P5463 Projectile Launcher

MECHATRONICS TERM PROJECT

Group 3

Po Ching Chen
James Cox
Gisselle Cunningham

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Introduction

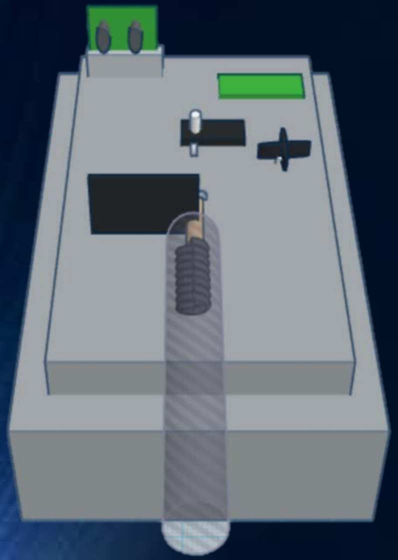


Figure 1: P5643 CAD Design

- Provide GK-12 Physics Educational Systems with a low-cost alternative to Physics Education
- Smart and integrated projectile launcher utilizing micro-controlled actuators and sensors
- Integrates three commonly taught Physics experiments into one device
    - 2D Projectile Motion
    - Hooke's Spring Law
    - Conservation of Energy

Mathematical Background

Hooke's Law:

$$F = -kx$$

Conservation of Energy:

$$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$$

$F = -kx$

Horizontal Distance:

$$d = \frac{v\cos\theta}{g}\left(v\sin\theta + \sqrt{(v\sin\theta)^2 + 2gy_o}\right)$$

Current Technology

Reference: American 3B

U10360 Projectile Launcher

- Launch angle: 0° - 90°
- Launch Distances: 1.1 m, 2.3 m and 4.5 m
- Launch Height: 146 mm
- Launch Speed: 0-6 m/s
- Steel Ball Diameter: 25 mm
- Steel Ball Mass: 7 g
- No Internal Photogate
- Dimensions: 205 x 65 x 60 mm
- Mass: 480 g
- Clamp Attachment
- Price: $408.00

Current Technology

Vernier Projectile Launcher

- Launch angle: 0° - 70°
- Maximum Launch Distance: 2.5 m
- Launch Height: 146 mm
- Launch Speed: 0-6 m/s
- Steel Ball Diameter: 17.46 mm
- Steel Ball Mass: 21.8 g
- Internal Photogate
- Price $289

Reference: Vernier Technology

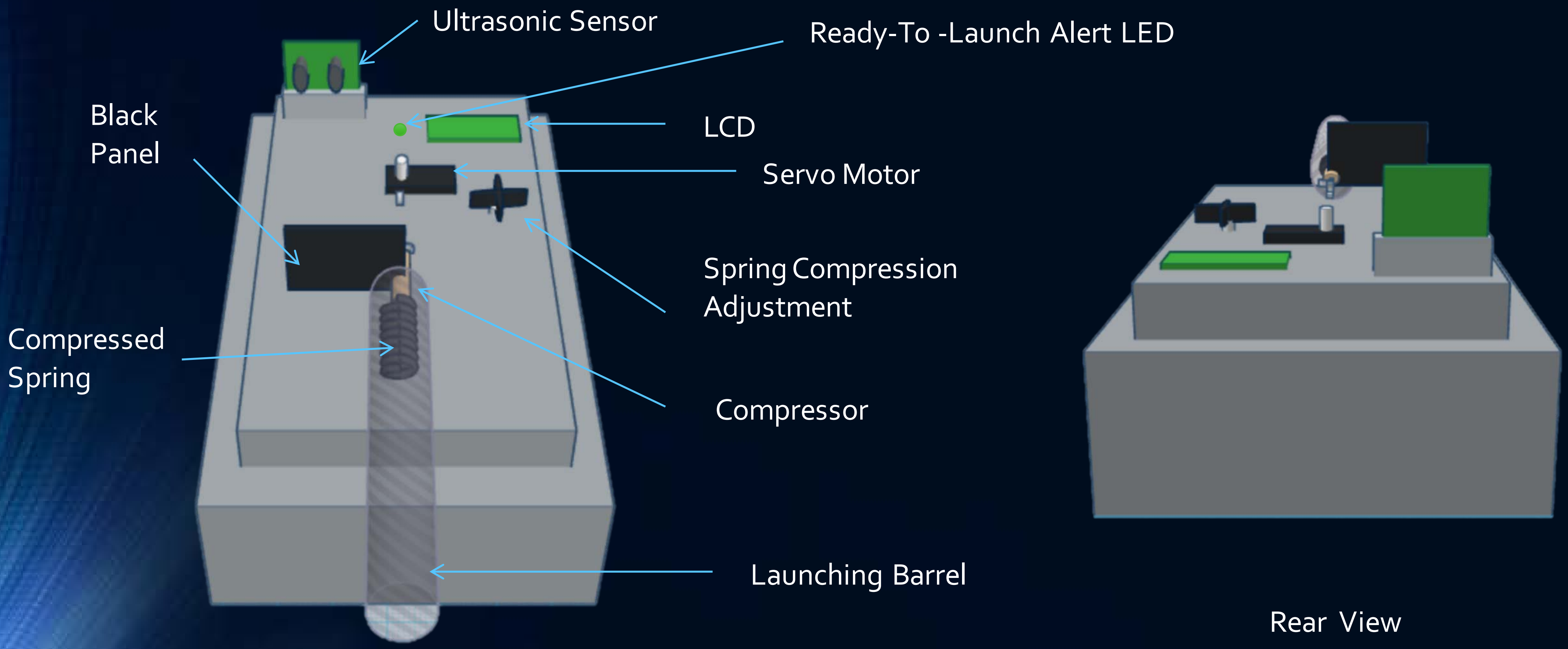
Current Technology

Reference: Abra-Electronics

PH0340 Projectile Launcher

- Spring Loaded Gun
- Launch angle: 15° - 90°
- Maximum Launch Distance: 3 m
- Launch Height: ---
- Launch Speed: ---
- Steel Ball Diameter: 17.46 mm
- Steel Ball Mass: 21.8 g
- No Internal Photogate
- Clamp Attachment
- Price $199.95

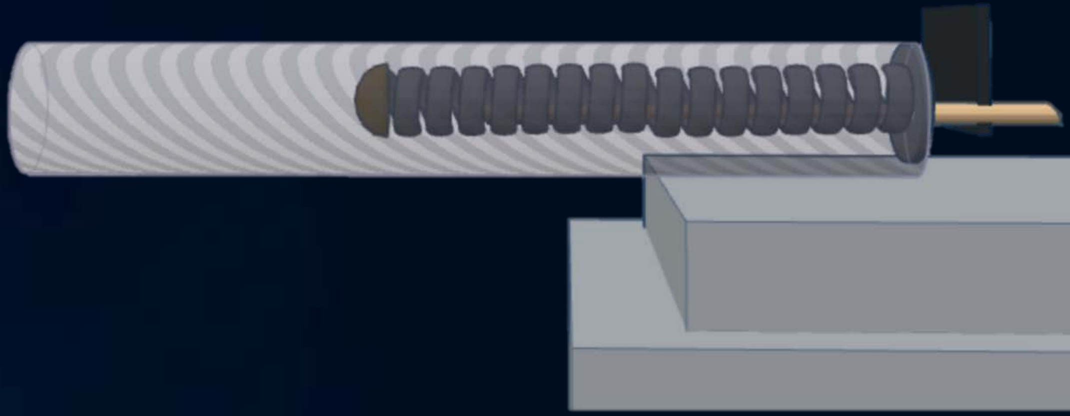
Mechanical Design



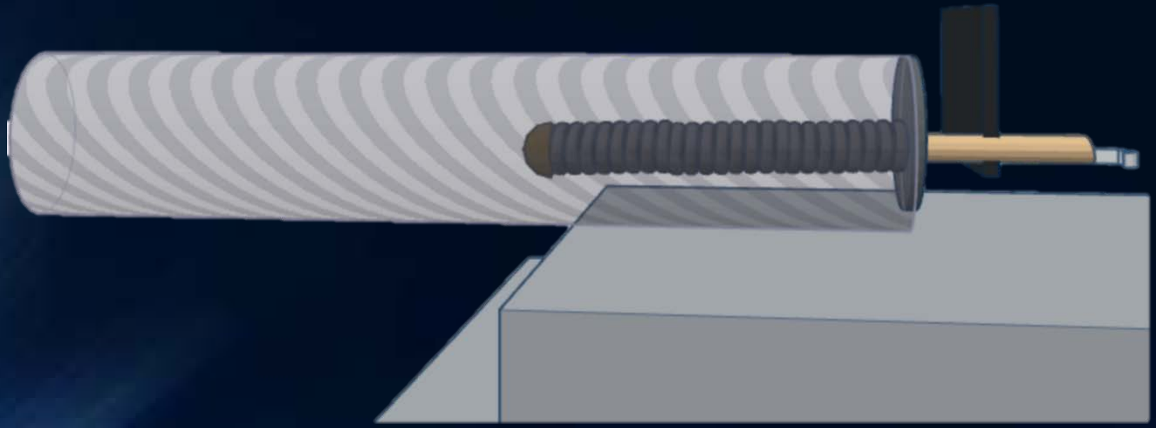
Rear View

Front View

Mechanical Design



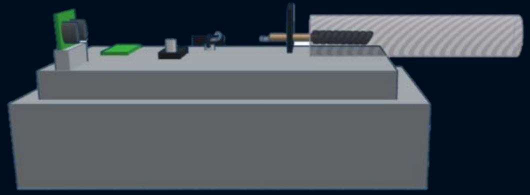
Compression Spring at Equilibrium



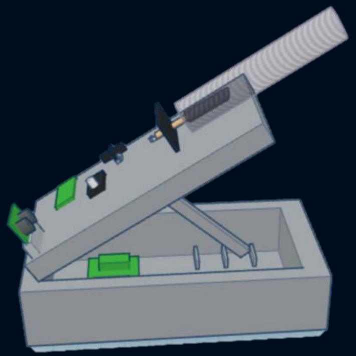
Compression Spring Fully Compressed

Mechanical Design

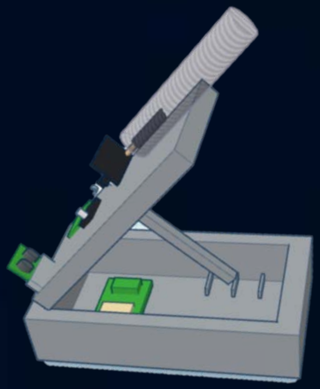
Customizable Launch Angles



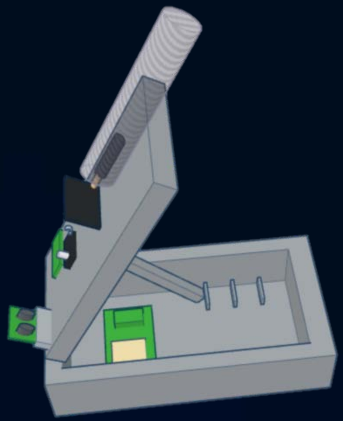
0° Launch Angle



30° Launch Angle

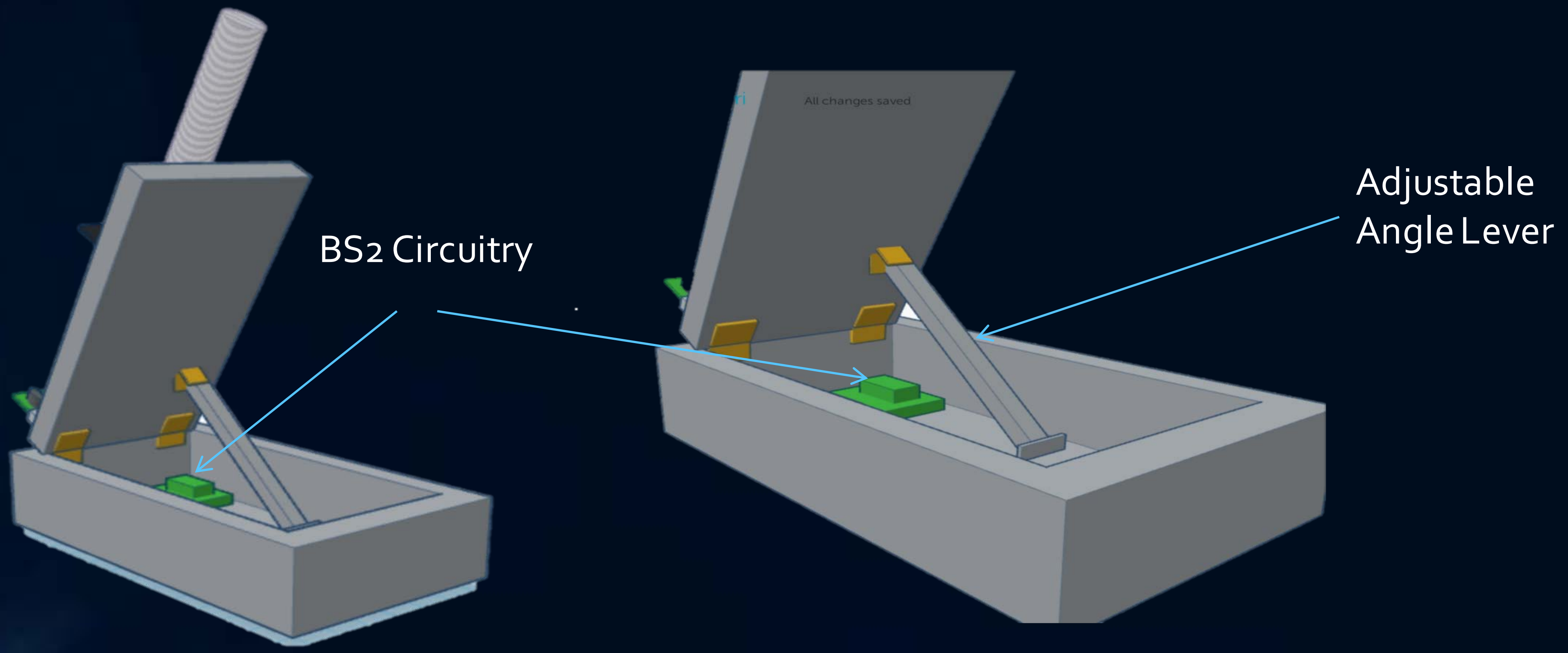


45° Launch Angle



60° Launch Angle

Mechanical Design



User Interface

Hook to anchor Compressor

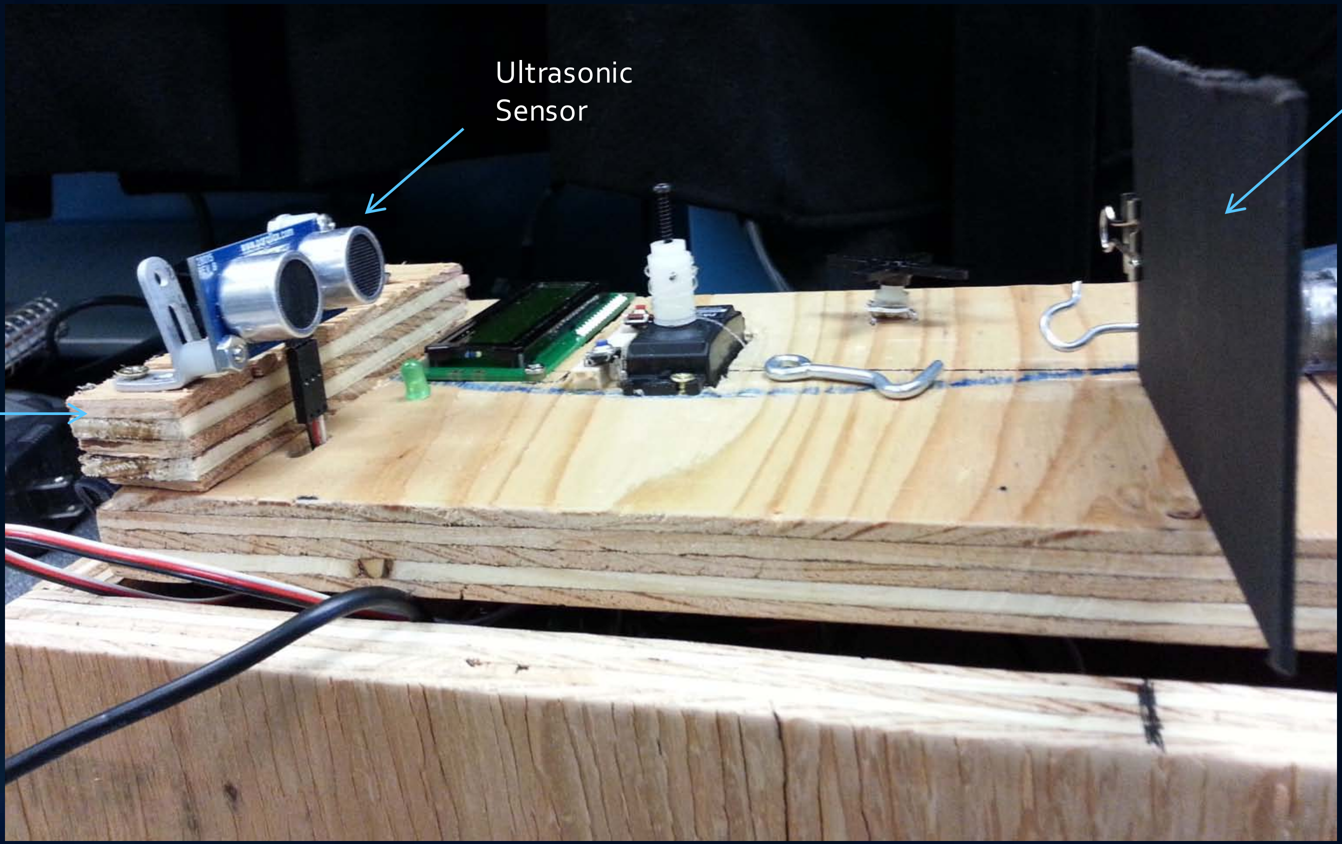
Push Buttons

Ready-To-Launch LED

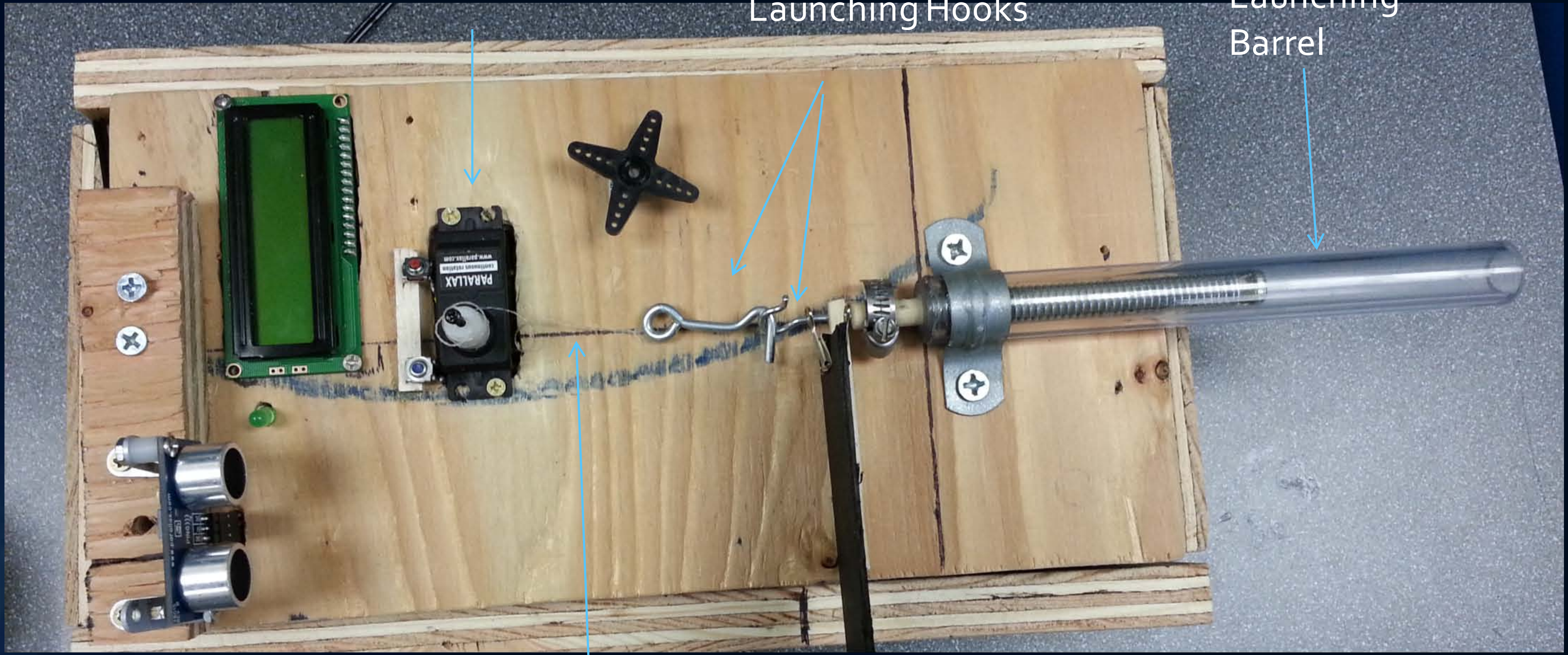
LCD

Adjustable Spring
Compression Knob

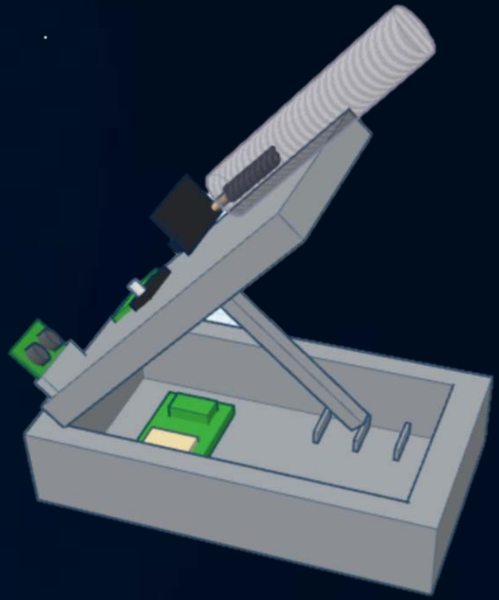
Sensors

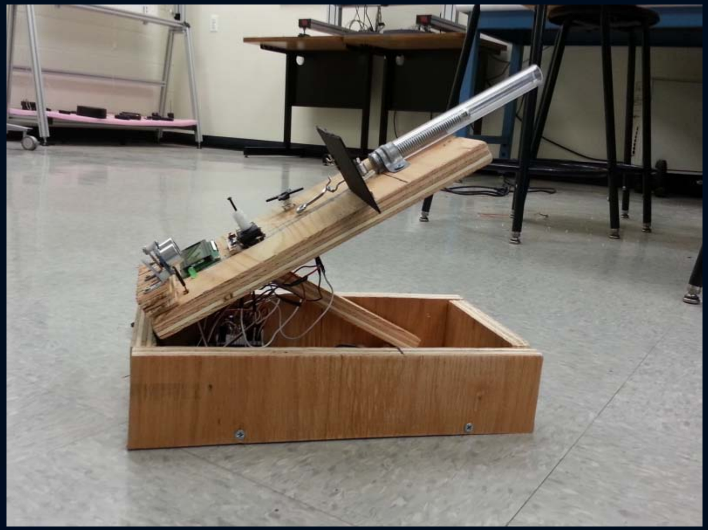


Actuator

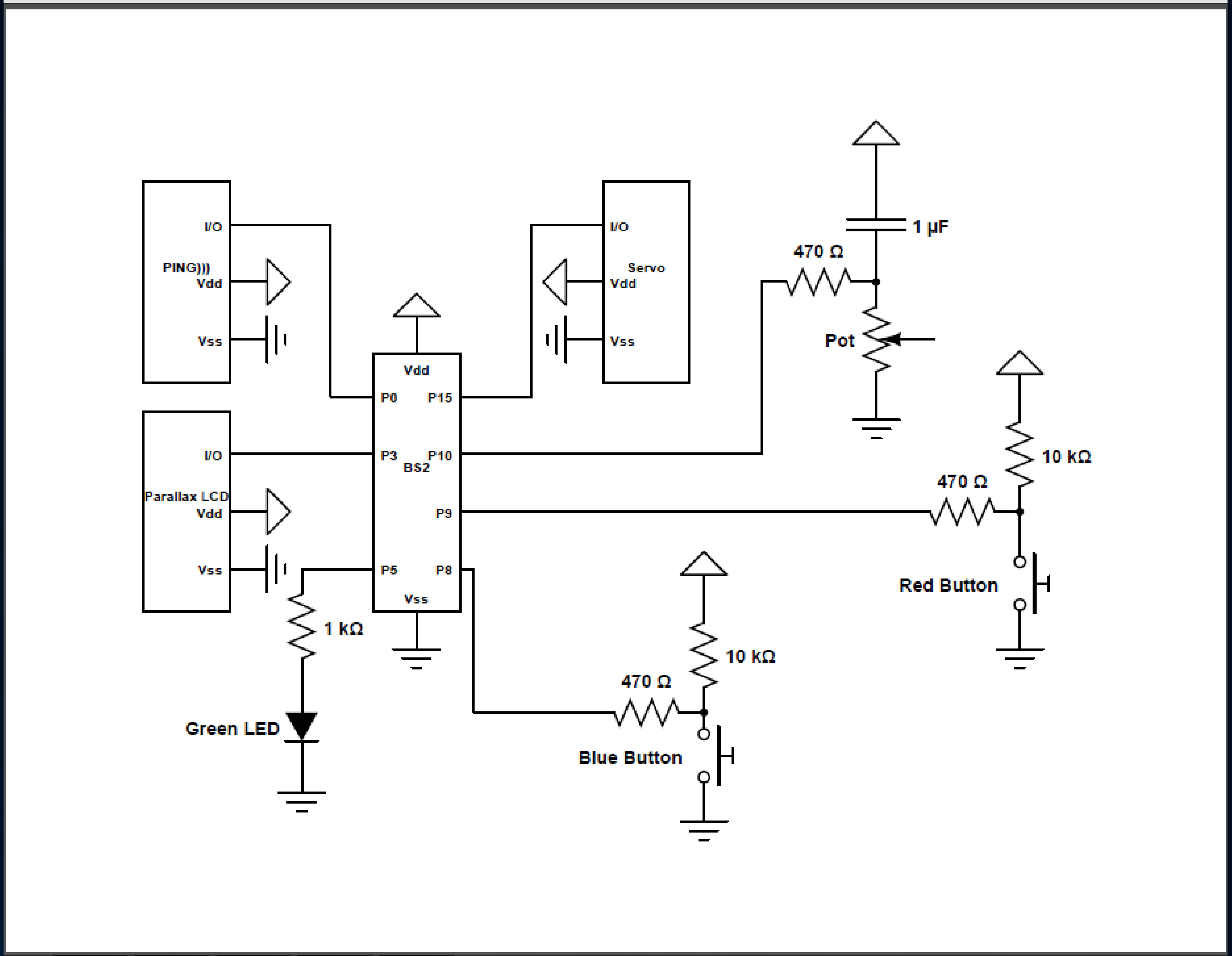

Servo Motor
Launching Hooks
Launching
Barrel
Attached
String

Final Product





Electronic Circuit



Bill Of Material

Materials	P5463 Qty Usage	Unit of Measure	Unit Cost	P5462 Usage Cost
Parallax Board of Education Development Board (Full Kit)	1	Each	$99.99	$99.99
Parallax (Futaba) Continuous Rotation Servo	1	Each	$12.99	$12.99
Servo Rotary Driver	1	Each	$5.95	$5.95
Parallax 2x16 Serial LCD (Non-Backlit)	1	Each	$27.99	$27.99
PING))) Ultrasonic Distance Sensor	1	Each	$29.99	$29.99
10K Potentiometer, Trim	1	Each	$1.50	$1.50
LEDs (Red and Green)	2	Each	$0.50	$1.00
Tact Switch (Pushbuttons)	2	Each	$0.50	$1.00
14" 3-wire F/F Extension Cable	2	Each	$2.50	$5.00
7" Clear Plexiglass Pipe	1/10	6'	$8.42	$0.84
Zinc-Plated Steel Compression Spring	1	6 Pack	$9.77	$1.63
12 mm Diameter Alloy Steel Metrical Ball	1	10 Pack	$4.16	$0.42
Monofilament 8lb Fishing Line	8"	One Roll	$4.99	$0.55
U-Clamp	1	Each	$0.49	$0.49
Hose-Clamp	1	Each	$0.99	$0.99
1-1/2" Butt Hinges	3	2-pack	$3.99	$5.99
¼" Steel Washer	1	Each	$0.11	$0.11
4'x 2' Pine Project Panel Plywood	1/3	1 Panel	$19.99	$6.63
40" Wooden Rod	1/4	1-40"	$1.29	$0.32
8-1/2" Wood Screws	12	25 Ct	$3.99	$2.00
Screw Hook	2	Each	$1.49	$2.98
¼" Steel/Zinc Plated Mirror Mount Nut	1	Each	2.96	$2.96
1.5 V AA Batteries	4	4-pack	$7.99	$7.99
Gorilla Glue Adhesive	0.05 oz	0.22 oz	$4.37	$0.99
	Prototype Total Cost:			$220.30

Prototype Cost/Cost Analysis For Mass Production

- The total construction cost for the came to an estimate total of $220.30.

- The greater bulk of the total cost:
  - Parallax Board of Education Development Board
  - Parallax 2x16 Serial LCD
  - PING))) Ultrasonic Distance Sensor

- Mass Production
  - Estimated Cost: $150
  - Estimations based upon 1/3 decrease in printing circuitry cost
  - Cheaper cost in hardware build material when purchased in bulk

Analysis/Calculations

Angle (Theta)	Theoretical Dist. (Inches)	Measured Dist. (Inches)	Percent Difference
30	33	31.5	4.55
45	33.8	31	8.28
60	27.5	23	16.36

Advantages

- Utilizes the intelligence of micro-controlled actuators and sensors to characterize and execute projectile motion

- Integrates three key physics experiments into one device:
  - 2D Projectile Motion
  - Hooke's Spring Law
  - Conservation of Energy

- Provides a low-cost alternative to teaching projectile motion in the GK-12 classrooms

Disadvantages

- No automated projectile release mechanism
- Fixated launch angles
- Spring loaded
  - Safety Precautions
  - However, dismantle switch is provided

Future Recommendations/Updates

- User input and automated launch angle adjustment
- Automated Launch Release Mechanism
- Additional safety features:
  - Protective mechanism to prevent premature launch release
  - Protective mechanism to prevent hook/string throwback after release

- More GK-12 aesthetically appealing

PBASIC Code

```
' {$STAMP BS2}
' {$PBASIC 2.5}

part VAR Bit
pressb VAR Bit
pressr VAR Bit
mmDist VAR Word         'actual distance in mm
rawtime VAR Word        'raw time of PING sensor
stopdis VAR Word        'distance between starting and ending displacement
startpos VAR Word       'starting displacement
maxpos VAR Word         'maximum allowable displacement
counter VAR Word
rctimer VAR Word
i1 VAR Word
i2 VAR Word
i3 VAR Word

'initialize
DIRS = %0000000000000000
SEROUT 3, 84, [22, 12]              'Initialize LCD
PAUSE 5


main:
  GOSUB start
  GOSUB motor
  GOSUB ready
GOTO main

start:
  SEROUT 3, 84, [128, "Welcome         ", 148, "                "]
  PAUSE 2000
  SEROUT 3, 84, [128, "Press the blue  ", 148, "btn to proceed  "]
  part = 0
  GOSUB bluebutton
  SEROUT 3, 84, [128, "Input spring    ", 148, "comp length     "]
  part = 1
  GOSUB bluebutton
  part = 2
  SEROUT 3, 84, [128, "Start motor?    ", 148, "                "]
  GOSUB bluebutton
RETURN


bluebutton:                         'Subroutine for checking blue button press
pressb = 0                          'Press blue button to proceed to next step
pressr = 0
DO
  IF IN8 = 0 THEN
    pressb = 1
  ELSEIF (IN8 = 1) AND (pressb = 1) THEN
    RETURN
  ELSEIF part = 1 THEN
```

PBASIC Code

```
     GOSUB enterinput
  ENDIF
  GOSUB redbutton
LOOP


redbutton:                        'Reset button to restart the experiment procedures
IF IN9 = 0 THEN
  pressr = 1
ELSEIF (IN9 = 1) AND (pressr = 1) THEN
  GOTO kill
ENDIF
RETURN


enterinput:                       'Potentiometer knob used to take user input
HIGH 10
PAUSE 20
RCTIME 10,1,rctimer               'RC time with 1 uF capacitor and 470 Ohm resistor
stopdis = rctimer/68              'Displacement knob for 0-85 raw time units
mmDist = stopdis*7/20             '7/20 is the conversion factor to get mm from rawtime
IF mmDist > 9 THEN
  SEROUT 3, 84, [159, "=", DEC mmDist, 162, "mm"]
ELSEIF mmDist < 10 THEN
  SEROUT 3, 84, [159, "= ", DEC mmDist, 162, "mm"]
ENDIF
RETURN


motor:                            'Subroutine for motor functions
startpos = 0
FOR counter = 1 TO 10             'For loop to obtain the initial displacement
  PULSOUT 0, 5                    'by averaging ten values
  PULSIN 0, 1, rawtime
  IF (rawtime < 480) AND (rawtime > 420) THEN
     startpos = startpos + rawtime    'positions use raw time values during calculations
  ELSE                                'convert to distance later when displaying
    startpos = startpos + 450
  ENDIF
  PAUSE 20
NEXT
startpos = startpos/10

maxpos = startpos - 85           'maximum spring displacement
IF stopdis > maxpos THEN
  stopdis = maxpos               'If user inputs higher than max, it is changed to max
ENDIF

i2=startpos
i1=startpos
SEROUT 3, 84, [128, "Comp Length     "]

pressr = 0
```

PBASIC Code

```
DO WHILE (counter < 1000)
  PULSOUT 0, 5
  PULSIN 0, 1, rawtime
  i3 = i2
  i2 = i1
  i1 = rawtime                    'smoothes out reading from PING sensor
  rawtime = (i3+i2+i1)/3          'by using a moving average of last 3 values
  IF rawtime > (startpos - stopdis) THEN
    PULSOUT 15, 775               'motor will turn
    counter = 0
  ELSE
    PULSOUT 15, 750               'motor will stop and hold position
    counter = counter + 25        'counter to determine duration of motor on
  ENDIF
  mmDist = (startpos - rawtime)*7/20
  IF mmDist > 99 THEN             'Display results
     SEROUT 3, 84, [148, "=", DEC mmDist, 152, " mm",155,"         "]
  ELSEIF (mmDist < 100) AND (mmDist > 9) THEN
     SEROUT 3, 84, [148, "= ", DEC mmDist, 152, " mm",155,"         "]
   ELSEIF mmDist < 10 THEN
     SEROUT 3, 84, [148, "=  ", DEC mmDist, 152, " mm",155,"         "]
   ENDIF
  GOSUB redbutton
  PAUSE 20
LOOP
RETURN


ready:
HIGH 5                            'Green LED on to show launch ready
SEROUT 3, 84, [128, "Ready for launch", 148, "                "]
pressr = 0
rawtime = maxpos
DO WHILE (rawtime < (startpos - (stopdis/2)))
  PULSOUT 15, 750                 'Holds motor position until user releases ball
  PULSOUT 0, 5
  PULSIN 0, 1, rawtime
  i3 = i2
  i2 = i1
  i1 = rawtime
  rawtime = (i3+i2+i1)/3
  GOSUB redbutton
  PAUSE 20
LOOP
LOW 5                             'Green LED off after release
SEROUT 3, 84, [128, "                ", 148, "                "]
PAUSE 2000
RETURN

kill:
LOW 5
GOTO main
```

Conclusion

The final prototype of the projectile launcher produced accurate results with a low percent difference between the theoretical and measured values. The prototype design was cheap to manufacture and simple to operate, with little user training required. There are various design improvements that could be implemented to further enhance the projectile launcher experience, such as fully automating the release and pull back mechanism. The prototype projectile launch will help teach and enforce basic Newtonian physics in the K-12 classroom.