Adaptive Eating Device

A Senior Project

Presented to

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California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Mechanical, Biomedical, and General Engineering; Bachelor of Science

by

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Executive Summary

The following document details a project that challenged students of different disciplines to create and design an adaptive eating device for the esteemed Nepalese writer, Jhamak Kumari Ghimire. Ghimire was born with a severe case of cerebral palsy. Growing up in a small village in Nepal, she taught herself to write and do things on her own despite her circumstances. She recently rose to fame when she became the second woman to receive the Madan Puraskar, Nepal’s most prestigious literary award, in 2011. The project is sponsored by Dr. James Widmann of the Cal Poly Mechanical Engineering Department. The need was discovered during his term as a Fulbright Scholar at Kathmandu University.

The team began by conducting background research relating to Jhamak Ghimire, the Nepalese culture, and adaptive eating devices currently on the market. Information specific to the client and her culture shaped many of the design requirements. The team was also introduced to its other half at Kathmandu that aided in recognizing cultural as well as overall mechanical design considerations of the device. After brainstorming, prototyping, and deliberation of conceptual designs between the teams at Cal Poly and Kathmandu, a final design was generated that included multiple parts from different top concepts.

The final design includes a revolving plate on which a push rod translates a portion of food across the plate surface and onto a spoon stationed at the plate edge. The spoon is then brought up to the user’s face by extension of rectangular telescoping sections. After consuming the spoonful of food, the sections are able to collapse into each other bringing the spoon back to its starting position at the edge of the plate. The design was broken down into subcomponents and each team member focused their responsibility for pursuing manufacturing, assembly, and making changes for one portion of the design. Many notable design changes were made during the manufacturing and testing processes; further details can be found in the following document. Presentation of the design at the end of the year found that the end product would not be ready for shipment to Nepal and further testing with the client.

Overall, the project was a learning experience that provided development in better understanding the design processing and working in multidisciplinary and multicultural groups. Recommendations on the design and manufacturing are added for possible future versions of the device. Specifics of concept development, design, analysis, and manufacturing can be found in the body of this report. The document also describes project management and costs followed during execution of the project.
Chapter 1: Introduction

This interdisciplinary project was a continuation of a project in Nepal for designing an adaptive eating device for the famous Nepalese writer Jhamak Kumari Ghimire. Jhamak Ghimire was born with cerebral palsy, and she is famous for the physical hardships she has overcome to be the inspirational writer she is today.

Jhamak Ghimire writes for the Kantipur newspaper in Nepal. Her works include four poems as well as multiple short stories. Most recently, she was awarded the Madan Puraskar for her autobiography, Jeevan Kaanda Ki Phul (Life is Thorn or a Flower). A copy was translated into English last year.

Jhamak is notable for writing solely with her left foot. Her case of cerebral palsy has inhibited her ability to speak and her hands remain clenched at most times. She has also had to struggle with the negative effects from her community due to her disability. The need for an adaptive eating device was discovered last year by a group of students at Kathmandu University, but the design was not finished due to time constraints.

Problem Statement/Definition: The purpose of the project was to create a device specifically for Jhamak Ghimire to aid with her physical and cognitive limitations associated with eating independently.

Looking more deeply into this problem statement, the team was able to divide this into two main customer specifications, which later was broken up even further. The first major specification is to reduce the strain in her neck that she feels as she traditionally bends over to eat food. At times this issue is fixed when she eats in her wheelchair and is fed by another family member. However, most individuals with disabilities strive to reduce their dependence on human assistance.

The second major specification that this project aimed to tackle was to instill independence when Jhamak eats, while still meeting the first specification. Meeting these common two goals would hit the basis of the goals, while additional specifications are outlined later in the report to improve the device further than simply basic needs. In order to work towards each of these specifications, it was first necessary to delegate responsibilities and break up tasks. Students at Cal Poly worked with three students at Kathmandu University, and together were able to work on not just the device but it’s mechanism for wheelchair attachment. The teams worked well together, and while new roles arose to fulfill, the division of tasks had been broken up into categories:

- Kevin was the team coordinator who was responsible for ensuring everyone was aware of the teams’ current progression and deadlines, and did what was necessary to complete milestones at the expected time. He also acted as the “team player” role in the aspect that he was readily available to help wherever needed.

- Jillian was in charge of documentation from the team’s regular meetings and was responsible for maintaining an official history of meeting minutes that was readily
available to the rest of the team afterwards in an organized and helpful manner. Also, when appropriate Jillian took pictures of team collaboration to record progression of the project.

- Patrick was responsible for preparing and bringing communication tools for video conferencing with the Nepalese teammates. He also took photos throughout the project in order to officially record specific milestones.

- Jeremy acted as the liaison responsible for setting up video conferencing with the Nepalese teammates. Also, he was in charge of being our Google Webmaster and dealing with calendar issues as well as creating new GoogleDocs whenever necessary.

- Bibhu, Dipendra, and Suk Raj, from Kathmandu University were responsible for attending scheduled video conferences and acted as the direct source of communication with Jhamak Ghimire and her representatives.

While our team had no major issues, we felt it was important to implement a conflict resolution in case controversy ensued sometime in the future. Our conflict resolution was as follows:

*If a minimum of two individuals in the group felt a sense of tension or uneasiness developing within an aspect of the group, a mandatory team dinner would be implemented in order to have an open and direct conversation addressing the issues and resolving the conflict. If this option did not suffice, attention on the manner would be addressed in the weekly meeting with the project advisor, Professor Widmann.*

Throughout this project milestones were reached, several of them on track with other slightly delayed with recovery plans. Overall positive progression and sequential steps were taken that moved the team towards creating a final product.

*Table 1 List of Milestones for Project Progression*

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone Reached</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/22/12</td>
<td>Cal Poly group formed</td>
</tr>
<tr>
<td>10/9/12</td>
<td>Initial video conference with Nepal students</td>
</tr>
<tr>
<td>10/11/12</td>
<td>Team contract written and signed</td>
</tr>
<tr>
<td>10/15/12</td>
<td>Project requirements document to sponsor</td>
</tr>
<tr>
<td>10/29/12</td>
<td>Conceptual model presentation</td>
</tr>
<tr>
<td>11/29/12</td>
<td>Conceptual design report and presentation reviewed with sponsor</td>
</tr>
<tr>
<td>1/29/13</td>
<td>Critical design presentation</td>
</tr>
<tr>
<td>2/8/13</td>
<td>Critical design report</td>
</tr>
<tr>
<td>3/26/2013</td>
<td>All Components Purchased</td>
</tr>
<tr>
<td>5/10/2013</td>
<td>Device Assembled</td>
</tr>
<tr>
<td>5/25/2013</td>
<td>Finish any Redesign and Testing</td>
</tr>
<tr>
<td>5/30/2013</td>
<td>Senior Project Expo Presentation</td>
</tr>
</tbody>
</table>
Chapter 2: Background

Jhamak Ghimire and Nepal

Jhamak Ghimire was born with a severe case of cerebral palsy, which greatly affects her speech and control of her arms. Cerebral palsy affects one’s motor control skills and has a major impact on the neural relationship between the brain and corresponding body parts. Jhamak has no control of her hands or arms and also has limited function of her mouth. While in Nepal, Dr. Widmann attended a public event for Jhamak Ghimire. He noted that she answered all questions with written answers, and at times she was drooling and someone assisting had to wipe her mouth. She seems to have very limited motor control of her mouth, but is still able to make sounds.

Although most articles state that she has no control of her arms, she is able to “crawl.” It is assumed that she has some control in her shoulders. Dr. Widmann also noted that Jhamak often needs to place items in her clenched hands to stop her from digging her nails into her hands.

Jhamak cannot walk freely, and needs assistance in many daily tasks. Her family has a “Didi” to care for her, a nanny common in most Nepalese families. It has been noted in many articles that she writes with her left foot. It is uncertain how well she is able to control her right foot or any of her other lower extremities. Earlier this year, Jhamak acquired a Sunrise Medical Quickee wheelchair, which she controls by joystick controller with her left foot as seen in “Jhamak on the Move.”

![Image of Jhamak's wheelchair](http://www.youtube.com/watch?v=UcVw7q9Cj7g)

**Figure 1 Jhamak’s wheelchair: Quickie Salsa Powerchair**

In the past, Jhamak has been observed and photographed sitting on the floor when she takes her meals. Her back is bent down towards the plate on the floor, and her feet lift the food a short distance from the plate to her mouth. Her ankles remain on the ground. She has mentioned the

1 http://www.youtube.com/watch?v=UcVw7q9Cj7g
pain in her neck from eating in this position. It is not known how she takes her meals now, but it is presumed that acquiring a wheelchair may have changed her eating position.

The most commonly eaten dish in Nepal is Dal Bhat, rice with spiced lentils. Dal Bhat is usually eaten with hands. The hands separate the rice and lentils into chunks. Other foods eaten with Dal Bhat are Takari (vegetable with curry), Masu (meat), and pickles and sauce (Achar). Another commonly eaten dish is Aloo Tama (bamboo shoot and potatoes). Some common snacks are breads and roti, beaten rice, Momo (meat-filled dumplings), Dahi (yogurt/curd), egg noodles, and Chatamari (similar to a pizza). Most foods seem to have a sticky or curry-like consistency.

**Past Adaptive Eating Devices**

*The Cal Poly Project and the Kathmandu Project*

Previous Cal Poly and Kathmandu students have made headway on projects relatable to this current project. First, Cal Poly’s recent project, known as the Dining Assistant, was completed with the aim to assist people with physical and/or cognitive disabilities, sponsored by the Vocational Training Center Enterprises. The user utilizes a trigger, which moves an arm to scoop food from a rotating bowl and then extend it to the user, providing movement in the vertical and horizontal directions.

Secondly, the previous Katmandu project was the first attempt at our current purpose, to help Ms. Jhamak Ghimire with her eating disability. The project reached a rough prototype, which consisted of a three bar mechanical linkage lifting food out of a mixer to the user. Other technical aspects of the projects were not reached, however there was much work done determining the needs of the customer and the engineering requirements.

*The Magpie*

The Magpie is a foot-controlled feeding device designed for the Nuffield Orthopedic Center in Oxford England. It has been mentioned and referenced in many articles, but there is little information available to the public.

The Magpie is operated by ankle, knee, and thigh movements. The arm of the machine that holds the feeding utensil has four degrees of freedom. The machine is used while in a seated position and involves a system of cables and pulleys that allow the parts of the leg to control the machine arm.

*MySpoon*

MySpoon is currently the most widely advertised and used product existing as an adaptive eating device. The device is compatible with almost all types of food, and allows the user the ability to pick a specific food compartment to have grasped and brought directly to their mouth.
The device has two primary operating modes: manual or fully automatic. The manual mode is for users who have more control of their muscles and can control a hand-operated joystick to control the arm. The fully automatic mode would be much more practical for Jhamak Ghimire in the sense that the device will feed the user autonomously. This mode however requires a much more complex electronic system, which will also limit the independence associated with eating.

MySpoon uses a comfortable spoon that is not too rigid, which uses a smooth scooping action to obtain the food. The device employs smooth motions, is quiet, and offers support with a great variety of food. However, the estimated cost of MySpoon is $3,500, which is quite expensive.

![Figure 2 MySpoon Adaptive Eating Device](image)

**Mealtime Partner**

The Mealtime Partner is another commercial adaptive eating device commonly used by the public today. Advantages of the device include: user independence, the ability to select specific foods, control of eating pace, as well as reliable operation. One element that correlates to user independence is the user’s ability to control the amount of food on the spoon.

This device has a complex electronic system, which utilizes computer controls to dictate the mechanical portion of the system. The device uses a clamping system to attach to either a table or tray, which is important to note because this means the device is mobile. The clamp is a safe and effective way to stabilize the device and support the attached adjustable arm.

The device uses a single lever to offer unlimited adjustments and locks. One specific safety aspect noted from this design is that if the user accidentally pushes or falls forward on the device, the Mealtime Partner will simply rotate away and prevent damage to the device. The associated cost is around $8,000.
Telethesis

Like people without physical disabilities, people with physical disabilities want to feel empowered and independent. They are encouraged to take responsibility of themselves. New technology allows someone with physical disabilities to take advantage of the limbs that they can still control. A telethesis is a device that is coupled to the user and acts as an extension of the user. It allows users to creatively control movement in an independent way. In this way, they receive exteroceptive feedback that resulted from their movement. It works more as an extension of the user which provides greater control for the user. There is full position awareness of natural body movements. Machines are passive and powered by the user, although many still contain power-assist mechanisms.

Adaptive Seating Devices

A study done on children (between the ages of 1 to 18) with physical and/or mental disabilities has concluded that the use of adaptive seating devices improves eating and drinking. Positioning is an important consideration. the device helps stabilize the individual in an optimum position-symmetrical alignment of the head and trunk, head and truck support, hip stabilization, etc. Researchers found that in this position, users were able to better retain food and liquid in the mouth, and there was an overall positive change in self-feeding behavior.

Spoon Designs
A challenge to design spoons for a wide array of users was headed by Professor B. K. Chakravarthy at ITT Bombay. In this challenge, designers focused on certain target groups and placed the focus of their concepts on the user (disregarding factors such as manufacturing to an extent). This user-centered design approach can help spark design ideas, which focus most on ergonomics and functionality.

![Figure 4 Two baby products on the market.](image)

(a) Baby spoon from product Chicco\(^1\) (b) Baby spoon from Terraillon\(^2\)

The two preceding photos picture two designs for baby spoons. Both are designed for baby meals, which have a consistency similar to curried lentils and rice. Both products are also designed to be safe and gentle for the user. The spoon from Chicco has a relatively small head so that it is able to fit into a baby’s mouth at different angles depending on how the baby handles the spoon. The silicone plastic material is also soft and elastic to provide minimal harm to the user if the spoon misses the mouth. The spoon from Terraillon is designed in such a way that food will stay in the bowl section of the spoon. The handle region is designed so that if food were to get on it, the food would just slide towards the bowl section.

**Functional Requirements/Specifications**

The eating device will be interacting with solid and liquid foods requiring it to both comply with OSHA standards as well as be water resistant. The interaction between human and machine requires both precision and accuracy in order to provide efficient food delivery and safe predictable human interaction with the device. The ease of use for the user and support staff is essential in order for the product to be continued to be used. Durability has similar importance, if the device constantly needs repairs it will be left behind. These requirements need to be met in order for this product to be successful as intended.


\(^2\)http://www.terraillon.com/produit_babycare-feeding-baby-spoon-for-baby_218.html
<table>
<thead>
<tr>
<th>Spec #</th>
<th>Parameter Description</th>
<th>Requirement or Target (units)</th>
<th>Tolerance</th>
<th>Risk</th>
<th>Compliance</th>
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<td>2 minutes</td>
<td>±30 seconds</td>
<td>M</td>
<td>T, I</td>
</tr>
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<td>Weight</td>
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<td>Max</td>
<td>H</td>
<td>T, I, A</td>
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<tr>
<td>3</td>
<td>Size</td>
<td>Tray 30cm x 40cm x 12cm</td>
<td>±5 inches</td>
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<td>T, I, A</td>
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<td>4</td>
<td>Durable</td>
<td>Withstand drops of 3 ft</td>
<td>Min</td>
<td>M</td>
<td>T</td>
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<td>5</td>
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<td>Min</td>
<td>H</td>
<td>T, I, A</td>
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<td>A</td>
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<td>M</td>
<td>T</td>
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<td>4 hours</td>
<td>Min</td>
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<td>A, T</td>
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<td>Life Cycle</td>
<td>10 years</td>
<td>Min</td>
<td>M</td>
<td>A</td>
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<td>10</td>
<td>Precision</td>
<td>Consistent placement</td>
<td>±.5 inches</td>
<td>H</td>
<td>T, A</td>
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<tr>
<td>11</td>
<td>Accuracy</td>
<td>Gets target food</td>
<td>±.5 inches</td>
<td>H</td>
<td>T, A</td>
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<td>12</td>
<td>Collapsible</td>
<td>Collapses into 40cm30cm30cm</td>
<td>± 5cm</td>
<td>H</td>
<td>T, A, I</td>
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<td>13</td>
<td>Nepal Social Acceptance</td>
<td>100% Social Acceptance from Students</td>
<td>Min</td>
<td>H</td>
<td>A, S</td>
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<tr>
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<td>Power Cap.</td>
<td>240V</td>
<td>Max</td>
<td>M</td>
<td>A, S</td>
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<td>15</td>
<td>Locally Acces. Parts</td>
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<td>± 25%</td>
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<td>16</td>
<td>Exchangeable Spoons</td>
<td>3 Spoons</td>
<td>±1 Spoon</td>
<td>L</td>
<td>A</td>
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<tr>
<td>17</td>
<td>Minimal Cracks Near Food Delivery</td>
<td>0 cm</td>
<td>± 3 cm</td>
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<td>A</td>
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<td>Max</td>
<td>H</td>
<td>T, A, I, S</td>
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<td>Guards to Block Food Fall-age</td>
<td>1 Guard</td>
<td>Min</td>
<td>M</td>
<td>T, I</td>
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<td>Food to Mouth Height</td>
<td>0 cm</td>
<td>± 3 cm</td>
<td>H</td>
<td>T, A, I</td>
</tr>
<tr>
<td>22</td>
<td>Horizontal Spoon Distance to Mouth</td>
<td>0 cm</td>
<td>±3 cm</td>
<td>H</td>
<td>T, A, I</td>
</tr>
<tr>
<td>23</td>
<td>Compacted Height (Assembled)</td>
<td>50 cm</td>
<td>± 10 cm</td>
<td>L</td>
<td>T, A, I, S</td>
</tr>
<tr>
<td></td>
<td>Food/scoop</td>
<td>2 oz</td>
<td>+/- 0.5 oz</td>
<td>H</td>
<td>T, A, I, S</td>
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<td>------</td>
<td>------------</td>
<td>---</td>
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<td>24</td>
<td>Food Fall-age</td>
<td>10.00%</td>
<td>MAX</td>
<td>H</td>
<td>T, A, I, S</td>
</tr>
<tr>
<td>25</td>
<td>Delivery Time</td>
<td>8 sec</td>
<td>+/- 4 sec</td>
<td>M</td>
<td>T, A, I, S</td>
</tr>
<tr>
<td>26</td>
<td>Meal Time</td>
<td>10 min</td>
<td>+/- 1 min</td>
<td>M</td>
<td>T, A, I, S</td>
</tr>
</tbody>
</table>

Analysis (A), Test (T), Similarity to Existing Designs (S), Inspection (I)
Chapter 3: Design Development

Below are the top seven designs presented to the students in Nepal for feedback and further review.

Concept A (Magic Wand)

This concept allows Jhamak the ability to choose each bite she wishes to eat. With her left foot she scoops with her own utensil the appropriate bite and then transfers it to the customized spoon attached to the device. Her right foot hits a button, which triggers the “power antenna” motor. This mechanism elevates the spoon on a small box to Jhamak’s mouth level. The box on which the spoon is attached houses a rechargeable battery as well as a small motor which is programmed to rotate the spoon 90° towards Jhamak’s face. The spoon is then extended again by another power antenna the appropriate amount to reach Jhamak’s mouth. The “power antenna” mechanism can be viewed here: http://www.youtube.com/watch?v=ORKKbsbyC7U
Concept B (Mealtime’s Brother)

**Figure 6 Concept B (Mealtime’s Brother) Design**

This concept uses a single button input to activate the system to rotate the bowl, scoop a bite of food, and then extend to Jhamak’s mouth. A microcontroller (Arduino board) would be used to trigger the motor controlling the rotation of the bowl as well as the servo motor responsible for scooping and extending the spoonful to Jhamak. The stopper on the top of the bowl is used to effectively scoop an appropriate spoonful that is not too large. This idea was influenced by this Youtube video (however, instead of 3 bowls, we would be using one):

http://www.youtube.com/watch?v=R27e_qzaOok
Concept C (Twisty Bowl)

This concept is called the “Twisty Bowl” and everything is based around the motion of a rotating bowl. With several different notches at different parts of the bowl, a mechanical arm that is attached to a fixed frame around the bowl moves the spoon to the user and back through torsional spring energy.

In the first drawing on the top right, the spoon lever is locked in its position because of a ledge, and as the bowl rotates, the spoon stays in this position, picking up food. When it reaches a notch, as shown in the small window on the middle right, the torsional energy is released, and the spring twists out of its position and, by the design of the spring lever, it moves to a predetermined spot where the user’s head is expected to be.

In the bottom right drawing, a bird’s eye view of the bowl, the spring has released its energy, and the spoon is facing the user. Now the spoon needs to return to the bowl. By pushing a button to rotate the bowl, a notch on the edge of the bowl catches the lever arm and twists the spoon lever and spring back into position. Energy used from the same bowl motor turning is used to twist the torsional spring. It is now in its locked position picking up food as the bowl rotates.
Concept D (Screwy Louie)

Figure 8 Concept D (Screwy Louie) Design
This concept has a collapsible tripod support system, which supports the box base. The box base houses a rechargeable battery, which is responsible for powering two motors and one servo. One motor would rotate the bowl, while one would allow the fixture holding the spoon to travel up and down the rod. The servo would be responsible for the scooping motion of the spoon. A microcontroller (Arduino board) would allow Jhamak to press a single button and begin the cycle: rotate the bowl, scoop a bite, and transport up the rod to her mouth level. The tripod support system can be adjusted to the desired height, so that the rod is placed directly near her mouth. The rod can be taken off of the device, so that it is not as “bulky” and mobility can be improved. We made a conceptual model of this device, as seen above to determine whether this idea was feasible.
Concept E (JLT)

The JLT relies only on physical input of the user; there are no motors or other power assist. This concept works by articulating the foot to control a specially-shaped “push bar” on the plate to move food towards the user’s mouth. The rod that the foot moves can be rotated and pushed backwards, forwards, and side to side. This allows for total range of motion on the plate. Pushing the rod forward and backward would move the “push bar” backwards and forwards, respectively, on the plate. Sideways action on the rod would move the pusher laterally on the plate. The twist allows the pusher to come in at an angle if the food needs to be directed more...
towards the center of the plate. This concept gives the user a sense of independence in the amount of control it offers them.

**Concept F (Sandbox Crane)**

This design is called the “Sandbox Crane” and utilizes the same idea of a crane in a children’s sandbox playground. This application can be seen here: [http://www.youtube.com/watch?v=_S_SPZ0oRrl&feature=related](http://www.youtube.com/watch?v=_S_SPZ0oRrl&feature=related)

A basic model is shown below using SolidWorks: In this first drawing, the only fixed point is the center, and the two bottom levers are attached to Jhamak’s feet. She would attach her feet to the foot holds depicted below. By moving her feet forward, backwards, and apart from each other, she has the ability to operate a “crane” shown at the top of the drawing (and labeled in the third picture).

![Fixed Point](image)

**Figure 11 Concept F (Sandbox Crane) Design**

In the position shown in the second drawing, the spoon scoops food out of the bowl/plate, so that now food is on the spoon. In order to get to this point, the user simply moves one food a tad
further back than the other foot. These incremental changes can be varied for optimal distance by just changing the lengths of the legs.

![Figure 12 Concept F (Sandbox Crane) positioned about bowl](image)

Lastly, the user moves the foot towards her face by slightly moving both legs towards herself, and watch the mechanism extend below. The spoon is now extended towards the user, ready to eat.
Furthermore, the spoon would “open” and “close” by a hydraulic tube running from the spoon, along the device, and two of the user’s legs. Jhamak would then close and open the spoon, by squeezing an air pouch or pushing on a syringe type device.

**Concept G (Cam-Driven Spoon)**
This conceptual design also focuses on physical input from the user and is purely mechanical (no battery or electrical input required). In this design, food is prepared by someone else and placed in a bowl next to a spoon guide. A weighted spoon placed in the bowl should align with the guide. When at rest, the spoon is just resting against the edge of the bowl, naturally positioned in such a way that the spoon will scoop food if moved forwards in the bowl.

The user would ideally use this device while sitting near a flat surface like a tray. In this position, the user can pedal using their feet to make the bottom gear rotate. This movement is translated to the top gear which is affixed to a large cam. The cam will push the spoon forward, and the spoon will be guided upwards to the user’s mouth. When the cam and spoon end do not make contact, the spoon will simply fall back into the bowl due to gravity. In this way, the user can choose his/her pace of eating and the direction of the spoon path (if the scoop of food is not at the desired amount).

This design is to be manufactured from wood with exception of the two gears and the chain.

After obtaining feedback from our teammates in Nepal, they had a design of their own, as well as a modification to one of our concepts. (Seen below)
Concept F (Head Master)

![Figure 15 Concept G (Head Master) Design](image)

The main part of the concept is the rotating head whose level is managed with the aid of lead screw rotation. There are two co-axial rotating motors; one for rotation of the head and other for the leadscrew rotation. The advantage of this mechanism is that it can be very precise. The head holds a connecting box, which holds spoon holder. Its degree of freedom is constrained with rotation only. Like our other mechanism, it has rotating plate.
Concept A (Magic Wand) Modification

Figure 16 Concept A Modified with Gramophone

The teammates in Nepal refer to this redesign as the Gramophone. It utilizes the power antenna mechanism originally thought of, but instead of a bowl aims towards a plate. A plate is a much more accepted eating apparatus and with the assistance of the push bar applied here, it would easier to obtain food. The push bar increases the precision of the system and allows us to accumulate all the food material in the plate.
There were two main conceptual designs, totally mechanical with no electric assist or automated with use of motors and servos. Input received from Arthur Yeager, Chief of Occupational Therapy at Reynolds Army Community Hospital therapist indicated that a mechanical system with no electronic assist would be preferable. With his background in physical therapy, the independence and instilling a sense of accomplishment is paramount. He stressed that people with disabilities should not be given any extra help than they need. Jhamak has mobility of her legs, the device should allow her to control it directly with them. This means no power assist if possible, giving her the greatest sense of independence as well as control and connectivity with the device. He feels automation will hinder her overall health because it removes her. This would allow for more independence and more of a feeling of accomplishment when using the device to feed herself. The input received from the Nepalese students was that they wanted to create an automated device. We used both of these two inputs to come up with better design criteria for the QFD and Design Matrix to better choose which concept to move forward with.

**Table 3 Decision Matrix**

<table>
<thead>
<tr>
<th>Customer Specs.</th>
<th>Weight</th>
<th>Concept A</th>
<th>Concept B</th>
<th>Concept C</th>
<th>Concept D</th>
<th>Concept E</th>
<th>Concept F</th>
<th>Concept G</th>
<th>Last Years’ Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy to Use</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Aesthetically Pleasing</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Mobile/Light Weight</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Easy to Clean</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Safe</td>
<td>3</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>A</td>
</tr>
<tr>
<td>Quiet</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
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<tr>
<td>Socially Acceptable</td>
<td>4</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Instils Independence</td>
<td>1</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>Food Acceptability</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>5</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Low Maintenance</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Efficient Food Delivery</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>Secure</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Σ (*Weight)</td>
<td></td>
<td>1.89</td>
<td>0.65</td>
<td>0.18</td>
<td>0.99</td>
<td>1.26</td>
<td>1.32</td>
<td>0.68</td>
<td>M</td>
</tr>
</tbody>
</table>

**Table 4 Pros and Cons of Concepts**

<table>
<thead>
<tr>
<th>Concept A (Magic Wand)</th>
<th>PROS</th>
<th>CONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lightweight she chooses exactly what she’s eating power antenna is interesting</td>
<td>Reliability of the power antenna (potential to twist, potential for food to fall off) Structurally sound? Regulating speed?</td>
</tr>
<tr>
<td>Concept B (Mealtime’s Brother)</td>
<td>Stopper is good at compacting bites, compacted food TWICE simple</td>
<td>Potentially not safe</td>
</tr>
<tr>
<td>Concept C (Twisty Bowl)</td>
<td>Simple</td>
<td>Concerned about picking up food without picking up from the same spot each time</td>
</tr>
<tr>
<td>Concept D (Screwy Louie)</td>
<td>Collapsible Interesting technology Variable speed</td>
<td></td>
</tr>
<tr>
<td>Concept E (JLT)</td>
<td>No big bulky battery Intuitive, can eat at her own pace, instills independence</td>
<td>Awkwardly large (not collapsible/mobile) “eating off a trough”</td>
</tr>
<tr>
<td>Concept F (Sandbox Crane)</td>
<td>Intuitive, instill independence Controls her own speed Good range of motion Could articulate a hand/spoon</td>
<td>Awkwardly large</td>
</tr>
<tr>
<td>Concept G (Cam-Driven Spoon)</td>
<td>Pedaling is fun variable speed</td>
<td>Pedal is not collapsible Huge cam rotating in front of her face while she’s eating</td>
</tr>
</tbody>
</table>

The team in Nepal believed that “the electronically supported ones [designs] have higher benefit than the mechanised ones.” Below is a table listing the three most appealing designs chosen by the team in Nepal from concept generation.

### Table 5 Feedback from Nepalese Teammates

<table>
<thead>
<tr>
<th>Concept Design</th>
<th>Appealing Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandbox Crane (Automated)</td>
<td>Best suited to the nature of Nepali food</td>
</tr>
<tr>
<td>Mealtime Brother</td>
<td>Looks compact and most effective</td>
</tr>
<tr>
<td>Screwy Louie</td>
<td>Variable height is an advantage</td>
</tr>
</tbody>
</table>

After further discussion taking into account the feedback from Nepal, the top three designs/features were chosen.

### Table 6 Appealing Features from Top Designs

<table>
<thead>
<tr>
<th>Concept Design</th>
<th>Appealing Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magic Wand</td>
<td>Power antenna, ability to choose bite portion size</td>
</tr>
<tr>
<td>Screwy Louie</td>
<td>Variable height, collapsible (more portable)</td>
</tr>
<tr>
<td>Sandbox Crane</td>
<td>“Spoon” design was closest to the more natural way to eat Nepali food, range of motion</td>
</tr>
</tbody>
</table>

Below is the first quick sketch of most of the appealing features put together.
The sketch most resembles Screwy Louie in that there is a rotating bowl mounted on a tray base. The base has a screw-in attachment for collapsible tripod legs to give variability in height of the overall mechanism when in use. Instead of the threaded rod in Screwy Louie, this sketch utilizes the power antenna mechanism from the Magic Wand idea. Some thought was put into creating a new spoon design similar to that in the Sandbox Crane.

Seen below is a SolidWorks drawing of this system composed of highlighted features of our favorite designs.
Taking into account several critical concerns from the Nepalese teammates, several changes have been implemented to this design. The first major concern dealt with the bowl. It is customary and much more widely accepted to use plates as opposed to bowls in Nepal. We will be taking the modified design that the Nepalese teammates submitted (Gramophone) and integrate it into this system. The bowl will be replaced with a plate utilizing a push rod to assist the spoon with accumulating an appropriate bite of food.

The second important issue addressed after talking to the Nepalese teammates involved eliminating the tripod. It has been confirmed that Jhamak Ghimire will only be using this adaptive eating device while in her wheelchair. A bracket attached to her wheelchair will support a tray in front of her, which will be the surface for our device. Therefore the bottom of our base will rest on top of the tray directly in front of her. The attachment bracket can be seen below.
After settling on the current design with several modifications, the plan was for the Cal Poly team to continue prototyping and begin manufacturing the final adaptive eating device. The Screwy Louie prototype was further expanded in order to determine feasibility and help the team predict any future problems that may exist during fabrication of the final device. Our proof-of-concept model demonstrated the necessity of utilizing a pushrod when a plate was mandated as a permanent replacement for our initial bowl idea. We were also able to optimize the geometry of the pushrod meeting the spoon as well as the necessary angle needed by the telescoping arm to reach Jhamak’s face. The Screwy Louie prototype was the framework of our final product and the testing on this prototype revealed how to successfully manufacture our slightly redesigned final device. The Nepalese team decided to focus more on the mechanical aspects associated with confirming the compatibility of the device with Jhamak’s new electric wheelchair.

Throughout the duration of this design process, many lessons were learned when overcoming obstacles in order to reach milestones. The first major milestone was making lots of quick prototypes in class in order to further stimulate ideas for potential systems. This activity allowed the team to have a better understanding of what kind of motion we wanted to use. A next major step was when the team compiled a list of seven promising ideas and placed them in the decision matrix to narrow down our designs. The team collectively weighed criteria judging each design and ruled out several ideas. With the input of the Nepalese students, another major decision made was to change our designs to incorporate a plate instead of a bowl. This was an obstacle because the Screwy Louie design we were pursuing seemed to be dysfunctional without a bowl. The team had to redesign quickly and decided to integrate a pushrod into the system in order to successfully deliver food to the spoon. During the design process it was learned that changes often need to be made unexpectedly and as engineers we are forced to find a solution and redesign quickly to meet the requirements.
Chapter 4: Description of the Final Design

Overview of Final Design

The final design is focused on a rotating plate that will allow foods similar to Dal Bhat (rice and curried lentils) to be loaded onto a spoon and efficiently delivered to the user’s mouth. The final design is a combination of the top conceptual designs that incorporates the use of a plate from the gramophone concept idea. In the final design, the base measures 30cm (length) by 35cm (width) and can be placed on a table or attached to the user’s wheelchair by a connecting bracket designed by the team in Nepal. The base is closed on all sides and houses all electrical components with the exception of the battery charger and button which are usually disconnected for storage. In operation, the base is situated like a feeding tray in front of the user. The Lazy Susan component sits on the top panel of the base, and its rotation is powered by a servo fastened and enclosed inside the base. In one feeding sequence, the Lazy Susan and the plate sitting on top of it will turn 22° for one spoonful of food.

A portion of food is pushed from the center of the plate to the edge of the plate in a curved path by the push rod. The push rod performs this motion because it is attached to a servo situated to the left of the plate. The pushing end of the push rod should always be positioned in the center of the plate and Lazy Susan when at rest. Its movement is the most predetermined, and it only travels to meet the open spoon face before retracting to its rest position.

The open spoon face usually waits at the edge of the plate to receive food. After the anticipated act, the “power antenna” motor and worm gear work to unwind a cable that will push telescoping segments outward and forward. This generates the extending of the antenna and spoon towards the user’s mouth. The motor is controlled in the code by the time expected for the arm to reach the top of its destination. After consuming the food on the spoon, the user pushes the button to finish the second half of one feeding sequence. On the push of the button, the motor will move in reverse to wind the cable back into the motor casing. The antenna then collapses to the start position with the device awaiting the signal for the next feeding sequence. The collapsed antenna and its motor and worm gear are housed in the aptly named “motor housing” (because it houses the only motor that is not a servo in the whole device). The motor housing is a red box attached to the side of the base, and it aids in keeping electrical components from being exposed or possibly harming the user.
The Base

The base is the unit responsible for housing most of the components of our system and the medium for integration of the different subsystems. The most important mechanical feature of the base is that it is able to support the weight placed on both the top surface of the frame as well as the weight placed on the bottom panel distributed from the various mechanical and electrical components. The structure of the base consists of a rectangular box frame with different diameter holes on specific panels for subsystems to interface with.

The image below shows the frontal view of the base design. Dimensioned at 35cm x 30cm x 12cm, the box is optimized to be as compact as possible to support the plate and operate effectively. The small hole on the bottom left of the topside is where the push rod connects to the servo motor directly beneath. The four indentations are encompassed within the 15cm “Lazy Susan” and will match up with the four extrusions on the bottom of the plate and to help secure a connection. The small cut directly in the center will bridge the connection from the “Lazy Susan” rotation piece to the stepper motor located directly below. The final hole seen in the picture below on the distal right side is necessary to interface the frame with the power antenna. A rod will secure the connection from the power antenna to its motor housed internally in the back right corner.
The picture below shows the rear view of the base and the associated holes and buttons needed. Considering human factors engineering, the power button represented by the circular extrusion on the back here is placed in the rear to make it more accessible by Jhamak’s foundation and assistants who will be helping her use the device. Right next to the power button are two small holes where LEDs will display the status of the power as well as the status of the battery charging. The rectangular cut on the right side represents where the charging cord will connect from an outlet to the battery housed in that corner of the base. The small hole seen on the right of the picture seen below is where a wire will be fed through to connect to the single button unit, which Jhamak will control with her left foot.

The material used to manufacture the base is polycarbonate. Polycarbonate is a relatively cheap, durable, high-impact resistant material, which is an excellent electrical inductor. This material is suitable for housing most of our electrical and mechanical devices, and it will also be resistant to any strong forces it may unintentionally be subject to. Analyzing the cost breakdown associated with the base, the primary cost revolves around purchasing a sheet of polycarbonate. Our total
surface area is 3660cm with 5mm thickness, which equates to a total price of approximately $100.00.

The bottom panel of the base is designed to open up if repair is needed. Screws and brackets attach the main part of the frame: the top with the four side panels, to the bottom individual side. This design will be accommodating for any future necessary repair that may be needed inside the base.

**Electrical Components**

The image below shows everything that will be housed internally within the base:

A. Power antenna motor
B. Arduino UNO board
C. Battery
D. Stepper motor for plate
E. Servo for push rod

![Figure 23 Exploded View of Internal Housing](image)

By having the battery and the power antenna on opposite sides, it will help localize the center of gravity and reduce one side being much heavier than the other. In regards to the weight distribution front to back, the back will be heavier, but the push rod and the servo motor controlling the push rod will help center eliminate any weight issues there. Not seen in the
picture above, there will also be a fair amount of wiring, which we will bundle and tape down with electrical tape to minimize any chance of tangling or possible failure.

**The Arduino Uno**

The brain of the operations is an Arduino UNO microprocessor board combined with a motor shield to power the motors and servos. The Arduino board was chosen because of its large programming capabilities as well as its ease of use. The motor shield receives the commands from the Arduino board and acts as the switch that turns the motors and servos on and off. The system is controlled by one push button that will serve as the only user interface. It will allow the user to cycle the system with one push of the button or rotate the plate while button is held down. This will enable the user to rotate the plate until the desired food is in position to be pushed by the push rod onto the spoon.

![Arduino Uno and motor shield](image)

*Figure 24 The Arduino Uno and motor shield*

The battery chosen for this system is a 2200mAh hour battery allowing the system approximately 18 meals in between charges. These charges should take approximately an hour and a half and will have to be performed every six days with the assumption that each day Jhamak will be eating three meals. This is an important consideration in case there is a power outage for a number of days or for travelling for an extended period without access to a power supply. The charger for the battery was selected because of its smart capabilities allowing it to charge the battery until full and then stop charging. This will greatly reduce the chances of battery damage during charging and also greatly decrease charge times. The charger also has a temperature sensor for the battery pack which can help prevent damage if it senses the batteries are getting too hot during charging by stopping the charge.
The push button is foot operated and either on or off. The button has been selected because of its robustness and specifically because it is designed to interface with feet. It also provides a solid base because it is made of metal and has a simple moment arm to activate the switch. Its standard 1/8\textsuperscript{th} inch mono jack will make it easy to attach and detach from the base for transport or disassembly.

![Image of a 12-volt battery pack and the Smart Charger]

**Figure 25 12-volt battery pack and the Smart Charger**

![Image of a foot pedal for user input]

**Figure 26 Foot pedal for user input**

*Flow Chart of one Cycle*

- **Antenna Retracts**
- **Antenna Extends**
- **Spoon Rotates Horizontally**
- **Spoon Rotates Vertically**
- **Plate Rotates**
- **Push Rod Rotates**

![Flow Chart of Operating Mechanism]

**Figure 27 Flow Chart of Operating Mechanism**
Details of Cycle

1. Antenna Retracts completely
2. Spoon rotates approximately 55° to from horizontal towards center of plate
3. Plate rotates approximately 20° to new position
4. Push rod rotates from center of plate to spoon and back to center. Rotation from center to spoon is approximately 55°.
5. Spoon rotates back to horizontal.
6. Antenna fully extends to eating position.

The Power Antenna

Taken from the vision of elevating the tip of a radio antenna smoothly and effortlessly into the air, this idea has morphed into the mechanism that will transport the food from the plate to Jhamak. The idea of sections of slightly different cross sectional dimensions expanding from another is a key feature of the design, and possible methods for expanding those sections relative to each other were considered.

The final design most closely resembles the technology used in the Magic Wand concept idea. The telescoping mechanism, of which in the entirety of this report is referred to as the 'Power Antenna' or 'the antenna,' consists of three main segments run by a motor connected to a worm gear encased in the “motor housing.” The subsystem is shown in its collapsed position in the figure below.

Figure 28 Collapsed power antenna with spoon.
When fully extended, the antenna should go from 20cm to 60cm in length. For the spoon to reach the predicted location of Jhamak’s mouth, the motor housing is oriented at $51^\circ$ against the side of the base.

**The Power Train**

Here, the input of the antenna is a shaft powered by a motor, and the output is the motion of the spoon to the user and back. The motor turns a single tooth worm gear, which in turn spins a 50 tooth gear that is seated on an orthogonal shaft. The internal power train can be seen below.

![Internal Power Train of the Power Antenna](image)

*Figure 29 Internal Power Train of the Power Antenna*

The 50 tooth gear transmits power to a similar elevated gear meant to mesh with a teflon rack that controls the extension of the antenna. Setting the appropriate gear ratio and choosing the right motor determines the speed at which the food is brought towards the user and returns back. When contracting, the rack coils itself in a cylindrical housing as seen below. Plastic inserts within the cylinder are used to insure the rack maintains contact with the top spur gear.
Several of the parts, including the worm gear, both spur gears, the cylindrical rack housing and the teflon rack will be used from an off the shelf power antenna. The structure that the power train is mounted on is housed within a die-cast aluminum box that can be purchased from a large manufacturer in the U.S. Bearings, of which hold the rotating shafts, are attached to the box by bearing flanges bolted into the sides and bottom of the box. The steel square posts, or antenna sections, having outer square widths of 10, 12, and 15mm respectively, can be purchased online with roughly a millimeter clearance.

Deflection of the Antenna at its Extended Length

This clearance, in combination with the load put at the end of the cantilevered beam and the moment caused by the cantilevered spoon, causes deflection from the anticipated final location of the food. By making several assumptions, such an analysis problem can be modeled as an overhanging load with simple supports, whereas an estimation can be made on the overall deflection. In the end, assuming a uniform cross section of the lowest moment of inertia and a horizontal arrangement, a deflection of 0.2 mm was calculated, and Appendix E lays out the analysis used in order the reach the result. Furthermore, in order to address the clearance between each of the sections, a similar solution used in collapsible canopies will be used, where plastic inserts are placed right at the merging of the two parts, of which reduces slope change to a comfortable level.

Spoon Controlled Micro-Servo

The other end of the power antenna controls the rotating motion of the spoon. A micro-servo motor with a moment bearing is connected to the end of the antenna, which turns a small shaft of which the handle of the spoon is connected to. The end of the spoon sits on a square post, and has the ability to move itself from the axis of rotation. This arrangement can be seen below.
By positioning the spoon off the axis of rotation, the spoon is allowed to perform more of a scooping arc motion, whereas when it lies on top of the axis of rotation it solely rotates. It must be noted that the figure shown lacks the moment bearing addition, which is an additional attachment of the servo motor.

The entire antenna unit is attached by two points on the side of the housing, positioned where the top of the antenna sits collinear with the back of the plate and the angle of the antenna can be changed by moving one of the two points that the antenna is attached by to a different notch.

**Attachment Pieces**

*The Modified Plate*
Figure 32 (a) Stainless steel lunch/dinner plate from the supply company www.indiamart.com. These plates are commonly used in Nepalese dining and come in a variety of sizes. (b) From left to right, top and bottom views of the modified plate.

A plate is used in the design because of its familiarity. Nepalese dishes are commonly served in a stainless steel plate like the one pictured above. The user currently uses a plate, and the design allows the user to feel more like her peers.

In this design, the plate will rotate 20° at each turn while a push bar pushes food onto a plate. The push bar is designed to have one movement along a pre-determined curvature, so the rotation of the plate controls the distribution of food for the duration of the meal.

Plates will be modified to be compatible with the mechanisms of the feeding device. A small hole is drilled into the center and four circular “feet” are added to the bottom of the steel plate. The center hole will be drilled 1.5 mm into the material, half the estimated thickness of the material, and will help center the plate on the Lazy Susan platform. The four “feet” will protrude from the bottom surface of the plate and fit into four corresponding holes on the “lazy Susan” platform so that the plate will rotate with the servo motor motion.

All plates should be easily obtainable in Nepal and online, and the proposed modifications are minimal. The center hole will have a diameter of 1 cm, and can be quickly manufactured in the machine shop. The four “feet” will be produced from a resin and spaced equally apart in a circular pattern about the center hole. Each “foot” is 2 cm in diameter with their center points 4 cm from the center hole.
The Push Rod

Figure 33 Isometric view of the SolidWorks CAD model for the push bar.

The push bar generated from the idea of the arm that holds the stylus on a gramophone. As the arm is able to guide the stylus over the surface of a record, this push bar is designed to guide a portion of food towards the edge of the plate where a spoon will be waiting for the food delivery.

Figure 34 Isometric view of the push bar with hidden lines shown.
The push bar is controlled by a servo at the cylindrical end. The connection at the cylindrical end will involve a square hole in the push bar. The square pin that matches this hole will be attached and oriented in the vertical direction (in the direction of the shaft) on the servo. This allows for easy and intuitive set up and disassembly. The removability also allows the part to be cleaned easily.

The push bar is made of a hard, food grade plastic ordered from McMaster-Carr. The push bar is comprised of familiar geometry and stocks of FDA food compliant plastics can be purchased in rectangular sheets and cylinder rods. The push rod is composed of three parts cut from the raw material, and parts are assembled by force fit or a food-safe adhesive. About 10-15 finished products will be made to ship to Nepal in spring. This will allow the user three days of meals without having to clean the device as well as 5 extra push bars in case of fracture or breakage because the product is not easily manufacture in Nepal.

The Spoon

The “spoon” utensil used with the device is a custom design. The spoon design focuses on aesthetics and ergonomics, and it attempts to deliver an adequate food portion to the user when the device is in use. The spoon is asymmetrical and has a curved shaped to create a pleasing design for the user in terms of look and mouthfeel. The curved shape gives the spoon a tolerance between its neck and the estimated 2 cm lip of the steel plate. The asymmetry allows the food to be better compacted into the bowl portion of the spoon (ellipse with major radius of 2 cm and minor radius of 1.5 cm) while still clearing the 2 cm lip.

The bowl portion of the spoon is modeled after a Chinese soup spoon which is deeper than a Western soup spoon and, therefore, capable to carry more food. The deeper bowl portion natural creates edges so that food is less likely to fall out when the spoon is in a horizontal position. This proved to be a significant aspect in testing of past designs, and it is even more important to consider in this design because of the long path from the plate to the user’s mouth. The spoon is not as wide as an Asian soup spoon and does not have a flat bottom so that it is able to fit in the user’s mouth.

Similar to the push bar, the spoon is designed with a square hole at the end connected to the servo motor. Again, this allows for easy and intuitive assembly and disassembly for cleaning.

Because of its unusual and asymmetric shape, the spoon is molded from a hard, food-grade plastic. About 10-15 finished spoons will be made to ship to Nepal in spring.

Safety Considerations
The nature of the usage of the device requires that many safety considerations be taken into account. Because the device will be used while dining, all surfaces expected to come into contact with food must be food-safe. The plate was obtained off the shelf, and all modifications were made to the underside of the plate away from food contact surfaces. The spoon was also an off-the-shelf component. The push rod was manufactured from a FDA-approved food grade material, and the resin adhesive was not exposed in areas of possible food contact. In addition to being food-safe, attachment pieces were light and durable so that they would not break easily or harm the user if they unexpectedly became detached.

There are many safety considerations regarding the extended arm because the subcomponent would be moving in close proximity to the user’s face. The extended arm itself is positioned to travel up and towards the right side of the user’s face with the spoon hanging like a cantilever beam situated in front of the mouth. In this way, the spoon is able to give way if it hit the user’s mouth too early. The device is also required to be lightweight and have limited pinch points to reduce potential harm to the user while in operation.

Cost Analysis

Throughout the project there was a financial budget of $1000 of which could go towards materials, off the shelf parts, and any needed manufacturing costs. Being a single device requiring small parts, many of the initial group project plans for purchasing components were altered when buying these components required the designer to buy in bulk and significantly increase the costs. In the end, at parts, the design was slightly changed to minimize those situations, and resulted in an overall initial design cost of $610.60, nearly 2/3’s of the overall budget.

Table 7 Initial Major Component Costs from Prototyped Design

<table>
<thead>
<tr>
<th>Component</th>
<th>Vendor</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servo to Shaft Couplers</td>
<td>RoboShop</td>
<td>36.74</td>
</tr>
<tr>
<td>Spoon</td>
<td>MV Trading Co.</td>
<td>0.30</td>
</tr>
<tr>
<td>Plate</td>
<td>MV Trading Co.</td>
<td>2.50</td>
</tr>
<tr>
<td>Low-Carbon Steel Rod</td>
<td>McMaster-Carr</td>
<td>14.56</td>
</tr>
<tr>
<td>ABS Shapes and Rod (Beige)</td>
<td>McMaster-Carr</td>
<td>40.97</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>Interstate Plastics</td>
<td>93.45</td>
</tr>
<tr>
<td>Metal Brackets</td>
<td>Home Depot</td>
<td>49.80</td>
</tr>
<tr>
<td>Square Aluminum Rods</td>
<td>Metals Depot</td>
<td>34.86</td>
</tr>
<tr>
<td>12V DC Gearmotor</td>
<td>Robot Marketplace</td>
<td>30.00</td>
</tr>
<tr>
<td>Nylon Webbing</td>
<td>Strapworks</td>
<td>9.43</td>
</tr>
<tr>
<td>Power Train Gears</td>
<td>Stock Drive Products</td>
<td>74.41</td>
</tr>
<tr>
<td>Misc. Telescoping Arm Hardware</td>
<td>Home Depot</td>
<td>51.58</td>
</tr>
<tr>
<td>Arduino Uno Board</td>
<td></td>
<td>50.00</td>
</tr>
<tr>
<td>Motor Shield</td>
<td></td>
<td>22.00</td>
</tr>
<tr>
<td>Rechargeable Battery</td>
<td></td>
<td>50.00</td>
</tr>
<tr>
<td>Battery Charger</td>
<td></td>
<td>50.00</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>610.60</strong></td>
</tr>
</tbody>
</table>
Furthermore, costs that were encountered over the extent of the project were not only derived from the initial costs developed through the critical design of the project, but also through additional costs in redesign during the manufacturing, assembling, and testing phases. The table below outlines such additional costs, pushing up the overall cost of the project.

Table 8 Additional Major Costs derived from Redesign

<table>
<thead>
<tr>
<th>Component</th>
<th>Vendor</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brushed DC Motor</td>
<td>Digi-Key</td>
<td>32.71</td>
</tr>
<tr>
<td>High Torque DC Motor</td>
<td>Hobby Headquarters</td>
<td>50.52</td>
</tr>
<tr>
<td>P-Train Gears (2nd Set)</td>
<td>Stock Drive Products</td>
<td>132.28</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>215.51</strong></td>
</tr>
</tbody>
</table>

These design changes are reflective in finding a new motor that spun at a higher RPM while having the same torque and fit all the existing constraints on the motor (discussed in Chapter 5 during design changes). Furthermore, an exponential increase in costs has been seen in the purchase of the two Stock Drive Product gears, with shipping alone being over 50% of the product costs.

Total project costs were the sum of the initial design costs, plus any additional redesign costs, and are shown in the table below. Because the team was able to minimize the initial costs, final costs had still remained nearly 15% below the financial budget.

Table 9 Total Project Costs Encompassing Initial and Redesign Costs

<table>
<thead>
<tr>
<th>Project Segment</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Design Materials</td>
<td>610.60</td>
</tr>
<tr>
<td>Additional Materials from Redesign</td>
<td>215.51</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>826.11</strong></td>
</tr>
</tbody>
</table>

Maintenance and Repair Considerations

Outside of troubleshooting and unexpected errors, basic maintenance is designed to be simple and fast. The device is designed with a detachable plate, pushrod, and spoon for easy cleaning after each meal, and the material of the housing allows for the user to wipe down any spill with a damp cloth. While making sure the battery is charged at least once every couple days, the device should be kept out of the sun for prolonged hours, as insufficient temperature monitor testing has been done. However, if the device reaches an escalated temperature, a thermocouple monitoring the temperature inside the device will shut everything down.

Since the device has been designed for the Jhamak while in her wheelchair, it is not recommended that if the device becomes fully functional and passes the necessary testing requirements to ship it abroad, that it should be used by other users, especially those in different settings and with different body heights.
For troubleshooting and repair, the device has undergone constant troubleshooting thus far with the telescoping arm and software, and would need to complete more extensive fixing before it can be able to work without errors within the extending/retracting of the arm, and possibly even safety faults written in the software to adjust and account for certain errors.

The table below lists several of the main problems in need of troubleshooting, a little description about the problem, and lastly how to repair them.

*Table 10 Troubleshooting Operations for Major Device Problems*

<table>
<thead>
<tr>
<th>Issue</th>
<th>About the Problem/Observations</th>
<th>How to Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Software Dysfunctional-Internal Parts Damaged</strong></td>
<td>Currently, internal system repair is needed if any liquid spills on the device and leaks through the corners of the housing, and leakage could damage the components inside.</td>
<td>Replace damaged parts.</td>
</tr>
<tr>
<td><strong>Software Dysfunctional-Unplugged Internal Wires</strong></td>
<td>Wires that communicate between each of the electrical components and the microcontroller have the ability to be pulled out.</td>
<td>Wires need to be placed back in their respective location.</td>
</tr>
<tr>
<td><strong>Snapping Fishing Wire</strong></td>
<td>If the fishing wire moves off track within the telescoping arm housing or along the sections, it has the potential to take more load than the other lengths and therefore snap.</td>
<td>Power train should be removed and each of the sections taken apart from the housing in order to measure the appropriate length of fishing wire to tie back in its place.</td>
</tr>
<tr>
<td><strong>Nonfunctional Limit Button/Spoon Rests Too Low</strong></td>
<td>The limit button at the bottom of the telescoping arm is secured with electrical tape and super glue, and has had a tendency in the past to slightly move off location. This throws off the rest position of the spoon at best, and could at worst prevent one of the sections from hitting the limit switch.</td>
<td>The power train and telescoping arm sections would have to be taken apart, and glue would need to be reapplied to the side of the limit button.</td>
</tr>
<tr>
<td><strong>Constrained Telescoping Arm</strong></td>
<td>If the telescopic arm ever seems to be restricted when extending, it could be because the micro servo wire, running through the center of all the sections, could be tangled or caught on something at the very bottom.</td>
<td>The micro servo wire needs to be unconstrained by a push/pull action of the other end of the wire (loose end) at the very bottom of the telescoping arm.</td>
</tr>
<tr>
<td><strong>Limited Moment from Pushrod/Not Reaching Spoon</strong></td>
<td>With the pushrod’s custom coupler attachment to the servo, J-B weld has been inserted as Loctite in the threads to keep the coupler from unscrewing from the servo when a moment is placed on the rod.</td>
<td>Unscrew the attachment and reapply Loctite or J-B weld into the threads. (In the future, it has been debated that this would be one continuous part to ensure a full moment from the servo.)</td>
</tr>
</tbody>
</table>
Chapter 5: Product Realization

Once the final design was solidified, the team grouped the manufacturing into four separate subcomponents: housing, electrical components, telescoping arm, as well as plate, pushrod, Lazy Susan, and spoon design. For the manufacturing of the base, six polycarbonate panels were ordered fitting the design specifications related to dimensions. Upon review, it was concluded that the lengths of the polycarbonate panels were not as exact as required. A table saw was used to ensure exact dimensions and shorten the length of several different panels. Kevin can be seen below using the table saw in the machine shop fine-tuning the polycarbonate panels.

![Figure 36 Kevin using the tablesaw to properly dimension the polycarbonate panels](image)

Once the six sides were dimensioned correctly, the next step was to mill and drill out the different holes for external attachments as well as the mechanical fasteners. The drill press was used to cut holes for servo attachments, LEDs, the button socket, and the battery charging socket. Several holes were filed down, so that different external attachments could be press fitted into place. The mill was used in order cut out any rectangular holes, such as the one specifically for
the power switch. The picture below shows Patrick milling out the rectangular hole for the switch, while Kevin help verify exact location.

![Image](image_url)

*Figure 37 Patrick and Kevin milling out a rectangular hole for the power switch*

A handheld drill was used to cut many holes for the internal brackets, which supported the connection between different sides. Initially, bending the polycarbonate for the housing was sought out, and samples of the material were bent using the sheet metal brake on campus. The team realized that a thickness of at least 5mm was needed, which was unsuccessfully bent using the sheet metal press, hence mechanical fasteners were used to attach each side together. Once all the holes were completely cut, each individual panel was sandblasted to make the internal electrical and mechanical components tougher to see and hence more aesthetically pleasing. Once the sides were all put together to form the base, a hand grinder was applied to round any sharp edges and increase safety. A recommendation in regards to the manufacturing of the housing would be to eliminate the use of internal brackets and instead increase the thickness, so that bolts could be used at joints to connect sides. Implementing this change would make the device look more appealing because less screw heads would be exposed.
Dealing with the electrical aspect of the system and the manufacturing necessary to ensure the hardware and software interfaced correctly was a significant part of the project. An Arduino board was obtained as well as a motor shield. The motor shield came with all the electrical components unattached, so Kevin and Patrick were able to solder the different components onto the board following the provided schematic. Once the microcontroller and the motor shield were functioning, code was written using the Arduino programming language. The finalization of the code was a major milestone in the project and allowed for the project to move into the final testing and verification of the project. The initial design of the code was done with LEDs lighting up in reference to the motors and servos moving in the program. This allowed the team to verify the code procedures.

![Testing the software with the servos and LEDs before hardware integration](image)

When testing with actual components the structure of the code was changed slightly in order for proper software and hardware interface. The code used the step switch function in the Arduino programming environment. This system allows for mini programs to be run in a specific sequence. The importance of this was that it allowed for one sequence to totally finish before another one started. This allowed for the arm to retract to its maximum position before the spoon and pushrod started rotating, which would have resulted in no food for the user. The importance of
starting with a framework is clear from this experience. Without the framework it could have resulted in hours of more time trying to work out sequencing. Once everything ran in sequence as designed it made it very easy to go back and fine-tune each individual part for finalization. The wiring internally required many wires to be stripped, extended, and soldered to their desired location. The image below shows some of the wiring allowing our electrical system to operate the mechanical aspects.

Figure 39 Internal wiring of the electrical components

One recommendation related to the electrical side of this project would be to more permanently secure the wires within the breadboard. Wires could become loose if the device was moved quickly and hot-gluing the wires into the breadboard would have absolved this problem.

The telescoping arm, after having a speedy design change from the power antenna, consisted of many small components that needed to be put together coherently for the entire device to function as needed. Some custom-manufactured parts are listed:

- spoon micro servo and moment bearing fixture at the top of the telescoping arm
- flanges used to hold down the motor and the shafts
- bearings that the fishing line/straps would wrap around
- several of the couplers used to connect the shafts to the motor or servo
- housing lid with additional sound buffering capabilities

The mill was used to create the spaces for the bearings in the sections, while a drill press inserted the holes that the bearing rod could sit in. Extensive milling was also taken into account on creating the fixture at the top of the telescoping arm, and holes were drilled and tapped for a #4-40 bolt set. Holes were also drilled and tapped in each of the couplers and one of the gears to
give the ability of using a set screw for positioning. A lathe was used to decrease the diameter on parts of the shaft necessary to fit in the bearings or couplers.

While all the pieces were manufactured so that they meshed with one another, the telescoping arm housing was rapid prototyped using ABS plastic. Once all of these pieces were manufactured, assembly of the sub-component took place.

Several design changes were made even during the sub-component assembly process, including running the spoon micro servo inside the telescoping arm rather than on the outside, seen in the figure below, and the transition from nylon webbing to fishing line because of the unexpected friction force along the sides of the telescoping arm sections that kept the motor from being able to lift the spoon. As will be discussed in the recommendations section, more extensive calculations analyzing the power requirements of the telescoping arm motor with the nylon webbing straps should have been done to provide enough torque to lift the spoon and food from the plate.

![Figure 40 Wiring Micro Servo through Telescoping Arm Sections](image)

Another major design change that was made during the assembly process was switching the “return” mechanism that brought the spoon back to the plate from a shaft on a belt to a 4 to 1 pulley system. In designing, a belt attached to the primary gear shaft should have turned another shaft at the very bottom of the telescoping rod when in reverse, which would in the end have
pulled down the sections of the telescoping rod. However, because of the difficulty in assembling the bottom corner shaft and fixing it in place enough to support the load from the belt, alternative approaches were taken into account to determine other ways for the telescoping arm to retract itself. In the end, it was determined that fishing wire would wrap itself around the bottom of the arm, and enter a 4 to 1 pulley system where the main gear shaft would rotate in reverse, and with the pulley system pull 4 times the length rotating on the shaft to bring the arm down in a relatively fast manner to meet the engineering requirements.

Furthermore, a major change was due to the fact that the initial motor purchased for the telescoping arm did not raise the food up to the user at the speed specified through our requirements. Because of this, effort went to find another motor that not only had the torque and rpm requirements, but had a similar shaft dia., size to fit in the housing, and fit within the current limitations imposed by the microcontroller. After an extensive and unsuccessful search, it was then determined to instead change the gear ratio by a factor of 4 and use the initial motor. This motor in its housing is pictured in the figure below.

![Figure 41 Assembled Powertrain for Telescoping Arm](image)

A last major change was the use of “shims” inside the telescoping arm, due to the fact that the fishing wire now provided for an increase in clearance between each of the sections that was not seen before with the nylon webbing. These shims helped decrease the overall twist of the arm.
from the moment imposed on the cantilevered spoon, however did not fully solve the problem, and had to be attached using various adhesives due the constrained space to implement a mechanical system of fasteners.

The rest of the manufacturing and assembling process for the telescoping arm was difficult due to the restrained constrictions of the telescoping arm housing, and small space for holding each of the small components in their required location necessary for adjoining.

The Lazy Susan component was designed similarly to the rotating bowl in the Dining Assistant device. Manufacturing of the Lazy Susan face was done in tandem with the modified plate to ensure proper interface clearance. The face was a free form part cut on the bandsaw from available easy-to-machine ABS material left over from manufacturing the push rod. The part was then filed and sanded to the appropriate shape, and holes were milled for the plate “feet” contact and the rod attachment to the servo. The steel rod attachment was cut to size and sanded for better fit with the shaft bearing and servo coupler.

![Figure 42 The Lazy Susan face was a free form cut on the bandsaw. Here it is filed down to obtain the final circle shape.](image)

Assembly and testing of the Lazy Susan component found that the face was not sufficiently attached to the steel shaft. The contact area was too small and the epoxy adhesive required more reinforcement. To meet these needs, a Lazy Susan bearing was added between the Lazy Susan face and the base top panel to help carry the load of the face and restrict bending moment about the shaft. Although the bearing fixed these problems, it also constrained the rotation of the Lazy Susan device because the design tolerances were much tighter than expected for manufacturing. This caused problems during assembly and reliability testing, but issues were resolved by fastening the face to the shaft with a screw to ensure face rotation with the servo.
Testing found that the Lazy Susan plate was not sufficient attached to the shaft (not pictured), so a Lazy Susan bearing was added to provide more attachment surface area and help carry the load.

Changes could have been made early in the design process to reduce allowable tolerance of the holes milled on the Lazy Susan face. Testing found that the plate had to be placed in one specific orientation, hence the matching green arrows on the plate interface. This problem could be resolved in a reproduction with careful measurements during manufacturing. As noted above, the large tolerance of the center hole to the shaft also caused problems in rotation which caused the Lazy Susan to act like a cam.

The modified plate and push rod were unique in the fact that they were intended to be detachable from the device. Both parts could be made independent of other components, but interaction with interfaces on the main body of the device was critical. For the modified plate, a 20mm diameter steel rod was ordered to create the plate “feet” that would fit onto the Lazy Susan component. Redesigning and manufacturing of the Lazy Susan device at the Cal Poly machine shops proved easier in imperial units. Because the holes milled into the face of the Lazy Susan were in imperial units, the sides of the disks cut from the steel rod required grinding and sanding to fit the diameter required for easy extrication when the device is in use. The “feet” pieces were then lined up with the Lazy Susan face to ensure a good fit before applying epoxy.
Disks cut from steel rod. Pieces are then grinded and sanded to create a smaller diameter and smooth surface finish.

Matching the plate feet to the Lazy Susan face to ensure fit/clearance between the surfaces.

Other cheaper materials could be exchanged in place of the steel rod. The steel rod proved harder to sand by hand to achieve smooth edges and prevent cuts from sharp edges. The most critical requirement for the “feet” material is being easy to clean.

The push rod was originally entirely designed in the metric system. During continuation of the design phase and the beginning of manufacturing, heights defined on the push rod and its attachment piece were remodeled in the imperial system to match dimensions of the Lazy Susan device. The length of the pushrod remained in metric units to match the radius of stainless steel dining plates bought off the shelf. The push rod proved simple to manufacture because the easy-to-machine ABS material only required small, straight cuts done on the table saw and bandsaw, and parts were later affixed with epoxy and sanded by hand to achieve a smooth surface. One large design change in the pushrod was the geometry of the attachment piece. Manufacturing a square hole proved difficult, so the face shape was changed to across created by making two slits
with the bandsaw. The push rod attachment piece was designed and modeled on SolidWorks, and the customized part was rapid prototyped in ABS material which proved sufficient for the specific device applications during testing. The custom made part was screwed in directly to the servo hub to ensure part-to-part interaction.

![Image of push rod](image1)

*Figure 46* Manufacturing of the pushrod mainly required small cuts. The parts were epoxied and left to cure overnight. The most critical connection was in achieving a right angle above the rotation part.

![Image of push rod assembly](image2)

*Figure 47* The push rod attachment piece was manufactured with the rapid prototyping machine and screwed onto the servo.

Both manufacturing processes were effective in producing the desired products. Some changes could have been made in the design of the push rod attachment piece. Testing with food revealed that the attachment piece was not as rigidly joined to the servo and a small amount of industrial strength resin was used to keep it in place and rotating with the servo shaft.
Chapter 6: Design Verification

Once all of the sub-components had been individually assembled, and then the entire device assembled altogether, only slight changes were needed for everything to mesh together coherently. A few component interactions are worth noting: the spoon, cantilevered off the end of the telescoping arm was required to rest right at the edge of the plate in the passageway of the pushrod; the bottom of the telescoping arm power train box sat flush with the bottom of the device; and lastly the plate was raised up just enough to only allow a fraction of an inch gap between the surface of the plate and the bottom of the pushrod. Figure X below shows the final device with food reading for testing.

In order to properly test the device to determine if all of the engineering requirements were met, a test plan was composed outlining five main points: the description of the test, its acceptance criteria, the team member responsible for taking the test, the stage and timing of the test as compared with our project timeline, the quantity of test that need to be completed, and lastly the type of test it was out of the four categories of: Analysis (A), Physical Test (T), Similarity to Existing Designs (S), or Inspection (I). Below is the test plan criterion for the device verification.

Figure 48 Assembled Device Prior to Testing
With 25 criteria, testing was carried out first by means of inspection (I) (if possible) and analysis (A), and then next by physical testing (T). Out of the 25 different criteria, some of the more notable test were those of the device’s ability to scoop up an adequate amount of food and lift it to a proximity of the user’s mouth. Because it is common to eat dal bhat in nepali culture, the foods chosen to test with were at first those of smooth consistency such as applesauce and black beans, and then Indian food from a local restaurant that had similar texture to that of Nepali food. Images below (figures X-X) display a small taste of the testing experience.

### Table 11 Test Plan Prior to Full Testing

<table>
<thead>
<tr>
<th>Item No</th>
<th>Specification</th>
<th>Test Description</th>
<th>Acceptance Criteria</th>
<th>Test Responsibility</th>
<th>Test Stage</th>
<th>Quantity</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Set up time</td>
<td>Record time attaching device to wheelchair and turning on operating mode</td>
<td>Under 2 minutes</td>
<td>1/2 Kevin, 1/2 Nepalese Students</td>
<td>Near the end</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>2</td>
<td>Weight</td>
<td>Weigh entire device on a scale*</td>
<td>Under 15 lb</td>
<td>USA</td>
<td>Near the end</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>3</td>
<td>Tray Size</td>
<td>Measure max width, height and length</td>
<td>Within a 35cm x 30cm x 12 cm enclosure</td>
<td>Kevin</td>
<td>Early</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>4</td>
<td>Durable</td>
<td>Drop from 3 ft.</td>
<td>Does not break</td>
<td>USA</td>
<td>Near the end</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>5</td>
<td>Safety</td>
<td>Inspect for sharp edges/pincher points and compare material to FDA Standards</td>
<td>Satisfies OSHA and FDA standards</td>
<td>Jillian</td>
<td>Near the end</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>6</td>
<td>Low cost</td>
<td>Add up receipts</td>
<td>Under 1,000</td>
<td>USA</td>
<td>Near the end</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>7</td>
<td>Quiet</td>
<td>Measure decibels via smartphone</td>
<td>Less than 60Db</td>
<td>Patrick</td>
<td>Middle</td>
<td>3</td>
<td>T</td>
</tr>
<tr>
<td>8</td>
<td>Battery Usage Time</td>
<td>Run device at normal operating conditions</td>
<td>Charge life of 6 meals</td>
<td>Patrick</td>
<td>Middle</td>
<td>2</td>
<td>T</td>
</tr>
<tr>
<td>9</td>
<td>Life Cycle</td>
<td>Analyze member with highest load</td>
<td>Member lasts over 10 years</td>
<td>Jeremy and Jillian</td>
<td>Early</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>10</td>
<td>Precision</td>
<td>Run device and measure it’s standard deviation from the model</td>
<td>+/- 0.5 inches</td>
<td>Jeremy</td>
<td>End</td>
<td>10</td>
<td>T</td>
</tr>
<tr>
<td>11</td>
<td>Accuracy</td>
<td>Run device and measure it’s deviation from the user’s mouth</td>
<td>+/- 0.5 inches</td>
<td>Jeremy</td>
<td>End</td>
<td>10</td>
<td>T</td>
</tr>
<tr>
<td>12</td>
<td>Collapsible</td>
<td>Measure width, height, and length in collapsed position</td>
<td>Within a 35cm x 30cm x 12 cm enclosure</td>
<td>Kevin</td>
<td>Near the end</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>13</td>
<td>Nepal Social Acceptance</td>
<td>Give device to Jhamak and her family</td>
<td>Receive o.k. and no rejection</td>
<td>Nepalese Students</td>
<td>At the very end</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>14</td>
<td>Power Capacity</td>
<td>Measure voltage requirements</td>
<td>240V</td>
<td>Patrick</td>
<td>Early</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>15</td>
<td>Locally Acces. Parts</td>
<td>Determine which parts are available in Nepal</td>
<td>75% +/- 25% local materials</td>
<td>USA and Nepal</td>
<td>At the very end</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>16</td>
<td>Exchangable Spoons</td>
<td>Number of operating spoons</td>
<td>3 or more spoons</td>
<td>Jillian</td>
<td>Middle</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>17</td>
<td>Minimal Cracks near Food Delivery</td>
<td>Visually inspect cracks near plate</td>
<td>0 cracks visible</td>
<td>USA</td>
<td>Middle</td>
<td>3</td>
<td>T</td>
</tr>
<tr>
<td>18</td>
<td>Removable Eating Surface</td>
<td>Verify that plate can be detached from tray</td>
<td>Full detachment and attachment</td>
<td>Jillian and Kevin</td>
<td>Middle</td>
<td>3</td>
<td>T</td>
</tr>
<tr>
<td>19</td>
<td>User Inputs</td>
<td>Count Buttons</td>
<td>Less than 3 buttons</td>
<td>Patrick</td>
<td>Early</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>20</td>
<td>Guards to Block Food Fallage</td>
<td>Count Guards</td>
<td>less than 1 guard</td>
<td>Jillian</td>
<td>Middle</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>21</td>
<td>Food to Mouth Height and Horizontal Distance</td>
<td>Measure Variance in two dimensions of spoon from mouth</td>
<td>Within a radius of 3cm from mouth</td>
<td>Jeremy</td>
<td>Middle</td>
<td>10</td>
<td>T</td>
</tr>
<tr>
<td>22</td>
<td>Height when assembled</td>
<td>Measure total height of device</td>
<td>Less than 50cm +/- 10cm</td>
<td>USA</td>
<td>Near the end</td>
<td>1</td>
<td>T</td>
</tr>
<tr>
<td>23</td>
<td>Food/Scoop</td>
<td>Weigh amount of food picked up by spoon</td>
<td>2 oz +/- 0.5 oz</td>
<td>Jillian</td>
<td>Middle - Early</td>
<td>10</td>
<td>T</td>
</tr>
<tr>
<td>24</td>
<td>Food Fall-age</td>
<td>Measure percentage of food falling off spoon</td>
<td>Less than 10%</td>
<td>Jillian</td>
<td>Middle</td>
<td>10</td>
<td>T</td>
</tr>
<tr>
<td>25</td>
<td>Delivery Time</td>
<td>Record time for one cycle</td>
<td>Under 8 sec</td>
<td>Patrick</td>
<td>Middle</td>
<td>10</td>
<td>T</td>
</tr>
</tbody>
</table>
Figure 49 After food is pushed onto spoon, pushrod rotates back to it's normal position

Figure 50 Telescoping arm raises food to user
Figure 51 User waits patiently for food (chair not used in this case)

Figure 52 Plate continues to turn until all food is picked up or user stops device.
After setting up the device and making initial observations of its movement, measurements were taken to determine whether or not the device met the engineering requirements, and if not, how it can be changed to fit them.

A few initial testing issues with the device, most commonly with the telescopic arm, made us make a few changes that pushed back the testing period. Still at the end of the project term, a few of those issues have still not been able to be solved without redesign, and as a result adequate testing needed before sending the device to Nepal could not be exercised. Furthermore, several of the tests require the device to be in Nepal, so these tests had to be put on hold.

In the end, still a majority of tests were able to be accomplished, and those are outlined below in Table X, with comments on the very right hand column. Tests that need to be in Nepal resulted in an NA, and several tests that could not be completed due to other parts of the device not working received in 0 for incomplete.
<table>
<thead>
<tr>
<th>Item No</th>
<th>Spec.</th>
<th>Test Description</th>
<th>Acceptance Criteria</th>
<th>TEST RESULTS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Set up time</td>
<td>Record time attaching device to wheelchair and turning on operating mode</td>
<td>Under 2 minutes</td>
<td>NA until in Nepal</td>
<td>NA  NA  Cannot be completed until in Nepal</td>
</tr>
<tr>
<td>2</td>
<td>Weight</td>
<td>Weigh entire device on a scale*</td>
<td>Under 15 lb</td>
<td>9.3lb</td>
<td>100  0  --</td>
</tr>
<tr>
<td>3</td>
<td>Tray Size</td>
<td>Measure max width, height and length</td>
<td>Within a 35cm x 30cm x 12 cm enclosure</td>
<td>22in x 43cm x 33cm</td>
<td>0  100  ---</td>
</tr>
<tr>
<td>4</td>
<td>Durable</td>
<td>Drop from 3 ft.</td>
<td>Does not break</td>
<td>Fail visual inspection</td>
<td>0  100  Device does not look durable for drop</td>
</tr>
<tr>
<td>5</td>
<td>Safety</td>
<td>Inspect for sharp edges/pincher points and compare material to FDA Standards</td>
<td>Satisfies OSHA and FDA standards</td>
<td>FDA approval, electrical hazard</td>
<td>50  50  FDA approval, but some pincher points</td>
</tr>
<tr>
<td>6</td>
<td>Low cost</td>
<td>Add up receipts</td>
<td>Under 1,000</td>
<td>950</td>
<td>100  0  noise from telescoping arm motor</td>
</tr>
<tr>
<td>7</td>
<td>Quiet</td>
<td>Measure decibels via Smartphone</td>
<td>Less than 60Db</td>
<td>80Db</td>
<td>0  100  tested without telescoping arm load because not able to run unassisted over 6 meals</td>
</tr>
<tr>
<td>8</td>
<td>Battery Usage Time</td>
<td>Run device at normal operating conditions</td>
<td>Charge life of 6 meals</td>
<td>5.5 meals 83 cycles 25 minutes continuous run time</td>
<td>92  8</td>
</tr>
<tr>
<td>9</td>
<td>Life Cycle</td>
<td>Analyze member with highest load</td>
<td>Member lasts over 10 years</td>
<td>2 years</td>
<td>20  80  Design Changes created weaker members</td>
</tr>
<tr>
<td>10</td>
<td>Precision</td>
<td>Run device and measure it’s standard deviation from the model</td>
<td>.+/- 0.5 inches</td>
<td>NA /s</td>
<td>0  100  Software not working to properly test</td>
</tr>
<tr>
<td>11</td>
<td>Accuracy</td>
<td>Run device and measure it’s deviation from the user’s mouth</td>
<td>.+/- 0.5 inches</td>
<td>NA /s</td>
<td>0  100  Software not working to properly test</td>
</tr>
<tr>
<td>12</td>
<td>Collapsible</td>
<td>Measure width, height, and length in collapsed position</td>
<td>Within a 35cm x 30cm x 12 cm enclosure</td>
<td>22cm x 43cm x 33cm</td>
<td>0  100  Remains the same size, design change</td>
</tr>
<tr>
<td>13</td>
<td>Nepal Social Acceptance</td>
<td>Give device to Jhamak and her family</td>
<td>Receive o.k. and no rejection</td>
<td>NA until in Nepal</td>
<td>NA  NA  Cannot be completed until in Nepal</td>
</tr>
<tr>
<td>14</td>
<td>Power Capacity</td>
<td>Measure voltage requirements</td>
<td>240V</td>
<td>240V</td>
<td>100  0  universal power supply</td>
</tr>
<tr>
<td>15</td>
<td>Locally Acces. Parts</td>
<td>Determine which parts are available in Nepal</td>
<td>75% +/- 25% local materials</td>
<td>25%</td>
<td>50  50  Spoon, plate can be found locally</td>
</tr>
<tr>
<td>16</td>
<td>Exchan. Spoons</td>
<td>Number of operating spoons</td>
<td>3 or more spoons</td>
<td>NA  NA  NA  change of design from bowl to plate – uniform spoon</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Minimal Cracks near Food</td>
<td>Visually inspect cracks near plate</td>
<td>0 cracks visible</td>
<td>0 cracks</td>
<td>100  0  ---</td>
</tr>
<tr>
<td>18</td>
<td>Remov. Eating Surface</td>
<td>Verify that plate can be detached from tray</td>
<td>Full detachment and attachment</td>
<td>plate is removable</td>
<td>100  0  ---</td>
</tr>
<tr>
<td>19</td>
<td>User Inputs</td>
<td>Count Buttons</td>
<td>Less than 3 buttons</td>
<td>1 button</td>
<td>100  0  ---</td>
</tr>
<tr>
<td>20</td>
<td>Guards to Block Food Fallage</td>
<td>Count Guards</td>
<td>less than 1 guard</td>
<td>0 guards</td>
<td>100  0  no guards needed</td>
</tr>
</tbody>
</table>
In order for the full device to be sent to Nepal, redesign would need to be taken into account with the telescopic arm in terms of increased power to allow for an initial strap-like design to work. Changing this would require a redesign of the telescopic arm housing for a stronger material and a slight location change of bearings holding the shafts to the housing. While redesigning the telescopic arm housing, it would also be advised to implement detachable side panels for areas that do not carry loads. This would ease the assembly process and make the device easier to repair if troubleshooting is needed.

In the end, several tests were not able to run because of software problems. Therefore, before the device is sent, necessary troubleshooting on the software should be done to ensure sound code and secure wiring within the housing.

Overall, further testing is strongly recommended before device is finished. Furthermore, it is also recommended to create a new test plan with any redesign that may occur.
Chapter 7: Conclusions and Recommendations

An adaptive eating device has been designed, manufactured, and tested specifically to help alleviate the physical disability of cerebral palsy affecting Nepalese author Jhamak Ghimire’s ability to eat meals. The design incorporates a single push button to stimulate a series of mechanisms delivering a bite of food to the user. The device is designed to be eaten in Jhamak’s wheelchair supported by an intermediate connective bracket designed by the Nepalese teammates. The goal of the Cal Poly team was to send the device to Nepal after completely finishing the product and meeting every requirement. Several critical engineering requirements were not met, as previously noted in the testing section. Some notable issues include safety requirements, particularly the sharp edges of the telescoping arm as well as evident pinch points associated with the base.

While the team met many of the engineering requirements initially set, there are several significant incomplete aspects of the final product. The material choice of the motor housing is not considering robustness and is likely to fatigue and be easily damaged. The spoon attachment also needs to reexamined and redesigned in order to lock the spoon in the correct orientation. The telescoping arm is operated by a fishing line pulley system, which is likely to fail over time. Redesigning for straps would provide less chance for failure and contribute to the robustness of the device. A major lesson learned was the necessity to design for both manufacturability as well as assembly in order to combat unforeseen challenges that arise when these stages of development occur.

The team has numerous recommendations for any future generations pursuing this project. In regards to the housing, it has been concluded that avoiding a myriad of mechanical fasteners would increase the aesthetics of the device. By increasing the thickness of the polycarbonate panels, bolts could be used at the intersection joints to make the frame. This would allow for easier assembly and disassembly and the overall weight of the device would not increase by too much because of the removal of the metal brackets. On the contrary, the polycarbonate panels could be thinner and a bending technique could be used to create rounded corners and contribute to the safety of the device. Several recommendations related to the attachments of the device include redesigning the pushrod, so that the base of it is permanently attached to the top surface of the frame. Designing so that the pushing interface alone could be detached for cleaning purposes would allow for a more rigid connection between the base of the pushrod and the top surface of the housing.

The lazy susan and plate connection could also be improved. The plate feet tolerance was very high making it difficult to find the necessary orientation to lock the plate onto the lazy susan. In the future, a simple magnetized system would have allowed for an efficient and much more compliant attachable and detachable connection between these two subcomponents. Analyzing the telescoping arm, several changes are evident that would increase the effectiveness of this part of the device. Implementing straps instead of fishing line to drive the internal pulley system would be a much more robust option. Resizing the motor would allow the arm to extend and retract at a much more desirable speed. In order to do this a new motor shield and battery would need to be spec’d out in order to supply the necessary current and power to the motor. The
housing for the telescoping arm would need to be redesigned to incorporate a stronger motor and a more robust material should be selected to avoid future damage. All these changes would assist in developing a more effective and reliable future device aimed towards helping Jhamak Ghimire eat independently.

While the goal for this project has not been met, the team hopes that our design can be referenced by future generations pursuing a similar project and aid in their success. Hours and hours of work have gone into this project, and the team genuinely feels that invaluable lessons regarding the entire design process have been ingrained within our engineering core values and will benefit us significantly with future endeavors. The team would like to thank Dr. James Widmann for his tremendous support and help with this project.
References

http://www.dsource.in/case-study/spoon/index.html
Appendices

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