

# Element I

## Testing and Evaluating the Prototype

## Introduction

In order to ensure the satisfaction and safety of the customer, multiple processes and tests must be conducted and analyzed. The Build Plan in Element G and the Test Plan from Element H will be documented down below. If the product does not meet the expected results for any of the tests, the product will be reevaluated and corrected.

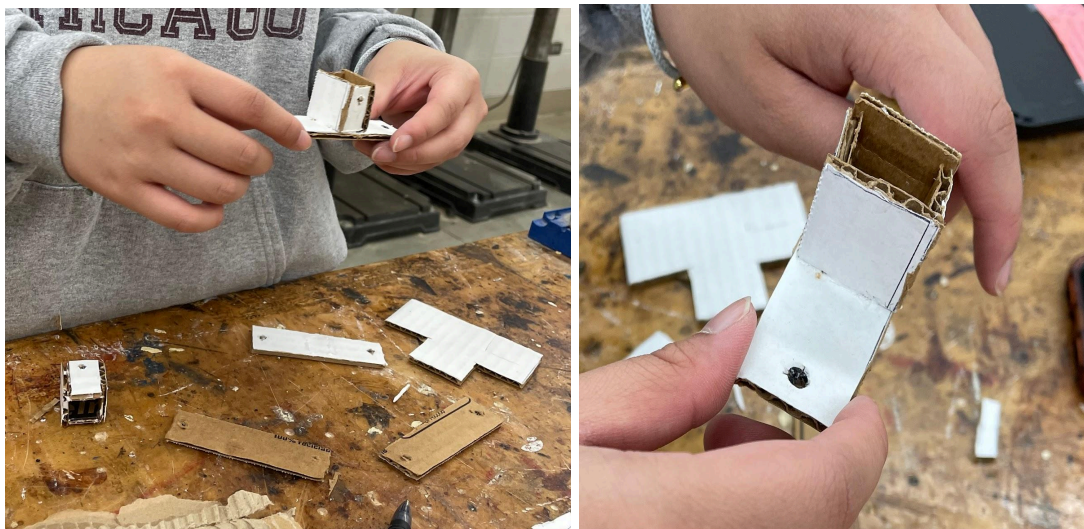
## Problem Statement

A spinal cord injury damages nerves which can cause long-term or permanent loss of function below the waist. Driving with this injury is impossible without special equipment and modifications. As of 2011, 36.5% of people with a spinal cord injury (SCI) in the US are reported to drive a modified vehicle. Studies show that this low number can be attributed to the high price of around \$20,000 to \$80,000 for modifications. Most patients feel a decreased quality of life because of their lack of transportation and fear of driving without another person's help.

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## Part I

### Building Process Documentation



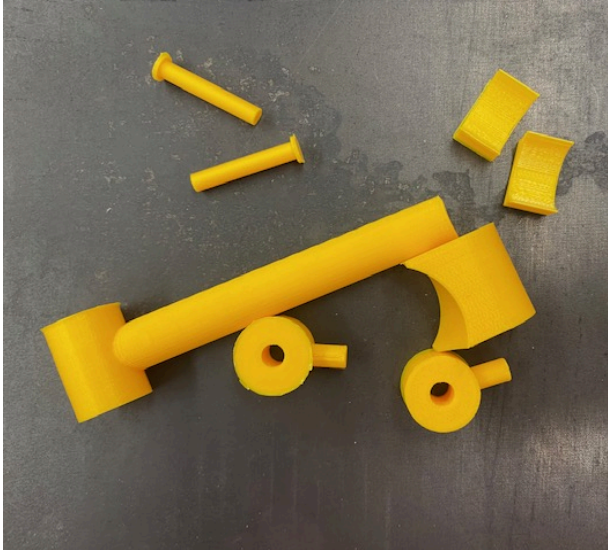
**Figures 1 & 2**

These images display the building process for the metal clamps of the prototype. Materials used were cardboard, cardstock, wood glue, rulers, various types of tape, pens, and sharp tools.



**Figure 3**

The above photo demonstrates the process of drawing precise and measured lines on the metal sheet to ensure the precision of the future cutting process.



**Figure 4**

The following parts were made by 3D printing: pins for the brake and accelerator clamps, the button for adjusting the length, the filling which creates the hinge-joint mechanism for the clamps, and the D-shaped rod.



**Figure 5**  
The metal sheet was initially cut with a small Dremel.



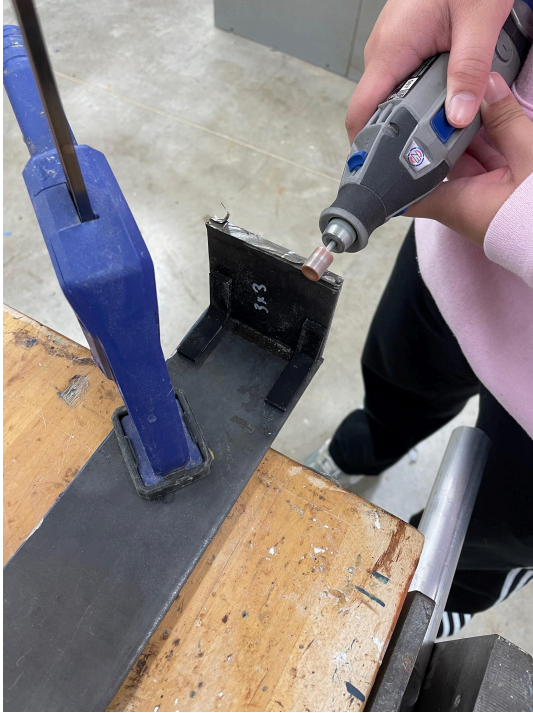
**Figure 6**  
To work more efficiently and within the time constraints, a larger blade was used instead of the small Dremel.



**Figure 7**  
A hole is drilled into the solid rod with adult assistance.



**Figure 8**  
The solid rod is cut using the larger blade.



**Figure 9**

A Dremel is used to buff the metal to smooth out the sides after being cut.



**Figure 10**

After assembling the parts to visualize the final product, the necessary parts were stuck together using adhesive.



**Figure 11**

The final product is installed in the vehicle and ready to be used.

## Testing Process Documentation

### 1. Test Procedure: Performance

- **Incremental Testing Summary:** None
- **Testing Location:** Empty parking lot
- **Purpose:** This test will determine the success rate of the device and how many times it operates both the acceleration and braking functions correctly out of a certain number of trials. This will help determine the effectiveness of the product.
- **Initial Conditions:** The prototype must be completed, the device must be installed properly in the vehicle, and the vehicle engine must be on.
- **Materials:** Auto Transmission vehicle, timer
- **Pass or Fail Criteria:** The test is successful if the driver can drive for 3 minutes which includes driving, turning, and parking using only the hand controls driving aid. The test fails if the prototype is unable to do any of these functions.
- **Procedures**
  1. Start the timer.
  2. Pull the handle of the prototype to test the acceleration function.
  3. Push the handle of the prototype to test the braking function.

4. Turn the vehicle left and right while using the prototype.
  5. Park the vehicle turning both ways.
  6. Stop the timer. If the timer shows a time greater than 3 minutes, the test is successful.
  7. If, at any point, the prototype does not work, immediately brake with the foot, switch to park mode, and analyze what's wrong.
- **Safety Considerations:** Must drive slowly and readily be able to brake with the foot, make sure there are no other vehicles or people in the area, and stay away from any buildings or property nearby.
  - **Data:**  
Quantitative: The percentage of the success rate is measured by taking the ratio of the number of times the test was successful to the number of times it failed and converting the number into a percentage.
  - **Data Collection Graph or Sheet:** Will create a table listing each function of the vehicle and mark if the function was successful or not which will determine if the overall test is successful.
- **Results:**  
The prototype passed the test twice but then broke on the third trial. This would count as a 66% success rate.
  - **Reflection:**  
The brake rod came off the prototype on the third trial due to there not being enough glue in between.
  - **Recommendations:**  
The brake rod should have been connected more securely, such as by screws or by wrapping around the central rod and given extra precaution considering that the brake pedal is harder to push than the gas.

## 2. Test Procedure: Adjustment Length

- **Incremental Testing Summary:** Measure the length of the rod
- **Testing Location:** Neuqua Valley High School - EDD Classroom
- **Purpose:** This test will determine if the length of the rod will expand a minimum of 8".
- **Initial Conditions:** The adjustment rods must be correctly assembled.
- **Materials:** Tape Measure
- **Pass or Fail Criteria:** The length of the rod must expand a minimum of 8". If the minimum length of the rod expands below 8", the test is a failure.
- **Procedures**
  1. Lay the brake rod on the ground.

2. Using the button mechanism in the device, adjust the rod's length by lining up the button on the outer rod with each hole on the inner rod.
  3. Use the tape measure to record the total length of the entire brake rod after the adjustment is made.
  4. Record the lengths on the Google sheet.
  5. Repeat this same procedure for the acceleration rod.
- **Safety Considerations:** Keep the tape measure locked
  - **Data:** Quantitative: The maximum amount of inches that the rod can extend to.
  - **Data Collection Graph or Sheet:** Will create a table on a separate Google sheet showing each increment of inches the rod can successfully extend.
- **Results:**  
Can adjust up to 8"
  - **Reflection:**  
The prototype passes this test, there are no changes to be made. The prototype can adjust anywhere between the seat closest to the wheel to the seat farthest from the wheel and it still works comfortably.
  - **Recommendations:**  
None.

### 3. Test Procedure: Device Range of Motion

- **Incremental Testing Summary:** Test the rod's hinge's range of motion and adjust accordingly
  - **Testing Location:** Neuqua Valley High School - EDD Classroom
  - **Purpose:** Determine if the rod's hinge's range of motion is 60 degrees
  - **Initial Conditions:** The prototype is completed, and the metal clamps are securely attached to the car pedals.
  - **Materials:** Protractor
  - **Pass or Fail Criteria:** Must be able to rotate 60 degrees with 10 degrees leniency
  - **Procedures**
    1. Lay the clamp and rod flat on the ground
    2. Hold up a protractor and align the rod so that it is at 0 degrees
    3. Rotate the rod as far as it can go
    4. Record the angle
  - **Safety Considerations:** None
  - **Data:**  
Quantitative: The range of degrees that the rod attached to the clamps can move
  - **Data Collection Graph or Sheet:** Will create a table on a separate Google sheet displaying the various angles.
- **Results:**

The prototype has a full range of motion of 62 degrees, thus passing this test

- **Reflection:**

The range of motion is enough to function when the prototype is pushed/pulled all the way.

- **Recommendations:**

None.

#### 4. Test Procedure: Comfort

- **Incremental Testing Summary:** None
- **Testing Location:** Neuqua Valley High School - EDD Classroom
- **Purpose:** Determine if the rubber handle provides sufficient comfort and grip support for the users' hands.
- **Initial Conditions:** The handle component of the prototype must be completed, and the rubber rings must be attached to the handle.
- **Materials:** Survey responses
- **Pass or Fail Criteria:** If the average of survey responses rate the comfort of the handle to be an 8 on a scale from 1 to 10, then the prototype passes the test. The prototype fails if the average is below 8.
- **Procedures**
  1. Obtain the handle part from the prototype.
  2. Ask individuals if they would like to take a survey for an engineering project
  3. Ask participants to hold the handle and rate it on a scale of 1 to 10 based on its comfort, 10 being the best
  4. Record their answers on Google Spreadsheet.
  5. After receiving at least 40 responses, calculate the average of all their ratings.
- **Safety Considerations:** None
- **Data:**

Qualitative: The survey responses rate the comfort of the handle to be a 9 on a scale from 1 to 10 (1 being the worst, 10 being the best).
- **Data Collection Graph or Sheet:** Google sheet so that all data can be displayed and calculated immediately, will present all graphs and data of each question from the survey.

- **Results:**

Out of 47 responses, the average was 8.2/10

- **Reflection:**

While this prototype still passed the test, it did not follow the design plan. Originally, the handle was supposed to have a rubber layer covering it, but the materials bought were incorrect.

- **Recommendations:**

Double-check that all of the materials are correct before purchasing them. Regardless, the handle still passed the test and since it is made out of plastic it would still be able to withstand being in a hot car for a short period of time.

## 5. Test Procedure: Weight

- **Incremental Testing Summary:** None
- **Testing Location:** Neuqua Valley High School - EDD Classroom
- **Purpose:** Determine if the product weighs no more than 12lbs
- **Initial Conditions:** Each part must be complete but the whole device does not have to be assembled
- **Materials:** Scale, calculator
- **Pass or Fail Criteria:** The product must weigh no more than 12 lbs with +/- 1 lb
- **Procedures**
  1. Turn on the scale and zero it.
  2. Place each part on the scale, making sure that the scale is holding the entire weight
  3. Record the weight in pounds
- **Safety Considerations:** Place the device gently on the scale
- **Data:**

Quantitative: notes of the sum of the weight of each part of the prototype.
- **Data Collection Graph or Sheet:** There is only one data point which is the total weight of the product.

- **Results:**

The prototype is 5.8 pounds.

- **Reflection:**

The prototype is much lighter than anticipated, which is good. It is comfortable for someone who may have limited strength

- **Recommendations:**

Using a mix of plastic and metal helped decrease the weight, and also using aluminum instead of steel. The prototype would be lighter if aluminum was used as an alternative for steel, but it exceeded the pass criteria by more than 6 pounds.

## 6. Test Procedure: Aesthetics

- **Incremental Testing Summary:** None

- **Testing Location:** Neuqua Valley High School
- **Purpose:** Determine on a scale of 1-10 how aesthetically pleasing the product is
- **Initial Conditions:** The product is fully assembled but not painted or decorated
- **Materials:** Survey responses
- **Pass or Fail Criteria:** If the average of survey responses rate the comfort of the handle to be a 9 on a scale from 1 to 10, then the prototype passes the test. The prototype fails if the average is below 9.
- **Procedures:**
  1. Take pictures of the prototype.
  2. Ask individuals if they would like to take a survey for an engineering project
  3. Show participants pictures of the prototype and how it would look with white paint, pink paint, or how it is.
  4. Ask them to rate the aesthetics on a scale of 1 to 10, 10 being the best
  5. Record their answers on Google Spreadsheet.
  6. After receiving at least 40 responses, calculate the average of all their ratings.
- **Safety Considerations:** None
- **Data:**

Qualitative: survey responses that rate the aesthetics of the to be a 9 on a scale from 1 to 10 (1 being the worst, 10 being the best).
- **Data Collection Graph or Sheet:** Google sheet so that all data can be displayed and calculated immediately, will present all graphs and data of each question from the survey.
- **Results:**

Out of 47 responses, the average was 6.4/10
- **Reflection:**

There was not enough time to focus on the aesthetics of the prototype. The original build procedure involved painting the entire prototype in a single color. Instead, the final prototype was a mix of four different colors that clashed.
- **Recommendations:**

Work on aesthetics throughout the build process instead of trying to do it all once all the components are assembled.

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## Part II

### **Do the results reflect a problem with the testing procedure?**

- **Build/Test Procedure**

The testing procedure was conducted in an empty parking lot to determine the success rate of the product. It was installed in the vehicle and used to accelerate and brake.

- **Results**

The product worked according to its desired functions successfully during the first two trials but broke on the third trial.

- **Recommendations**

Find a more sturdy and durable way to attach the rod to the main base instead of solely using adhesive. A stronger idea would be to include a part on the attachment that wraps around the base rod.

### **Do the results reflect a problem with the materials used for the prototype?**

- **Build/Test Procedure:**

Cardboard, cardstock, and duct tape were used to create the prototype. Metals and 3D-printed parts were used to create the second prototype.

- **Results:**

The prototype was left incomplete to have enough time to create the second prototype.

- **Recommendations:** To save more time, it would be wiser

### **Do the results reflect a problem with the quality of the building process of the prototype?**

- **Build/Test Procedure**

The build procedure involved cutting and drilling holes through metal and then assembling the parts using a strong adhesive.

- **Results**

Too much time was allotted for cutting out the clamp parts out of the metal sheet. 7 days were used up in this process. After cutting out the parts, it was determined that it would be better to just 3D print the small pieces instead.

- **Recommendations**

Use different materials to build a prototype that would be appropriate given the tools, such as wood instead of metal. Spending more time analyzing the build plan and questioning the challenges that might be encountered would have helped save time through trial and error.

### **Do the results reflect a problem with the design of the prototype?**

- **Test Procedure:**

Gluing the 3D pieces to the central handle.

- **Results:**

One piece of the design kept falling off. The design did not have enough surface area surrounding the central rod to have the glue stick.

- **Recommendations:**

Redesign the 3D-printed part that fell off to wrap around the rod, similar to how the handle was attached to the central rod.

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## **Conclusion**

This design solution is an iterative procedure as it implements the process of trial and error. Putting parts together, analyzing the combination, and taking it apart just to rearrange it is an inherent part of any successful product on the market. Evaluating test results pinpoints exactly where the error in the building or testing process occurred and allows for a faster and easier rebuilding process.

Element I documents the full building and testing process. Furthermore, it includes the analysis of what and where an error occurred, and the reasons explaining how and why it was able to be improved upon.