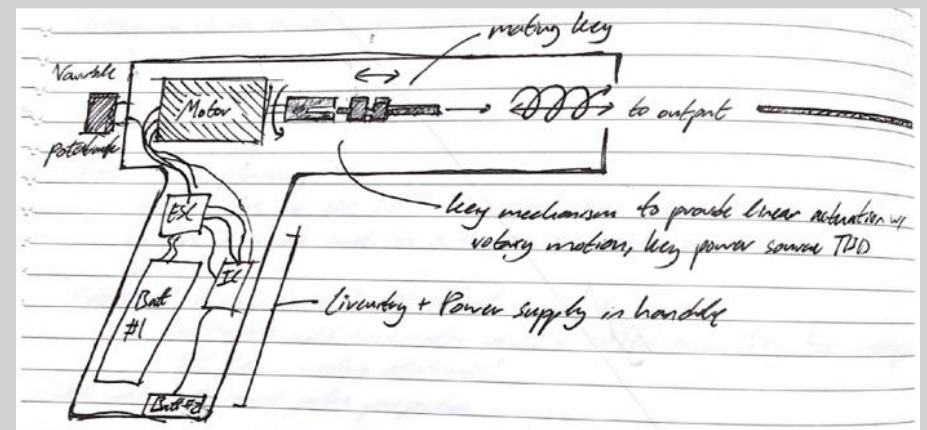


Engineering Release Review

The Fifteen Hundred Dollar Shave Club

Contents

- Project Objective
- Value Proposition
- Device Background
- Product Requirements/Solutions
- Circuitry
- CAD Drawings
- Bill of Materials
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- DVP
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- Demonstration and Questions



Project Objective

- The objective of this project to complete development of a previously constructed arthroscopic bone and cartilage shaver for the following:
 - Allow for appropriate sanding of bone and cartilage surfaces via approximation of a random orbital sanding motion
 - To strengthen the device and provide a robust tool for manufacturing and testing
 - Porcine and bovine bone/cartilage testing
 - Simple, strong components that are reliable adjustable for a variety of surgical settings



Project Value Proposition

- Arthritis is characterized by roughening of a joint bone and cartilage
 - Cartilage, bone breakdown leading to chronic pain and inflammation due to increased friction between surfaces
 - ~750,000 annual knee arthroscopies occur in the US
 - Healing is limited by strategies that involve cutting and probing of afflicted tissues to stimulate blood flow and healing
 - Arthroscopic tooltips are often designed for aggressive cutting
 - Cutting removes surfaces designed to lessen friction
 - Surfaces are often roughened or cratered, and could be smoothed
- Our device will incorporate random-orbital sanding into the shaving platform, modular tooltips, better ergonomics, and user comfort than traditional arthroscopic tools
 - Purpose of device

Device Background



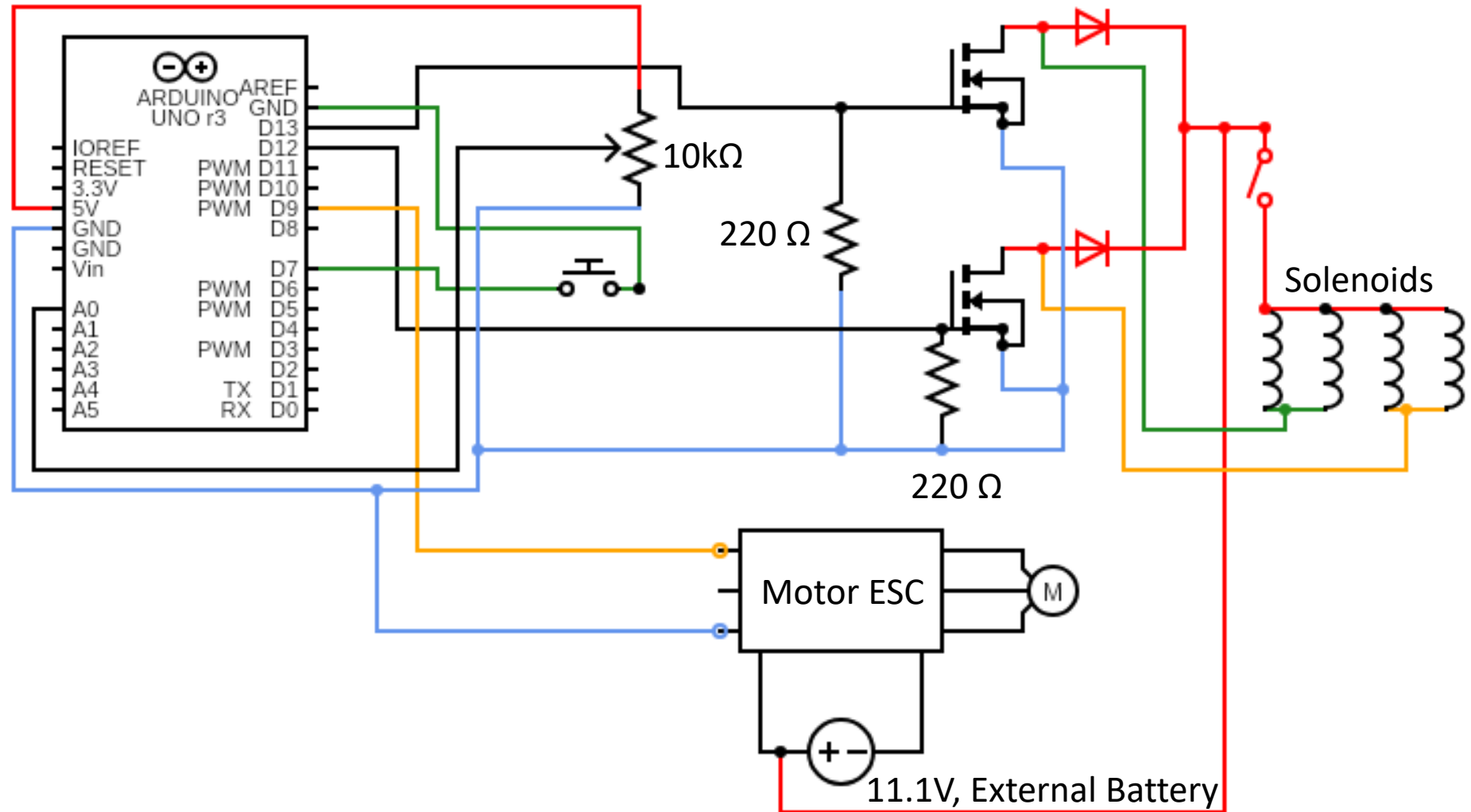
- Sponsored by Dr. Doug Hiller
 - Fellowship Trained, Sports Medicine Orthopedic Surgeon, participated as active physician for the Olympic and Paralympic Games
- Found consensus amongst experts in the field, gap in treatment of arthroscopically shaving cartilage in knee joint
 - Without appropriate tool, no way to induce cartilage to regenerate without proper stimulation, no tool exists
- Total knee replacement could be appropriately avoided if device could smooth irregular surfaces in knee
- Using devices designed for other purposes to achieve desire typically results in less than ideal outcomes
 - There is a need for a tool that can work as a smooth arthroscopic shaver

Project Requirements/Solutions

- Variable speed output with 900-6000 RPM oscillation settings
- Random orbital sanding action within a pistol-grip device
- Maximum output shaft diameter of 6mm
 - Output shaft should be able to withstand corrosion in saline-rich environments
- Compatibility with 100-1200 grit shaver heads/burs
 - 300-400 grit shaver heads/burs have been previously noted to work the best
- Reliable two-hour battery life
- Compatibility with existing surgical suction pumps
 - Debris removal during shaving (condyle, menisci cartilage, bone fragments)
- The device should be reusable, and compatible with different shaver heads
 - Autoclaving (60kPa, 150 degrees Celsius)



Circuitry



Arduino Code

```
// constants won't change
const int BUTTON_PIN = 7; // Arduino pin connected to button's pin
const int Motor_PIN   = 9; // Arduino pin connected to LED's pin

// variables will change:
int motorState = LOW; // the current state of LED
int lastButtonState; // the previous state of button
int currentButtonState; // the current state of button

#include <Servo.h>
Servo ESC; // create servo object to control the ESC
int potValue; // value from the analog pin

void setup() {
  Serial.begin(9600); // initialize serial
  pinMode(BUTTON_PIN, INPUT_PULLUP); // set arduino pin to input pull-up mode
  pinMode(Motor_PIN, OUTPUT); // set arduino pin to output mode

  currentButtonState = digitalRead(BUTTON_PIN);

  // Attach the ESC on pin 9
  ESC.attach(9,1000,2000); // (pin, min pulse width, max pulse width in microseconds)
}

void loop() {
  lastButtonState = currentButtonState; // save the last state
  currentButtonState = digitalRead(BUTTON_PIN); // read new state

  if(lastButtonState == HIGH && currentButtonState == LOW) {
    Serial.println("The button is pressed");

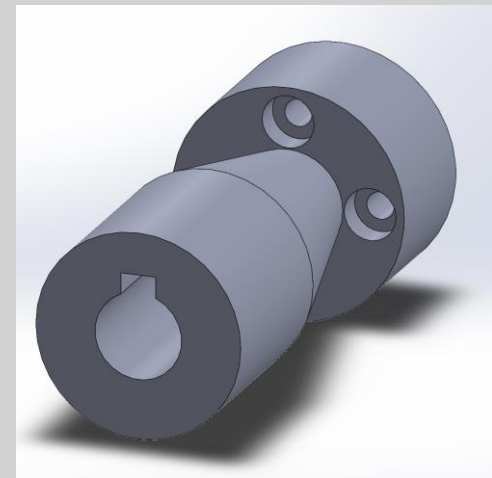
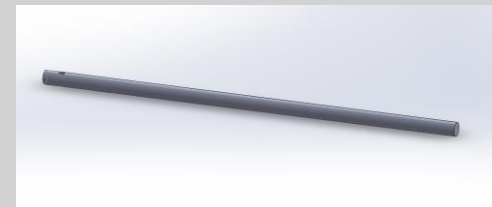
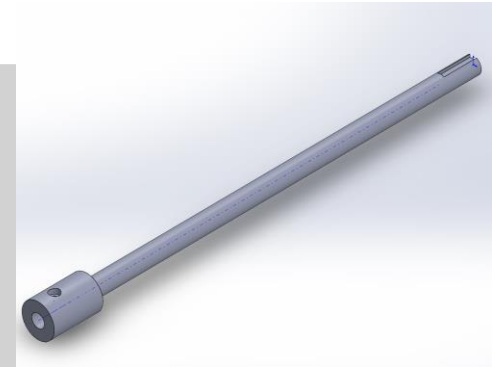
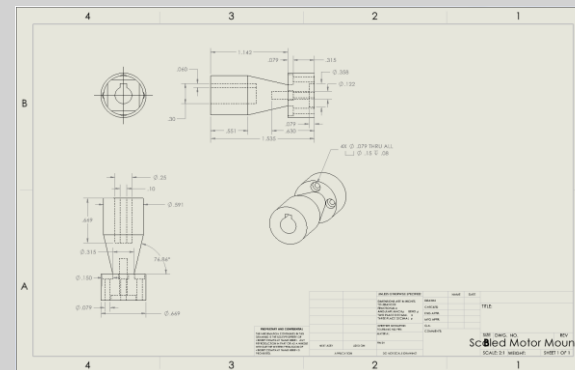
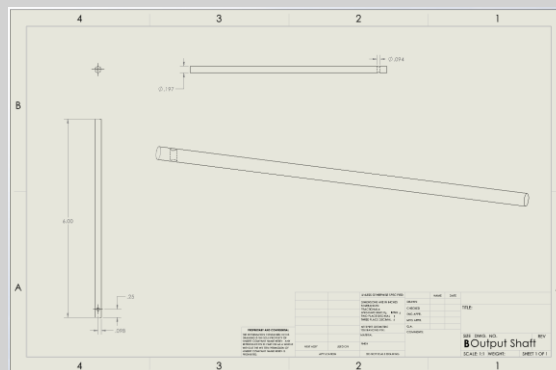
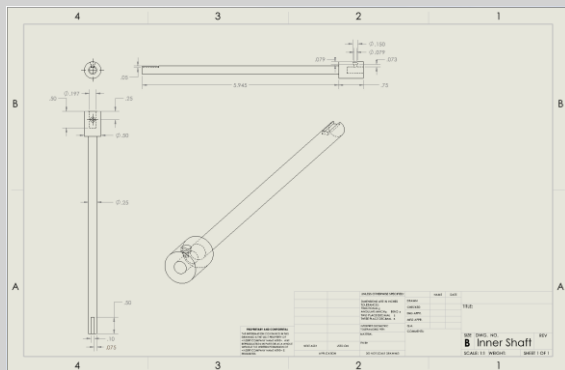
    // toggle state of Motor
    motorState = !motorState;

    // control Motor arccoding to the toggled state
    digitalWrite(Motor_PIN, motorState);

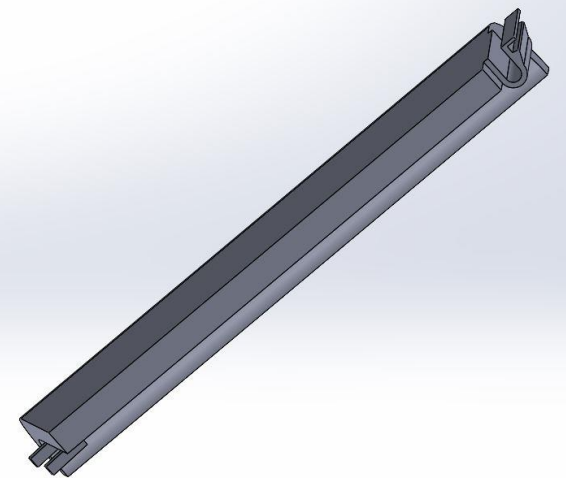
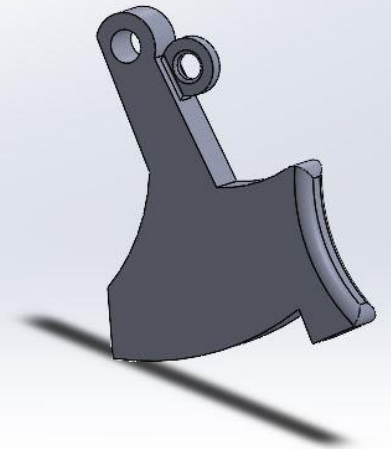
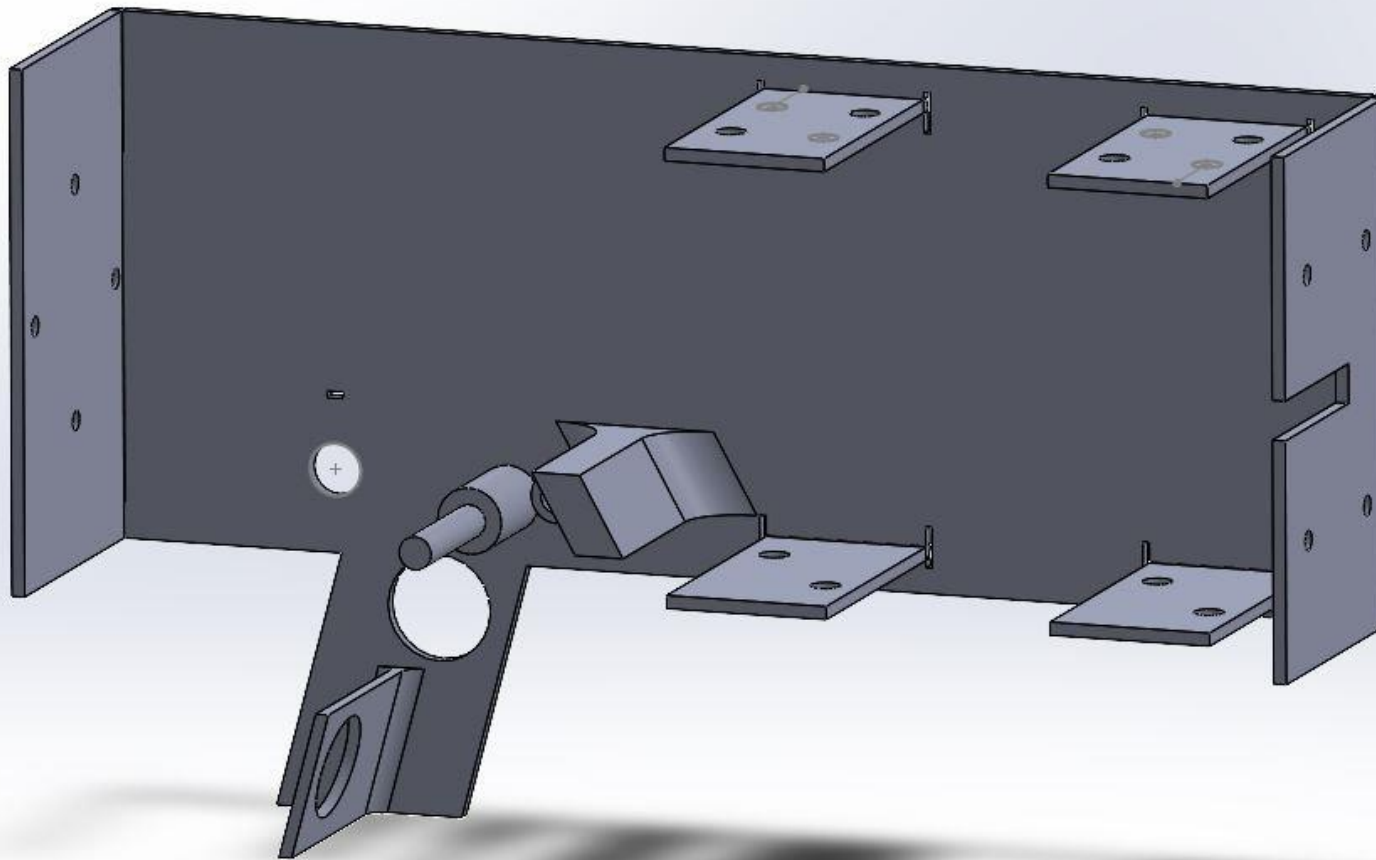
    potValue = analogRead(A0); // reads the value of the potentiometer (value between 0 and 1023)
    potValue = map(potValue, 0, 1023, 0, 180); // scale it to use it with the servo library (value between 0 and 180)
    ESC.write(potValue); // Send the signal to the ESC
    Serial.print(potValue);
  }
}
```


CAD Drawings

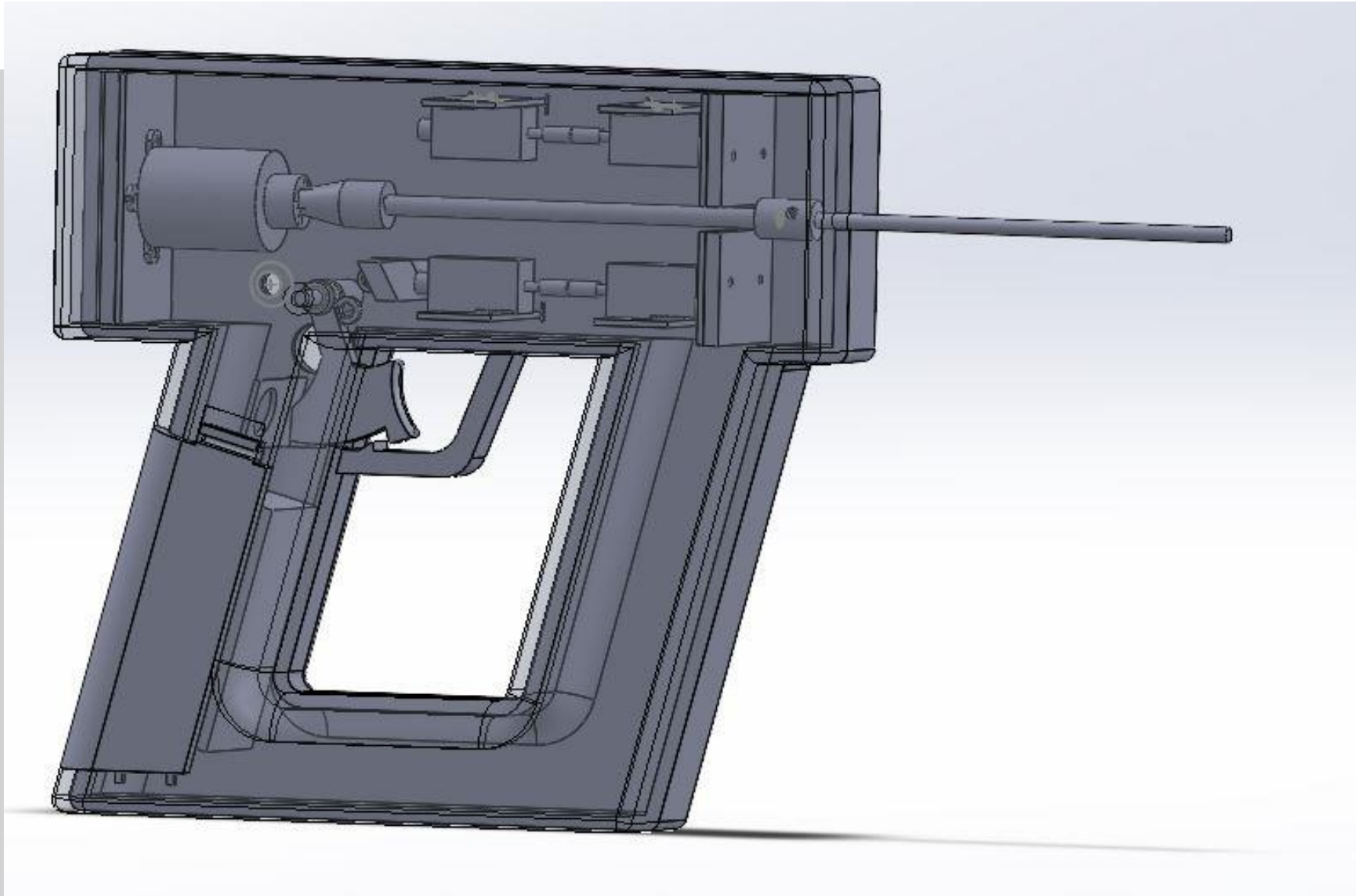
- All 3D modelling completed with SolidWorks 2020
- Parts designed were inner/outer shafts, motor mount, handle, solenoid housing unit
- Handle and solenoid housing unit to be 3D printed, inner components to be machined



CAD Models



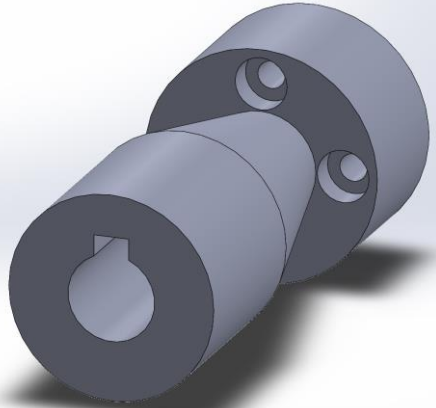
CAD Models (cont.)



Bill of Materials

Bill of Materials					
Project: Smooth Arthroscopic Shaver					
Last Updated: 2/16/2021					
Component	Description	Material	QTY	Cost/Unit	Total Cost
3D Printer Filament	-	Fiberglass w/Carbon Fiber inlay	1	\$72.13	\$ 72.13
Motor Mount	Connect inner shaft to DC motor	Aluminum	1	\$ 6.03	\$ 6.03
Inner Shaft	Keyed to motor mount	Aluminum	1	\$ 5.84	\$ 5.84
Outer Shaft	Connect to inner shaft	Sandblasted titanium	2	\$ 11.62	\$ 23.24
M2 Machine Screws	Motor mount, outer shaft connection points	Stainless Steel	5	\$ 0.36	\$ 1.80
Mosfet	Use in circuit	-	1	\$ 7.99	\$ 7.99
Battery Charger	-	-	1	\$ 13.99	\$ 13.99
DC Motor	-	-	1	\$ 15.97	\$ 15.97
Speed Controller	Connect arduino to DC motor	-	1	\$ 15.99	\$ 15.99
Protoboard	Use in circuit	-	1	\$ 9.99	\$ 9.99
Potentiometer	Control device function	-	1	\$ 9.72	\$ 9.72
Microcontroller	Input/output code device	-	1	\$ 8.09	\$ 8.09
Solenoid	Prototype/final	-	4	\$ 12.99	\$ 51.96
Wiring Kit	Use in circuit	-	1	\$ 10.16	\$ 10.16
Switch	Control device function	-	1	\$ 6.99	\$ 6.99
On/Off Switch	Control device function	-	1	\$ 4.99	\$ 4.99
Shaft Collar	Clamp to inner shaft	Stainless Steel	2	\$8.71	\$ 17.42
Bushing	Decrease friction on inner shaft	Brass	1	\$ 14.71	\$ 14.71
LED	Use in circuit	-	1	\$ 4.99	\$ 4.99
Push Button	Control device function	-	1	\$ 11.02	\$ 11.02
Potentiometer knob	Accessibility improvement	-	1	\$ 0.89	\$ 0.89
				TOTAL	\$ 313.91

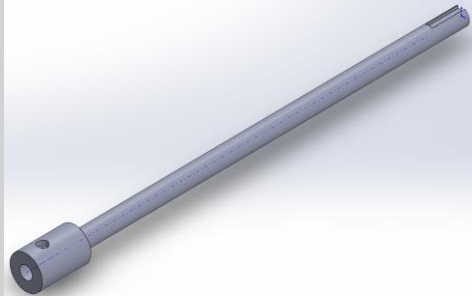
Manufacturing Plan (Timing, Costs)



Parts to be Machined:
 Female Key Connection
 Male Key Connection
 Inner Rod

Total Cost of Machining:
 Approximately \$160

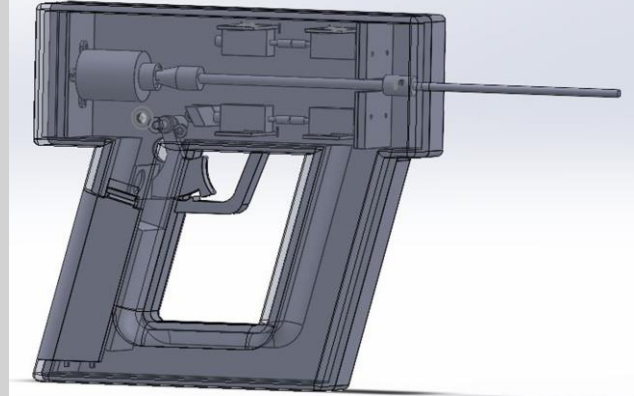
Estimated Date of
 Completion: 3/4



Parts to be 3D Printed:
 Outer Shell (2)
 Inner Bracket
 Trigger
 Battery Access Port

Total Cost of Filament:
 Approximately \$72.13

Estimated Date of
 Completion: 3/4



Component	Description	Material	QTY	Cost/Unit	Total Cost
3D Printer Filament	-	Fiberglass w/Carbon Fiber inlay	1	\$72.13	\$ 72.13
Motor Mount	Connect inner shaft to DC motor	Aluminum	1	\$ 6.03	\$ 6.03
Inner Shaft	Keyed to motor mount	Aluminum	1	\$ 5.84	\$ 5.84
Outer Shaft	Connect to inner shaft	Sandblasted titanium	2	\$ 11.62	\$ 23.24

Design Validation Approach

Requirement	Test	Test Subject	Target Date
Compatible with 100-400 grit shaver heads	Ensure that head design does not have interference with shafts on Solidworks, test with actual components	Prototype #1	4/15/20
Final Prototype battery will last for two hours	Conduct mathematical analysis, Test fully working circuit to battery failure	Final Prototype	4/29/21
Compatible with surgical suction pumps	Model suction pump in solidworks then test for interference in assembly	Final Prototype	4/29/21
Tip can be easily swapped out and sterilized via autoclave	Check that design can be disassembled in 3 minutes; handle casing can be autoclaved	Final Prototype	4/29/21
Bone must be shaved	Ensure that the motors are able to overcome friction force to be able to shave bone	Final Prototype	3/4/21
Smooth shaving surface must be achieved	Qualitatively identify smoothness via feel after manual sanding of cartilage and bone vs. device	Final Prototype	3/4/21
Device must be thermostable	Ensure that circuit does not overheat	Final Prototype	3/4/21
Device must operate reliably under load	Shave cartilage and bone separately to ensure full shaving head articulation for > 1hr	Final Prototype	3/4/21
Multiple End Attachments	Making sure that the shaver can have different shaving heads on the output shaft.	Final Prototype	3/4/21
Make device compatible with current Operation Room batteries	Power Device with Currently Used Batteries.	Final Prototype	3/4/21
Make device able to switch from predetermined motor speeds.	Change speed of motor with buttons	Final Prototype	3/4/21
Ensure that handle components are durable enough for back-to-back surgeries	Shave bone for > 1hr, disassemble and reassemble handle with new tip (simulate sterilization), and retest	Final Prototype	4/29/20

Project Schedule/Budget

Capstone Project Budget Template - Fall/Spring												
Project: Smooth Arthroscopic Shaver												
Last Updated 2/16/2021												
	Year								Item Total			
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr				
Equipment/Tools:												
Prototypes				\$ 80			\$ 80	\$ 18	\$ 178			
Miscellaneous				\$ 5			\$ 10		\$ 15			
Travel:												
Trip to hospital							\$ 15		\$ 15			
									\$ -			
Supplies / Parts / Services:												
Stainless steel									\$ -			
Prototypes				\$ 10			\$ 200	\$ 50	\$ 260			
Power Supply	\$ 17								\$ 17			
Shaft Collars					\$ 5				\$ -			
Bushings					\$ 15				\$ -			
Servo Motor	\$ 13								\$ -			
DC Motor	\$ 16								\$ 16			
Speed Controller	\$ 16								\$ 16			
Battery Charger	\$ 14								\$ 14			
Potentiometer	\$ 10								\$ 10			
Microcontroller	\$ 9								\$ 9			
Mosfets	\$ -		\$ 8						\$ -			
Switch			\$ 7						\$ -			
Heat Shrink Kit						\$ 10			\$ -			
On/Off Switch						\$ 5			\$ -			
LED						\$ 5			\$ -			
Pushbutton+Shipping						\$ 11			\$ -			
Potentiometer Knob						\$ 1			\$ -			
Solenoids		\$ 8	\$ 40						\$ 48			
Shop Usage (est. Hrs):												
									Hours			
							30	25	55			
									0			
									0			
									0			
									0			
									0			
									0			
Graduate Student Support									\$ -	Including fringe		
Shop Overhead									\$ -			
University Overhead									\$ 30	5% of all expenses		
Spent		\$ 158							Totals	\$ 628	\$ 1,500	\$ 872
										Budget	Excess	

Risks

- Device overheating
 - Melting plastic of handle body
 - Solenoids
- Vibrations from linear actuation
 - Misalign internal components
- Grooves left behind in use
- Poor angle control
- Lifetime of product
 - Circuitry
- Battery life
- Limited functional troubleshooting without extensive understanding
- Poor wired connections
- Disruptive noise



Demonstration and Questions

- Prototype demonstration time!
- Thanks for listening
- Any Questions?