REVERSE ENGINEERING REPORT

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STEM 2°

INTRODUCTION

For this project, we were asked to break apart an item, learn how it works, sketch and analyze the parts, modify the item to make it more effective, and rebuild it. We followed the Reverse Engineering Design Process, and the steps in this process form the sections of this report:

STEP 1: DETERMINE THE DESIGN PURPOSE

General Purpose: To learn how an object works by breaking it apart and sketching and analyzing the parts, then modifying it to make it more effective and eventually rebuilding it.

Device Description: Nerf Nite Finder Ex-30

Device Purpose: This device was made so people could play with guns and not get hurt. Engineers identified a problem that there were no toys that allowed kids to shoot each other and not be harmed, so they created Nerf blasters to solve this problem. The purpose of the LED on the blaster is to show where the dart is targeted. Engineers identified a problem that users of the blasters wouldn't know where the dart would land, so they solved the problem by adding an LED.

Dimensions: 27.94 cm x 20.57 cm x 5.84 cm

Bill of Materials: Here is a list of all materials used in the blaster, including part #, name, quantity, dimension, function (check Step 4), cost, interactions (check Step 4), and website source (check references)

Plastic for shell, trigger, plunger, barrel: ABS plastic, dimensions found above

Spring 2 kg "Current Production" NF spring: (Older NF springs have lower constants, but more compression, so they are generally more powerful at full compression), unable to find part number

Outer Diameter: ~.825" Inner Diameter: .7"

Length: 3.25"

Coils: 17 (Older ones have 15)

Spring Constant: ~3.9 lbs/in

Catch Spring: Made of zinc-plated steel, unable to find part number

Outer Diameter: 5 mm, Inner Diameter: 4 mm

Length: 12 mm, Compressed Length: 5 mm

2 AA batteries: 1.5 Volt alkaline batteries

Resistor: Made of metal film, 39 Ohms 5%, unable to find part number

Resettable Fuse[5] : Made with conductive plastic, part number is C139094

O-ring: Made with rubber, unable to find part number

Timeline: Below is a Gantt Chart to plan our process for this project and keep track of our tasks.

1	**Project Conception and Initiation**				
1.1	Research Mods	Everyone	9/6/19	9/19/19	100%
1.2	Sketch Nerf Gun	Josh	9/6/19	9/19/19	100%
1.3	Research Types of Plastic/Materials	Matt, Juan	9/9/19	9/19/19	60%
1.4	Measure Spring Size	Josh	9/9/19	9/19/19	100%
2	**Project Work**				
3.1	Modifying the Blaster	Juan, Nic, Matt	9/11/19	9/19/19	100%
3.2	Modifying Nerf Bullet	Everyone	9/11/19	9/19/19	0%
3.3	Final Resume	Everyone	9/13/19	9/20/19	20%
3.4	Presentation	Everyone	9/13/19	9/19/19	30%
3	**Project Performance / Testing**				
4.1	Testing Blaster Distance	Juan, Matt, Nic	9/16/19	9/19/19	100%
4.2	Testing Blaster Precision	Juan, Matt, Nic	9/16/19	9/19/19	100%

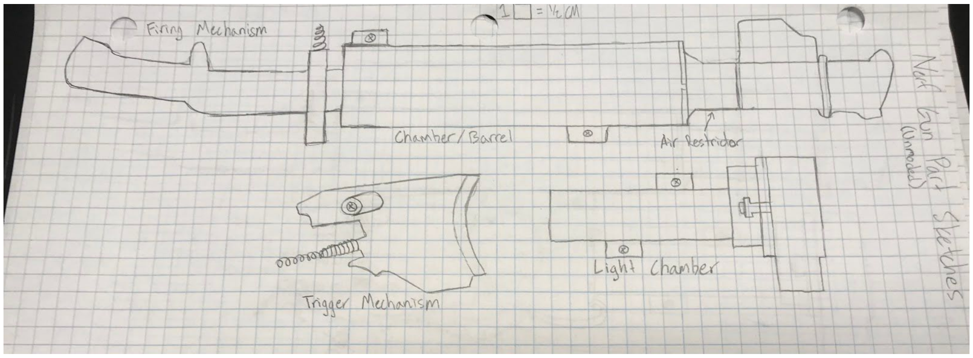
Hypothesis: If we remove the air restrictor from the Nerf blaster, then the dart will travel a further distance.

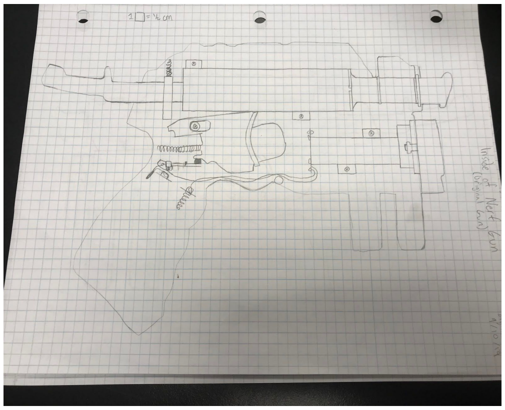
STEP 2: OBSERVE HOW IT WORKS

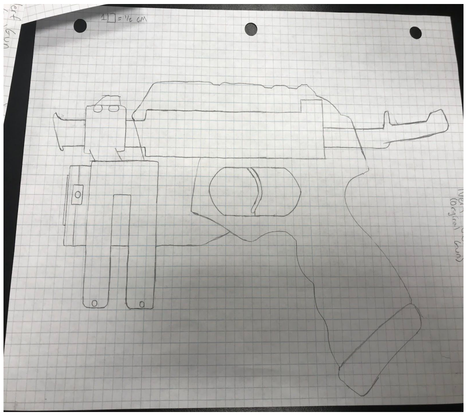
Procedures: The Nerf blaster is air and spring powered. When the plunger is pulled back it will click into place, indicating that the blaster is ready to fire. Pulling the trigger all the way down will release the catch, allowing the spring to push the plunger back into the gun and push air through the chamber to the foam dart. The force of the air accelerates the dart out of the barrel and towards the target.

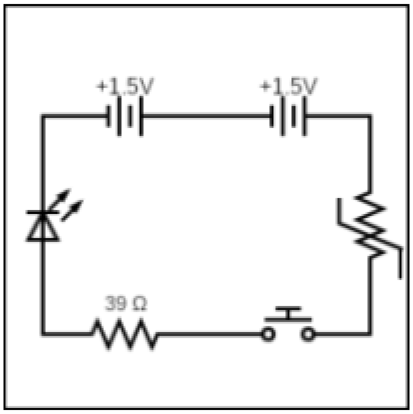
If the trigger is pulled back a small amount, the electrical circuit will be closed, allowing electrical current to flow from the batteries to the LED. When the electrons reach the LED, electron holes within the device allow the electrons to drop to a lower orbital, releasing quantized energy as photons. The photons are what make the LED appear lit up.

Device Model/Sketches: Below are a few sketches of the Nerf blaster. The first shows the main parts after we took it apart (all parts are explained in Step 4 on page 6), and the second two show how the parts fit together in the blaster (all sketches are drawn to a 1-1 scale; 1 box is 0.5 centimeters).









Above is the circuit diagram for the LED part of the Nerf blaster. When the trigger is pulled back, the switch is closed, and the circuit is completed. The two sections labeled with +1.5V represent batteries. The zigzag line labeled 39Ω is the resistor. The zigzag line with a diagonal line is a resettable fuse. The triangle with arrows is the LED. The part with two circles and lines above it represents the push switch.

Flow Chart:

Here is a flow chart demonstrating how the Nerf blaster achieves its purpose of firing a dart:

Plunger Pulled ⇨ Trigger Pulled ⇨ Catch Released ⇨ Spring Pushes Plunger ⇨ Plunger Pushes Air ⇨ Air Pushes Dart out of Blaster

Here is a flow chart demonstrating how the LED lights:

Plunger Pulled ⇨ Trigger Pulled ⇨ Switch Closed ⇨ Circuit Completed ⇨ LED turned on

STEP 3: DISASSEMBLE

Disassembly Process: We disassembled the Nerf blaster by first taking out all the screws on the outside of the green plastic. Then we removed the screws that help hold down the barrel and the LED. Inside of the barrel was the plunger, spring, and o-ring. We broke off the front half of the barrel to access the air restrictor, which we took out. After this we took pictures of all individual parts.

Pictures: Explanations of each parts' function can be found in Step 4: Analyze (page 6).

Above is the plunger (top), large spring (on plunger), and barrel (bottom) of the blaster. The air restrictor is in the barrel.

Above is the air restrictor. It consists of a small spring (left) and a three-pronged orange cap (right).

Above is the trigger (orange), the shell (green), and the electric circuit (starting from black below trigger going through the red and black wires).

STEP 4: ANALYZE

Functions of Individual Parts: Here you can discover what each part does and how it interacts with other parts. We figured out how these parts work by analyzing the blaster when it was disassembled.

Air Restrictor: Our immediate question after breaking apart the blaster was why there was an air restrictor. Several guides on the Internet explained that an easy modification to increase the range of the blaster was to remove the air restrictor. We soon realized that the air restrictor was there because the blaster is intended for children's use, and a more powerful blaster could result in harmful shots. The air restrictor consists of a spring and a three-pronged cap, and it restricts the air flow going to the dart by adding another spring that the plunger must push. This adds another energy transfer from potential to kinetic energy and results in some energy being converted to thermal. This decreases the force on the dart.

Plunger: The plunger serves as the main force mechanism. Attached to the plunger is a large spring which compresses when the plunger is pulled back, increasing the potential energy. When the trigger is pulled, the back part of the trigger pushes up the catch (which is holding the plunger in place) so it gets released, allowing the spring to return to its equilibrium state. This restoring force pushes the air in the barrel and pushes the dart out of the blaster.

Barrel: The barrel serves as a holding place for the Nerf dart. It is also the area where the plunger pushes the air toward the Nerf dart.

Trigger: The trigger is what releases the catch and what completes the electrical circuit. When the trigger is pulled back by the user, the back part of the trigger pushes up the catch (which is holding the plunger) and the plunger is released. The

Catch: The catch is what keeps the plunger pulled back, and it also keeps the string from being compressed to far. The catch gets pushed down just above the trigger, when the trigger is pulled back the catch is pushed up and the spring is released.

LED/Electrical Circuit: The LED works as a laser; when it is activated, a red light can be seen on the surface that the blaster is pointing at. It is connected to the trigger. When the trigger is partially pulled, the circuit is completed and the LED will turn on.

Shell: The shell holds every piece together; it keeps everything sturdy and in place.

Material Analysis: This section serves to explain why each material was used for each part.

Plastic: ABS plastic was likely used because it is durable and cheap.

Spring: Zinc-plated steel was used because it can compress and expand easily.

Resistor: The metal film is used for the resistor because its resistivity keeps at a good resistance (39Ω).

Resettable Fuse: Conductive plastic is used because it can conduct electricity, which is important for the circuit.

O-ring: The rubber ring is slightly larger than the plunger head and is able to move through the barrel easily to create a tighter seal.

STEP 5: REDESIGN

Modifications: Our only modification that we could complete in the time we were given was the removal of the air restrictor, which restricts the force of the air that pushes the dart out of the blaster. The air restrictor is removed by taking apart the barrel and removing a small spring and a three-pronged orange cap. A picture of the components of the air restrictor can be found in Step 3: Disassemble (page 5).

This modification resulted in the blaster's firing distance almost doubling. We wanted to replace the spring on the plunger for one with a higher spring constant and load weight, but we were unable to find and order the part in time.

Tests:

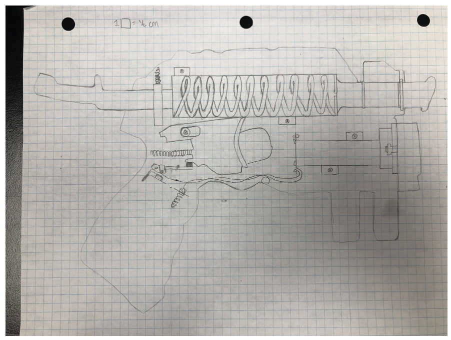
TRIAL NUMBER	DISTANCE BEFORE MODIFICATION	DISTANCE AFTER MODIFICATION
1	378.46 cm	544.83 cm
2	358.14 cm	600.71 cm
3	332.74 cm	566.42 cm
4	287.02 cm	607.06 cm
5	350.52 cm	482.6 cm
Average	341.37 cm	560.324 cm

How to Rebuild: After removing the air restrictor, the blaster can be rebuilt. First, reattach the barrel together. Second, put the plunger back into the barrel. Then, put the barrel back into the main body of the gun, making sure to keep the catch in its small compartment. The spring attached to the catch should fit into the compartment. After screwing the barrel back on the body, screw the other half on the shell. To test fire, put the dart at the end of the barrel, pull back the plunger until it clicks into place, then pull the trigger all the way back, and watch the dart go flying.

CONCLUSION

We conclude that our hypothesis was correct; removing the air restrictor in the Nerf Nite Finder Ex-30 is effective in increasing the range of the blaster. We tested the range of the Nerf blaster before and after removing the air restrictor, and got results that proved our claim. We shot the dart from the same height (3 feet) at the same angle (horizontal to the ground) and with the same dart. We measured the distance after five trials with a tape measure and found that the average distance after removing the air restrictor was 86.2 inches greater. All numbers for distance after the modification were significantly greater than all numbers for distance before the modification. We conclude that our modification was successful and that our hypothesis was correct.

We also conclude that our spring replacement task went poorly. We initially aimed to replace the large spring in the plunger with a spring that had a higher spring constant and load weight, but we never did. The reason this went poorly was because we had trouble finding a spring that would exactly fit in our blaster, and by the time we found one, there was not enough time to order the part and install it. However, we included a sketch (pictured below) that shows how a new spring would fit in with the other parts, just in case someone found our blaster and needed to know how to improve it.



Another possible improvement for next time could be a modification of the dart itself. If the purpose is to fire a dart as far as possible, then the dart plays an important role. When the dart is flying through the air, it is subject to two forces: gravity and friction (air resistance). The gravity is what accelerates the dart toward the ground, and cannot be changed. The air resistance, however, depends on the shape of the dart. If we had researched how to make the most aerodynamic dart and modified it, we may have further improved our Nerf blaster.

REFERENCES

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