# Motorized Wheelchair Mounting System

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## Abstract

*A speech generation device is a critical tool for an individual whose speech is impeded by a disability. However, operation and handling of the device may be difficult for those confined to a wheelchair and have limited physical capabilities. In addition, the position required for use of the device may interfere with one's ability to see or perform other functions. If the position causes a significant decrease in the user's field of vision, the ability to drive or maneuver a wheelchair may be compromised. This semester, a motorized wheelchair mounting system was designed to give physically impaired users access to a speech generation device that stows safely out of the way. The design utilizes a mounting plate to provide support as well as protection for both the user and the mechanical components.*

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## Problem Statement

Design a motorized wheelchair mounting system for a Vanguard Plus speech generating device. The client currently drives an electric wheelchair without the Vanguard mounted. However, with the device attached to his chair with the current mount, he cannot see to drive the wheelchair. Developing a mounting system that better meets his need would increase his independence by allowing him to use the Vanguard whenever necessary. We are interested to find out if a standard wheelchair mounting system could be adapted so that he is able to move his Vanguard into position to use it and then out of the way to store it and drive.

## Background Information

Cerebral palsy (CP) is a non-progressive condition of brain damage that causes physical impairment, affecting body movement and posture. Seventy-five percent of all cases of CP are developed during pregnancy. While there is no cure at this time, therepy treatments continue making advancements and improve the quality of life for those living with the condition. (Bax et al, 2005; Jan, 2006) Our end-user, Will, is an 18-year-old male with cerebral palsy. His motor skills have been strongly affected and as a result, a wheelchair is currently used for

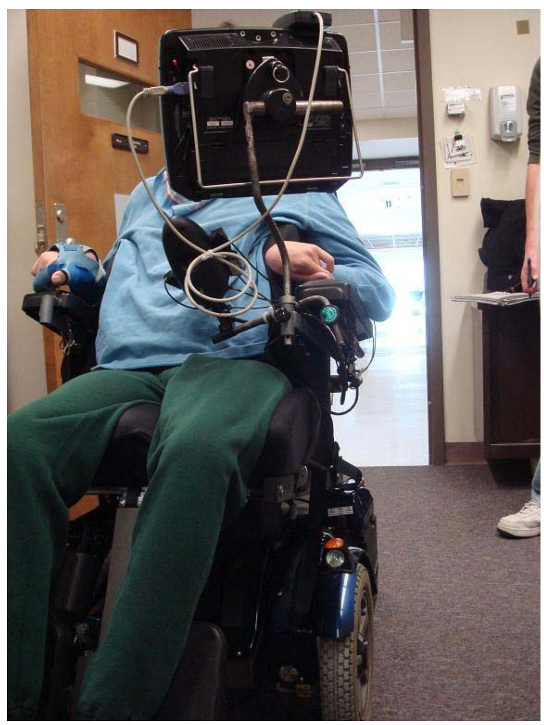

**Figure 1:** Wheelchair with attached speech generation device.

mobility (**Figure 1**). In addition, his speech has been affected such that it is difficult to communicate with unfamiliar persons. However, recently he has made great progress in the tactile use of his left hand, which has enabled the use of a touch-activated speech generation device. The model he uses is a Vanguard Plus. The user is able to type sentences or select preprogrammed phrases that are spoken out loud by the device. The Vanguard also functions as a cell phone and is able to connect to and control a computer. In order to operate the device, it must be mounted on the left side of his wheelchair near his face so that he can easily see the display and comfortably touch the screen. When he uses his left hand to access the joystick, all his focus goes to the left.

## Current Devices

At this time, there are no commercially available mounting devices sufficient to meet our user's needs (DAESSY, 2004; Goodwin, 2007). Thus, a custom device is currently the only satisfactory solution. The mounting device he presently uses has been custom fabricated by his father. It consists of a vertical steel rod that attaches to the armrest of his wheelchair (**Figure 2)**. Welded at the top of this rod is a horizontal steel cylinder. This horizontal piece serves as the interface between the mount and the Vanguard's standard mounting bracket (**Figure 3**). While this

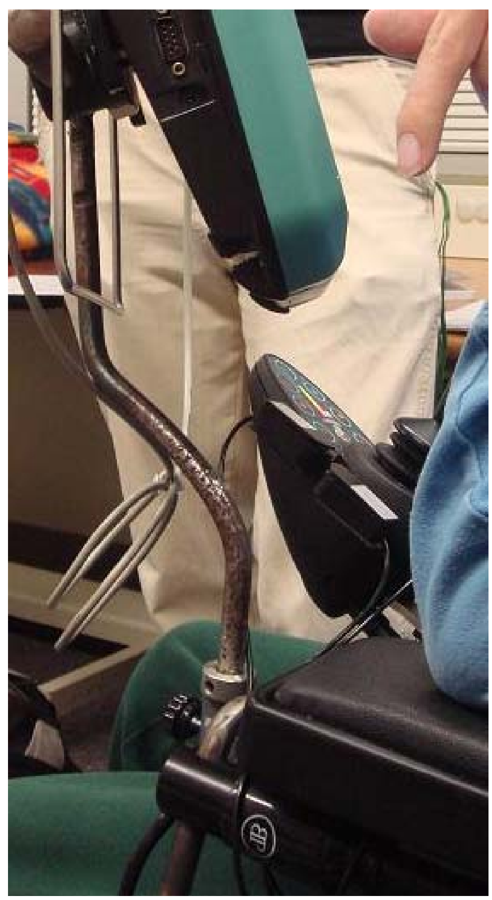

**Figure 2:** The current mount attaches to the armrest of the wheelchair.

**Figure 3:** Vanguard mounting bracket interface.

current mount does succeed in securing the device to the wheelchair, overall it is insufficient and does not meet user needs. With the device mounted in place as is, it severely hinders his field of vision and thus affects his ability to navigate and drive his wheelchair. As an additional problem with this mount, our end-user is unable to attach, position, or remove the device by himself at this time. Thus, in order to use the Vanguard, someone else is required to mount and position the device for him. Additionally, when he then wants to drive his wheelchair, someone else needs to remove the device and store it until the next use. Because of these problems, the speech generation device is currently only used during therapy sessions. Developing a custom motorized mounting system would increase the user's independence by allowing him to always have access to the device and thus be able to effectively communicate with others whenever necessary.

## Design Constraints

The Vanguard mount needs to be motorized because the user has limited strength and mobility. This restricts him from being able to manually move any type of non-motorized mount and does not allow him to attach or remove the Vanguard on his own. Ideally, the only user input needed will be the touch of one button to move the system from its position of typical use (eye level and to the left) to its final storage position, and then return with the same switch.

The final storage position of the device needs to be such that the user can quickly access it while in transit. Currently, because the Vanguard is not usually attached when he is moving in the wheelchair, he has no way of effectively communicating with people that do not deal with him on a regular basis. With the system accessible, he will be able contact his parents if his ride does not pick him up. If he needs to communicate with someone unfamiliar with his speech, such as a bus driver, he needs to have access to the Vanguard in order to do this. The final storage position also needs to be safe and within the chair perimeter. The device is expensive ($7000-8000) and its protection needs to be ensured.

The motorized mount can be powered from the wheelchair 24 V battery or an independent battery attached to the chair. If the wheelchair battery is used, a 24 V to 12 V converter may be needed depending on the type of motors selected. With this in mind, the new attachment can not interfere with any of the current functions of the wheelchair (joystick and toggle switches) and cannot provide any backflow of current into the wheelchair. Finally, the parents have set aside $1000 for this addition to the wheelchair. A summary of these product design specifications is attached as **Appendix A**.

## Design Alternatives

Each design consists of a motorized mechanical system capable of repositioning the device between the operation and stowage positions. The user will activate this system by depressing a sensitive spring-loaded button. This button will act as a toggle switch to cycle between the two positions.

**Design 1: Shoulder Position**

*Overview*

The storage position for this design is behind the user's left shoulder, above the armrest of the wheelchair. When the switch is activated, the Vanguard will slide forward, rotate so the screen is visible, and move up and toward the midline of the wheelchair to be in the best position for use (**Figure 4**). This could be accomplished with a system of actuators and rotary motors. It could attach to either the base under the wheelchair seat or onto the armrest.

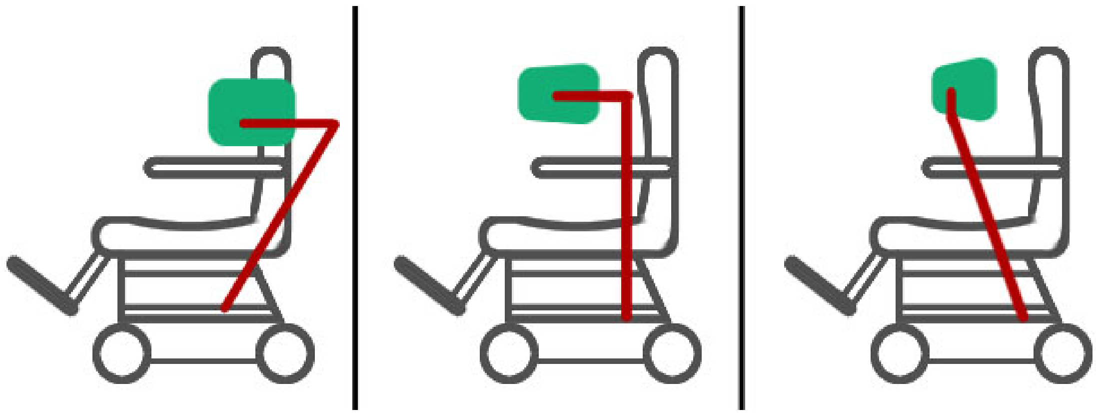

**Figure 4:** Transition of shoulder design from stowed position (left) to final operating position (right).

*Advantages and Disadvantages*

A good thing about this design is that it stores completely out of the user's sight and would not impair his driving ability. However, as evidenced by numerous scratches in the back corners of the wheelchair, this may not be the optimal position for storage of the Vanguard. He has previously hit door frames and walls while cornering which does not bode well for the protection of the device. Also, this storage position does not allow for quick access to the Vanguard while in transit. If he were in need of the communication device, he would have to activate the switch and wait for it to move to its final position. In emergencies or situations where time is of the essence, the setup is not ideal. In addition, the user was not comfortable with this storage position.

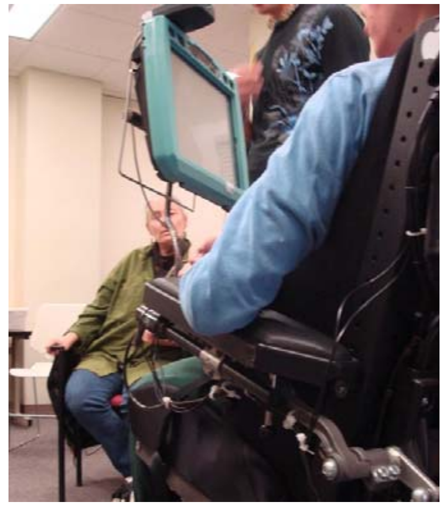

**Figure 5:** Shoulder area of wheelchair armrest.

While the actual mechanism of moving the device may be feasible for this design, the attachment of the mount and storage position may provide difficulties. As shown in **Figure 5**, the user's arm overhangs the armrest. This limits not only the area where the device can be stored, but also the mechanism that can be used if the arm is in the way of any of the moving mount components.

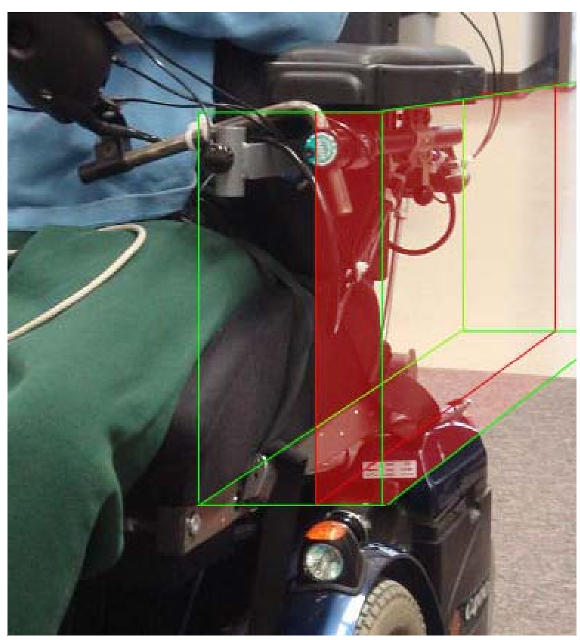

**Figure 6**: The wire box depicts space occupied by the side design. The outer shaded area shows where design extends beyond the perimeter of the wheelchair.

**Design 2: Side Position**

*Overview*

The second design candidate describes a mounting system that stores completely under the end-user's left armrest. The support rails that are used to extend the Vanguard Plus display outwards and upwards to its final operating position must be arranged next to the display due to the area constraints of the side space, which is depicted in **Figure 6**. To minimize screen damage, the rails rest on the outside in such a way that they extend the perimeter of the wheelchair. When activated, the motor-driven rails must slide over each other and fold once fully extended, as seen in **Figure 7**. This type of movement is necessary because the system might be blocked from swinging outwards from the wheelchair's side, and must stay within the wheelchair's perimeter as much as possible.

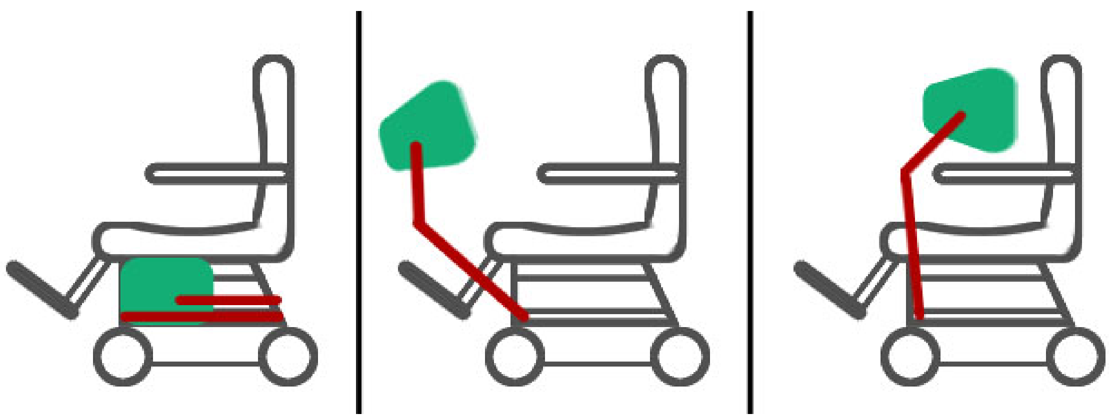

**Figure 7**: Transition of side design from stowed position (left) to final operating position (right).

*Advantages and Disadvantages*

The best thing about the side design is that the entire assembly stows completely out of the end-user's immediate space as well as sight. However, because of the tight space occupied by the mounting device, the outer moving parts are directly in harm's way. Extreme wear and tear of the mounting device requires extra support and stronger materials, making this one of the most mechanically complex design alternatives.

Furthermore, this design does not allow the end-user to access the Vanguard Plus while in transit. In the case of an emergency, there's a good chance that the extending and folding mechanism would be blocked by something like wheelchair restraint belts on a bus or any tables or walls in front of the wheelchair.

### Design 3: Lap position

*Overview*

The third and final design alternative is motivated by the end-user's need to access the Vanguard Plus while in transit, and is stowed with the screen face-up above the lap and below the joystick. This mounting device, like the others, is secured and mobilized at the wheelchair's base. Because the display does not need to occupy the space below the armrest, the mounting rails can be contained entirely within the wheelchair's perimeter. When activated, a single actuator moves the lower rail which first slides the screen outwards from underneath the joystick, and then swings the screen upwards and over the joystick to the final operating position, as seen in **Figure 8**. A stationary rotating collar, which can be either mounted underneath the left armrest or held in position by a stationary rail fastened to the wheelchair's base, facilitates the elliptical path the Vanguard Plus takes during activation.

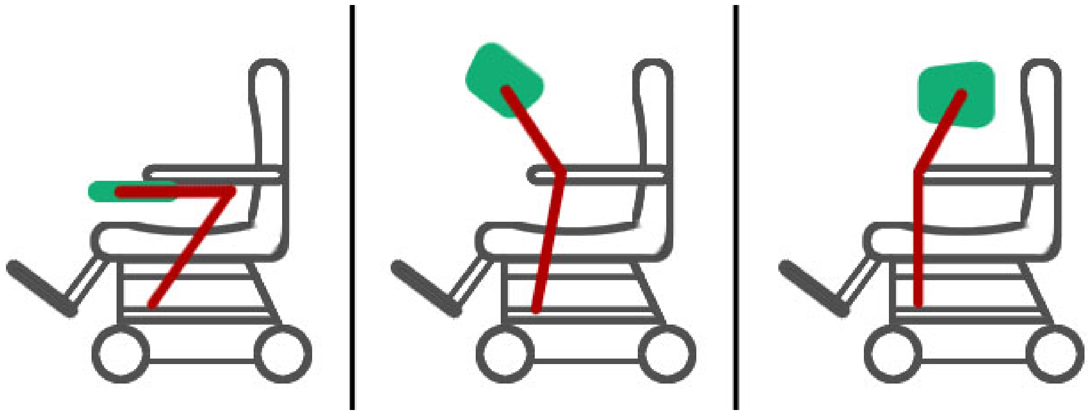

**Figure 8**: Transition of lap design from stowed position (left) to final operating position (right).

*Advantages and Disadvantages*

The key aspect of this design is the ability to operate the screen from the stowed position. Even if the end-user is unable to reach the screen while stowed, the path of movement for this device is contained entirely within the bounds of the wheelchair, making it much less likely to be blocked by an outside object. This space-conscious method also keeps the screen and mounting supports out of harm’s way. Since the design is simple and effective, it will be possible to build and test by the end of this semester-long project. This is important because of the end-user’s immediate need for this device. Although the device may seem to inhibit access to a desk or table, the end-user already has adjustable tables which eliminate this problem. Another proposed difficulty involves daily entering and exiting of the wheelchair, which would be blocked by a permanent mount over the lap. Easily removable parts and/or a fold-away mechanism would circumvent this problem altogether.

## Design Matrix

With the three proposed designs in mind, each design idea was evaluated against several design criteria. The respective results were summed together and tabulated to form the design matrix (**Table 1**) in order to determine which design undertaking was the most feasible given the limitations of time, budget and expertise. Each design criteria was weighted differently according to order of importance for the end user and towards the design of a successful mechanism. One design criteria used for the design matrix above was established to rate each design idea in terms of how accessible the Vanguard Plus would be for the end user while in motion, especially when transiting through narrow passageways. Stowage position was how well the Vanguard would stow in the selected position provided that it is well protected from physical contact with obstructing elements. Mechanical feasibility of each design was also evaluated based on how practical each device would be to construct and how durable it would be with repeated use. Deliverability was a measure imposed to determine whether the design could be successfully constructed, function, satisfy the end user and be sufficiently tested given the semester long constraint and budget limit. The cost criterion was an evaluation method by which each design was rated on cost efficiency of design incorporation into a working model.

| | Accessibility in Transit *(30pts)* | Stowage Position *(25pts)* | Feasibility *(25pts)* | Deliverability *(10pts)* | Cost *(10pts)* | Total *(100pts)* |
|---|---|---|---|---|---|---|
| Behind Shoulder Position | 10 | 18 | 15 | 7 | 8 | 58 |
| Under Armrest Position | 8 | 22 | 10 | 5 | 6 | 51 |
| Lap Position | 28 | 20 | 20 | 9 | 10 | 87 |

**Table 1:** Design matrix of the three design alternatives

Upon completion of design idea evaluations, it turned out that the lap position was the ideal design idea to be incorporated for this project due to the fact that its ratings for all criteria excelled across the board. Moreover, this design idea would be incorporated such that device use in transit would be enabled due to the close proximity of the storage position to the end user.

## Final Design

After rating each design alternative in the design matrix, the lap position was chosen as the final design.  This mounting method is less likely to be damaged while stowed or in use, making the lap position ideal for our client.  More importantly, this stowing position makes it possible for our client to use the Vanguard while it transit, even while it is stowed on top of the lap.  The mechanism allows the motion of the screen to swing out from this lap position, around the joystick, and up to its position of use.  The lap design also has the fewest moving parts, inherently making it last longer and cost less. The many reasons explaining how the lap position is the best option justifies the decision for a final design.

**Prototype/Design**

Building the prototype meant careful planning. Many different ideas for moving this device were generated, all keeping the same sliding collar mechanism that is common to all three design alternatives. Some of these ideas were decided upon for the following prototype construction problems: moving the end of the mounting rod from a stowed position to a functional position, supporting the weight of the mounting rod and Vanguard, motorizing the device, and mounting all of the parts onto the baseboard of the wheelchair.

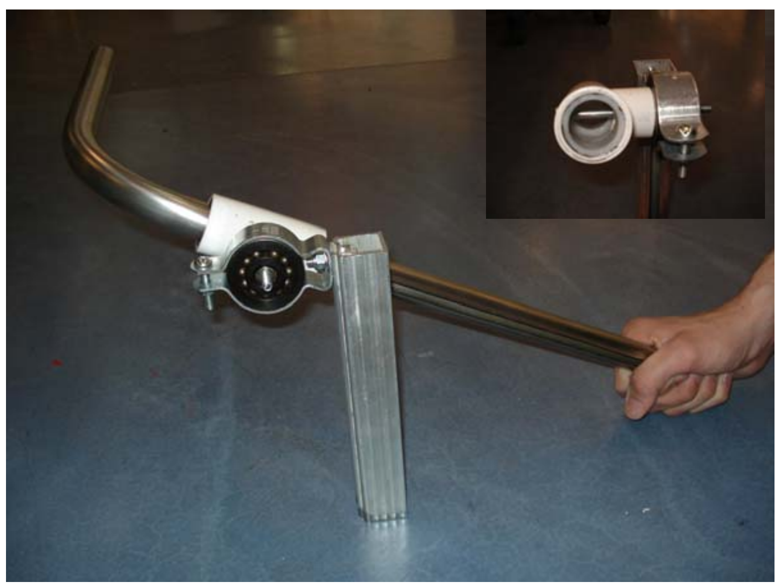

**Figure 9**: Sliding collar mounted to ball bearing (top). Collar mechanism with mounting rod (bottom).

First, the collar mechanism was created by attaching a T-shaped pipe fitting onto a ball bearing as seen in **Figure 9**. The bolt holding the collar and ball bearing together fits through a slot in the mounting rod that defines the boundaries of sliding movement. The collar is fitted with low-friction polyethylene ring inserts to promote smooth operation of the device. The ball bearing is tightly fastened into a hollow metal beam for sturdy support.

Designing a mechanism for moving the mounting rod was difficult. The small space limitations made linear actuators and rotating parts hard to work with. Due to part availability and fabrication feasibility, a chain-driven system was chosen. As seen in **Figure 10**, the end of the mounting rod is fastened to a link within the chain. This is accomplished by the use of an expanding mandrel to attach the mounting rod to a pin inserted through a link in the chain. Two bicycle gears provide a track for the mounting rod path to follow.

The weight of the mounting rod is supported by a sturdy beam which is stationed between the top and bottom chain halves and in-line with the two bicycle gears. This added support removes extra tension and prevents "sagging" of the chain. With this added feature, less power is required to move the entire system from stowed to functional screen positions.

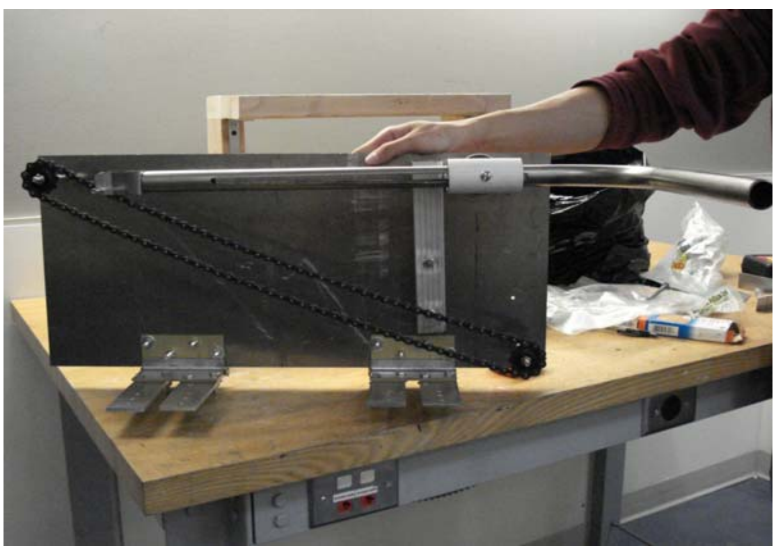

**Figure 10**: The chain mechanism connected to the rod and sliding collar assembly.

Motorizing the device became a difficult problem when taking multiple design possibilities into consideration. Due to time constraints, a worm drive was mounted in place of an electronic motor, and a power drill was used to demonstrate the movement of the screen. Further construction of this prototype would include replacing the worm drive with an electric motor and installing circuitry to allow the prototype to change from stowed to functional positions with the push of a button. Ideally, the motor will be powered by the wheelchair battery. A diode would have to be installed to prevent motor current from flowing back into the wheelchair battery.

To mount the prototype's components, a ¼" thick aluminum plate was used. This plate faces outward from beneath the armrest, as depicted in **Figure 11**. This orientation allows sturdy support of the prototype components, protection against collisions, and even enhances the commercial potential of this device by grouping everything into one piece. The gears, sliding collar assembly, weight-supporting bar, and worm drive were all fastened to the aluminum plate with bolts. Four angle brackets and strong aluminum plates were used to mount the bottom of the mounting plate to the base. Two door hinges, one per two angle brackets, were placed between the mounting brackets and the aluminum plate. A hook from one of the angle brackets clips onto the aluminum plate and prevents it from rotating outward. When this hook is removed, the entire assembly can be swung out of the way to allow exit and entry of the wheelchair (by moving the screen out of the user's lap).

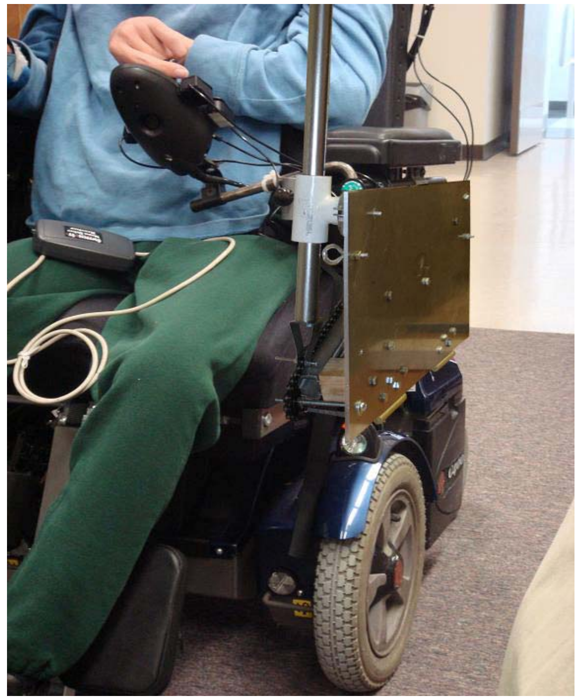

**Figure 11**: An image of the prototype superimposed onto the client's wheelchair.

## Future Work

The future work for this project would be to purchase and install an electric motor to automate the current chain-driven system. With this in mind, a motor operation circuit with variable outputs should be built and integrated into the wheelchair controls, which will feed directly into the wheelchair power source or an alternate battery. It will also be imperative that the materials for the design prototype be upgraded to improve durability and decrease overall weight in order to ensure a satisfactory device efficacy lifespan. This device will need to be attached to the end-user's wheelchair and therefore adjustments should also be made to account for any minute differences that may have been overlooked in the design process. For the sake of device performance improvement, an automated system of levers and/or hinges to flatten and rotate the screen approximately 55° clockwise about the long axis can be introduced and incorporated to meet end-user specifications and enhance viewing possibilities of the Vanguard while it is loaded. In the long-run, the chain-driven system of this design prototype could be upgraded to that of a direct drive shaft to further improve stability, durability and mechanical output of the device.

Formal long term plans for this design prototype would include the possibility of device commercialization due to the compact size, low cost of production and efficacy of design for a market lacking in more customizable motorized peripheral wheelchair devices. This device has the potential to positively impact and cater to other individuals with similar maneuverability issues experienced by our end-user by allowing wheelchair users to experience heightened mobility and independence.

**Usability Testing**

To ensure the quality of the designed mechanism, a proposed list of tests should be conducted such that the device functions properly and its functions are convenient for the end user. Among these tests, a "stress and strain" test should be performed to evaluate structural integrity and reliability of the mechanism when loading and stowing the device. A "load" test can be conducted to determine torque optimization of the design mechanism such that loading and stowing of the device is done in an efficient and effective manner. In addition, a "motion" test could be conducted to guarantee the stowage effectiveness of the designed mechanism where the device moves according to designation and does not veer off track. The "electronics" testing will be conducted and is of high priority because it will be integral to the success of this project. The designed mechanism will be motorized with the press of a button and therefore its electronic components must be maintained in working order with a constant supply of power from the wheelchair power source to ensure that the stowing and loading of the Vanguard device is achieved.

Overall, these tests must prove that the design prototype meets or exceeds the functions of the current mount and ensure that it is ergonomically sound for repeated operation and sturdy enough to withstand repeated wear and tear. Moreover, this design prototype should be accessible in transit and not interfere with wheelchair mobility or other functions.

## Conclusion

The end goal for this semester was to design and construct a motorized wheelchair mounting system prototype for a speech generation device that required minimal user input and enabled the user to position the device in proper locations for use and storage. The speech generation device that the end user uses is a critical tool for communication with individuals unfamiliar with his speech pattern. However, because the end user is confined to a wheelchair and is unable to physically move and position the device, the everyday operation and handling of the machine is difficult. In addition, the position required for use of the device interferes with the end user's ability to see and drive the wheelchair. Being able to have the Vanguard accessible at all times will greatly improve independence and communication with everyone.

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# Appendix A - PDS

**Motorized Wheelchair Mount (February 2008)**

**Problem Statement**

Design a motorized wheelchair mounting system for a Vanguard Plus speech generating device. The client currently drives an electric wheelchair without the Vanguard mounted. With the device mounted on his chair he cannot see to drive the wheelchair. We are interested to find out if a standard wheelchair mounting system could be adapted so that he is able to move his Vanguard into position to use, then out of the way to drive.

**Client Requirements:**

- Device should run on 12 V or 24 V wheelchair battery or independent source.
- Vanguard Plus should be stowed in position that does not impede user's line of vision.
- User must be able to drive wheelchair while device is still connected.
- Device stored in a safe position free from external collision damage
- Budget $1000.

**Design Requirements**

1. **Physical and Operational Characteristics**
    a. *Performance requirements:* Quiet, ergonomic, easy to use
    b. *Safety:* Must be safe for use and transport
    c. *Accuracy and Reliability:* Consistently relocate to intended position
    d. *Life in Service:* 5 years
    e. *Shelf Life:* N/A
    f. *Operating Environment:* Must be able to withstand year-round outdoor weather and endure collisions with walls, doorways, etc.
    g. *Size:* Should not extend beyond wheelchair perimeter or interfere with user.
    h. *Weight:* Should not exceed 10 kg.
    i. *Materials:* No specific requirements, but must be durable.
    j. *Aesthetics, appearance, and Finish*: Should not appear excessively gaudy.

**2. Production Characteristics**

a. *Quantity:* 1
b. *Target Product Cost*: <$1000

3. **Miscellaneous**

a. *Standards and Specifications:* Must not create any back-current into wheelchair battery. Must not interfere with other wheelchair functions such as movement, joystick operation, or seat positioning.
b. *Customer:* Should be accessible and user-friendly to facilitate Vanguard use to ultimately increase user's independence.

c. *Competition:* Currently there is no standard motorized wheelchair mount that meets the user's needs. Our product should provide increased functionality over non-motorized mounts.