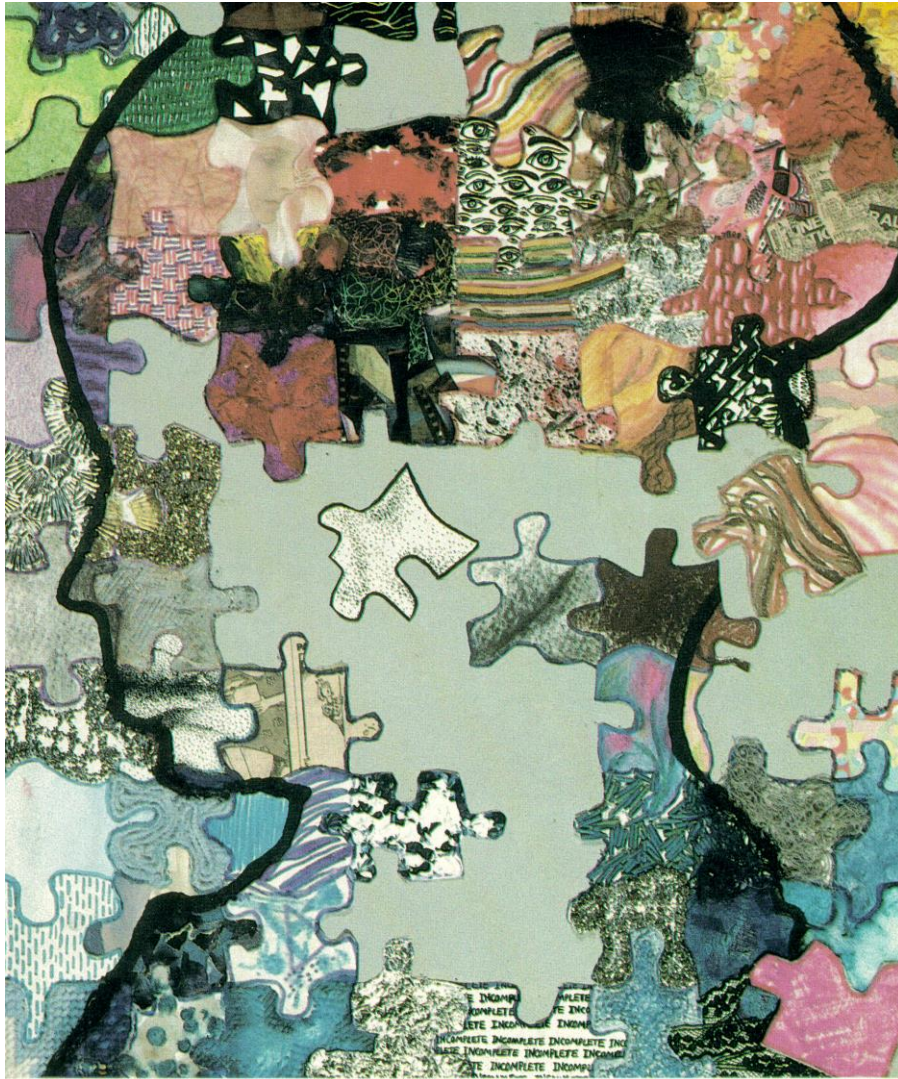


**NATIONAL SCIENCE FOUNDATION  
2011  
ENGINEERING SENIOR DESIGN  
PROJECTS TO AID PERSONS WITH  
DISABILITIES**



**Edited By  
John D. Enderle**



**NATIONAL SCIENCE FOUNDATION**

**2011**

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Edited By  
John D. Enderle

Creative Learning Press, Inc.  
P.O. Box 320  
Mansfield Center, Connecticut 06250

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# PUBLICATION POLICY

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# FOREWORD

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Welcome to the twenty-third annual issue of the National Science Foundation Engineering Senior Design Projects to Aid Persons with Disabilities. In 1988, the National Science Foundation (NSF) began a program to provide funds for student engineers at universities throughout the United States to construct custom designed devices and software for individuals with disabilities. Through the Bioengineering and Research to Aid the Disabled<sup>1</sup> (BRAD) program of the Emerging Engineering Technologies Division of NSF<sup>2</sup>, funds were awarded competitively to 16 universities to pay for supplies, equipment and fabrication costs for the design projects. A book entitled NSF 1989 Engineering Senior Design Projects to Aid the Disabled was published in 1989, describing the projects that were funded during the first year of this effort.

In 1989, the BRAD program of the Emerging Engineering Technologies Division of NSF increased the number of universities funded to 22. Following completion of the 1989-1990 design projects, a second book was published describing these projects, entitled NSF 1990 Engineering Senior Design Projects to Aid the Disabled.

North Dakota State University (NDSU) Press published the following three issues. In the NSF 1991 Engineering Senior Design Projects to Aid the Disabled almost 150 projects by students at 20 universities across the United States were described. The NSF 1992 Engineering Senior Design Projects to Aid the Disabled presented almost 150 projects carried out by students at 21 universities across the United States during the 1991-92 academic year. The fifth issue described 91 projects by students at 21 universities across the United States during the 1992-93 academic year.

Creative Learning Press, Inc. has published the succeeding volumes. The NSF 1994 Engineering

Senior Design Projects to Aid the Disabled, published in 1997, described 94 projects carried out by students at 19 universities during the academic 1993-94 year. The NSF 1995 Engineering Senior Design Projects to Aid the Disabled, published in 1998, described 124 projects carried out by students at 19 universities during the 1994-95 academic year.

The NSF 1996 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 1999, presented 93 projects carried out by students at 12 universities during the 1995-96 academic year. The ninth issue, NSF 1997 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2000, included 124 projects carried out by students at 19 universities during the 1996-97 academic year. NSF 1998 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2001, presented 118 projects carried out by students at 17 universities during the 1997-98 academic year. NSF 1999 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2001, presented 117 projects carried out by students at 17 universities during the 1998-99 academic year.

NSF 2000 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2002, presented 127 projects carried out by students at 16 universities during the 1999-2000 academic year. In 2002, NSF 2001 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 134 projects carried out by students at 19 universities during the 2000-2001 academic year. NSF 2002 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2004, presented 115 projects carried out by students at 16 universities during the 2001-2002 academic year. In 2005, NSF 2003 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 134 projects carried out by students at 19 universities during the 2002-2003 academic year.

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<sup>1</sup> The program name is now called the General & Age-Related Disabilities Engineering program.

<sup>2</sup> This program is now in the Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET).



NSF 2004 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2005, presented 173 projects carried out by students at 17 universities during the 2003-2004 academic year. In 2006, NSF 2005 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 154 projects carried out by students at 16 universities during the 2004-2005 academic year. NSF 2006 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2007, presented 152 projects carried out by students at 15 universities during the 2005-2006 academic year. In 2010, NSF 2007 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 139 projects carried out by students at 16 universities during the 2006-2007 academic year. NSF 2008 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2011, presented 118 projects carried out by students at 12 universities during the 2007-2008 academic year. In 2011, NSF 2009 Engineering Senior Design Projects to Aid Persons with Disabilities was published, presenting 160 projects carried out by students at 19 universities during the 2009-2010 academic year. NSF 2010 Engineering Senior Design Projects to Aid Persons with Disabilities, published in 2012, presented 155 projects carried out by students at 16 universities during the 2009-2010 academic year.

This book, funded by the NSF, describes and documents the NSF-supported senior design projects during the twenty-second year of this effort, 2010-2011. After the 5<sup>th</sup> chapter, each chapter describes the projects carried out at a single university, and was written by the principal investigator(s) at that university and revised by the editor of this publication. Individuals desiring more information on a particular design should contact the designated supervising principal investigator. An index is provided so that projects may be easily identified by topic. Chapters on best practices in design experiences, outcomes assessment, and writing about and working with individuals who have disabilities are also included in this book.

Hopefully this book will enhance the overall quality of future senior design projects, directed toward persons with disabilities, by providing examples of previous projects, and also motivate faculty at other universities to participate because of the potential benefits to students, schools, and communities.

Moreover, the new technologies used in these projects will provide examples in a broad range of applications for new engineers. The ultimate goal of this publication, and all the projects built under this initiative, is to assist individuals with disabilities in reaching their maximum potential for enjoyable and productive lives.

This NSF program has brought together individuals with widely varied backgrounds. Through the richness of their interests, a wide variety of projects has been completed and is in use. A number of different technologies were incorporated in the design projects to maximize the impact of each device on the individual for whom it was developed. A two-page project description format is generally used in this text. Each project is introduced with a nontechnical description, followed by a summary of impact that illustrates the effect of the project on an individual's life. A detailed technical description then follows. Photographs and drawings of the devices and other important components are incorporated throughout the manuscript.

Sincere thanks are extended to Dr. Allen Zelman, a former Program Director of the NSF BRAD program, for being the prime enthusiast behind this initiative. Additionally, thanks are extended to Drs. Peter G. Katona, Karen M. Mudry, Fred Bowman, Carol Lucas, Semahat Demir, Robert Jaeger, Gil Devey and Ted Conway, former and current NSF Program Directors of the Biomedical Engineering and Research to Aid Persons with Disabilities Programs, who have continued to support and expand the program.

I acknowledge and thank Lindsay Gaedt for editorial assistance. I also appreciate the technical illustration efforts of Justin Morse. Additionally, I thank Ms. Shari Valenta for the cover illustration and the artwork throughout the book, drawn from her observations at the Children's Hospital Accessibility Resource Center in Denver, Colorado.

The information in this publication is not restricted in any way. Individuals are encouraged to use the project descriptions in the creation of future design projects for persons with disabilities. The NSF and the editor make no representations or warranties of any kind with respect to these design projects, and specifically disclaim any liability for any incidental or consequential damages arising from the use of this

publication. Faculty members using the book as a guide should exercise good judgment when advising students.

Readers familiar with previous editions of this book will note that I moved from North Dakota State University to the University of Connecticut in 1995. With that move, annual publications also moved from NDSU Press to Creative Learning Press Inc. in 1997. During 1994, I also served as NSF Program Director for the Biomedical Engineering and Research Aiding Persons with Disabilities Program while on a leave of absence from NDSU. Brooke Hallowell, a faculty member at Ohio University, became the co-editor of this book series beginning with the 1996 edition and ended with the 2007 edition to devote time to other pursuits.

Previous editions of this book are available for viewing at the web site for this project:

<http://nsf-pad.bme.uconn.edu/>

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# CHAPTER 1

## INTRODUCTION

Devices and software to aid persons with disabilities often require custom modification. They are sometimes prohibitively expensive or even nonexistent. Many persons with disabilities have limited access to current technology and custom modification of available devices. Even when available, personnel costs for engineering and support make the cost of custom modifications beyond the reach of many of the persons who need them.

In 1988, the National Science Foundation (NSF), through its Emerging Engineering Technologies Division, initiated a program to support student engineers at universities throughout the United States in designing and building devices for persons with disabilities. Since its inception, this NSF program (originally called Bioengineering and Research to Aid the Disabled, then Bioengineering and Research to Aid the Disabled, and now the General & Age-Related Disabilities Engineering program) has enhanced educational opportunities for students and improved the quality of life for individuals with disabilities. Students and faculty provide, through their Accreditation Board for Engineering and Technology (ABET) accredited senior design class, engineering time to design and build the device or software. The NSF provides funds, competitively awarded to universities for supplies, equipment and fabrication costs for the design projects.

Outside of the NSF program, students are typically involved in design projects that incorporate academic goals for solid curricular design experiences, but that do not necessarily enrich the quality of life for persons other than, perhaps, the students themselves. For instance, students might design and construct a stereo receiver, a robotic unit that performs a household chore, or a model racecar.

Under this NSF program, engineering design students are involved in projects that result in original devices, or custom modifications of devices, that improve the quality of life for persons with disabilities. The students have opportunities for practical and creative problem solving to address well-defined needs, and while persons with disabilities receive the products of that process at no financial cost. Upon completion, each finished project becomes the property of the individual for whom it was designed.

The emphasis of the program is to:

- Provide children and adults with disabilities student-engineered devices or software to improve their quality of life and provide greater self-sufficiency,
- Enhance the education of student engineers through the designing and building of a device or software that meets a real need, and
- Allow participating universities an opportunity for unique service to the local community.

Local schools, clinics, health centers, sheltered workshops, hospitals, and other community agencies participate in the effort by referring interested individuals to the program. A single student or a team of students specifically designs each project for an individual or a group of individuals. Examples of projects completed in past years include laser-pointing devices for people who cannot use their hands, speech aids, behavior modification devices, hands-free automatic telephone answering and hang-up systems, and infrared systems to help individuals who are blind navigate through indoor spaces. The students participating in this program are richly rewarded through their activity with persons with

disabilities, and justly experience a unique sense of purpose and pride in their accomplishments.

### ***The Current Book***

This book describes the NSF supported senior design projects during the academic year 2010-2011. The purpose of this publication is threefold. First, it is to serve as a reference or handbook for future senior design projects. Students are exposed to this unique body of applied information on current technology in this and previous editions of this book. This provides an even broader education than typically experienced in an undergraduate curriculum, especially in the area of rehabilitation design. Many technological advances originate from work in the space, defense, entertainment, and communications industry. Few of these advances have been applied to the rehabilitation field, making the contributions of this NSF program all the more important.

Secondly, it is hoped that this publication will serve to motivate students, graduate engineers and others to work more actively in rehabilitation. This will ideally lead to an increased technology and knowledge base to address effectively the needs of persons with disabilities.

Thirdly, through its initial chapters, the publication provides an avenue for motivating and informing all involved in design projects concerning specific means of enhancing engineering education through design experiences.

This introduction provides background material on the book and elements of design experiences. The second chapter highlights specific aspects of some exemplary practices in design projects to aid persons with disabilities. The third chapter addresses assessment of outcomes related to design projects to aid persons with disabilities. The fourth chapter provides details on enhancing students' writing skills through the senior design experience. The fifth chapter addresses the importance of fostering

relationships between students and individuals with disabilities.

After the five introductory chapters, 18 chapters follow, with each chapter devoted to one participating school. At the start of each chapter, the school and the principal investigator(s) are identified. Each project description is written using the following format. On the first page, the individuals involved with the project are identified, including the student(s), the professor(s) who supervised the project, and key professionals involved in the daily lives of the individual for whom the project has been developed. A brief nontechnical description of the project follows with a summary of how the project has improved a person's quality of life. A photograph of the device or modification is usually included. Next, a technical description of the device or modification is given, with parts specified in cases where it may be difficult to fabricate them otherwise. An approximate cost of the project, excluding personnel costs, is provided.

Most projects are described in two pages. However, the first or last project in each chapter is usually significantly longer and contains more analytic content. Individuals wishing more information on a particular design should contact the designated supervising principal investigator.

Some of the projects described are custom modifications of existing devices, modifications that would be prohibitively expensive were it not for the student engineers and this NSF program. Other projects are unique one-of-a-kind devices wholly designed and constructed by students for specific individuals.

### ***Engineering Design***

As part of the accreditation process for university engineering programs, students are required to complete a minimum number of design credits in their course of study, typically at the senior level.<sup>3,4,5</sup>

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<sup>3</sup> Accrediting Board for Engineering and Technology. Accreditation Policy and Procedure Manual Effective for Evaluations for the 2010-2011 Accreditation Cycle. ABET: Baltimore, MD.

<sup>4</sup> Accrediting Board for Engineering and Technology. Criteria for Accrediting Engineering Programs, 2010-2011. ABET: Baltimore, MD.

<sup>5</sup> Enderle, J.D., Gassert, J., Blanchard, S.M., King, P., Beasley, D., Hale Jr., P. and Aldridge, D., The ABCs



Many call this the capstone course. Engineering design is a course or series of courses that brings together concepts and principles that students learn in their field of study. It involves the integration and extension of material learned throughout an academic program to achieve a specific design goal. Most often, the student is exposed to system-wide analysis, critique and evaluation. Design is an iterative decision-making process in which the student optimally applies previously learned material to meet a stated objective.

There are two basic approaches to teaching engineering design, the traditional or discipline-dependent approach, and the holistic approach. The traditional approach involves reducing a system or problem into separate discipline-defined components. This approach minimizes the essential nature of the system as a holistic or complete unit, and often leads participants to neglect the interactions that take place between the components. The traditional approach usually involves a sequential, iterative approach to the system or problem, and emphasizes simple cause-effect relationships.

A more holistic approach to engineering design is becoming increasingly feasible with the availability of powerful computers and engineering software packages, and the integration of systems theory, which addresses interrelationships among system components as well as human factors. Rather than partitioning a project based on discipline-defined components, designers partition the project according to the emergent properties of the problem.

A design course provides opportunities for problem solving relevant to large-scale, open-ended, complex, and sometimes ill-defined systems. The emphasis of design is not on learning new material. Typically, there are no required textbooks for the design course, and only a minimal number of lectures are presented to the student. Design is best described as an individual study course where the student:

- Selects the device or system to design,
- Writes specifications,
- Creates a paper design,
- Analyzes the paper design,

- Constructs the device,
- Evaluates the device,
- Documents the design project, and
- Presents the project to a client.

### ***Project Selection***

In a typical NSF design project, the student meets with the client (a person with a disability and/or a client coordinator) to assess needs and identify a useful project. Often, the student meets with many clients before finding a project for which his or her background is suitable.

After selecting a project, the student then writes a brief description of the project for approval by the faculty supervisor. Since feedback at this stage of the process is vitally important for a successful project, students usually meet with the client once again to review the project description.

Teams of students often undertake projects. One or more members of a team meet with one or more clients before selecting a project. After project selection, the project is partitioned by the team into logical parts where each student is assigned one of these parts. Usually, a team leader is elected by the team to ensure that project goals and schedules are satisfied. A team of students generally carries out multiple projects.

Project selection is highly variable depending on the university and the local health care facilities. Some universities make use of existing technology to develop projects by accessing databases such as ABLEDATA. ABLEDATA includes information on types of assistive technology, consumer guides, manufacturer directories, commercially available devices, and one-of-a-kind customized devices. In total, this database has over 23,000 products from 2,600 manufacturers and is available from:

<http://www.abledata.com>

or

(800) 227-0216.

More information about this NSF program is available at:

<http://nsf-pad.bme.uconn.edu>

### **Specifications**

One of the most important parts of the design process is determining the specifications, or requirements that the design project must fulfill. There are many different types of hardware and software specifications.

Prior to the design of a project, a statement as to how the device will function is required. Operational specifications are incorporated in determining the problem to be solved. Specifications are defined such that any competent engineer is able to design a device that will perform a given function. Specifications determine the device to be built, but do not provide information about how the device is built. If several engineers design a device from the same specifications, all of the designs would perform within the given tolerances and satisfy the requirements; however, each design would be different. Manufacturers' names are generally not stated in specifications, especially for electronic or microprocessor components, so that design choices for future projects are not constrained.

If the design project involves modifying an existing device, the modification is fully described in detail. Specific components of the device, such as microprocessors, LEDs, and electronic parts, are described. Descriptive detail is appropriate because it defines the environment to which the design project must interface. However, the specifications for the modification should not provide detailed information about how the device is to be built.

Specifications are usually written in a report that qualitatively describes the project as completely as possible, and how the project will improve the life of an individual. It is also important to explain the motivation for carrying out the project. The following issues are addressed in the specifications:

- What will the finished device do?
- What is unusual about the device?

Specifications include a technical description of the device, and all of the facts and figures needed to complete the design project. The following are examples of important items included in technical specifications:

- Electrical parameters (including interfaces, voltages, impedances, gains, power output, power input, ranges, current capabilities,

harmonic distortion, stability, accuracy, precision, and power consumption)

- Mechanical parameters (including size, weight, durability, accuracy, precision, and vibration)
- Environmental parameters (including location, temperature range, moisture, and dust)

### **Paper Design and Analysis**

The next phase of the design is the generation of possible solutions to the problem based on the specifications, and selection of an optimal solution. This involves creating a paper design for each of the solutions and evaluating performance based on the specifications. Since design projects are open-ended, many solutions exist. Solutions often require a multidisciplinary system or holistic approach to create a successful and useful product. This stage of the design process is typically the most challenging because of the creative aspect to generating solutions.

The specifications previously described are the criteria for selecting the best design solution. In many projects, some specifications are more important than others, and trade-offs between specifications may be necessary. In fact, it may be impossible to design a project that satisfies all of the design specifications. Specifications that involve some degree of flexibility are helpful in reducing the overall complexity, cost and effort in carrying out the project. Some specifications are absolute and cannot be relaxed.

Most projects are designed in a top-down approach similar to the approach of writing computer software by first starting with a flow chart. After the flow chart or block diagram is complete, the next step involves providing additional details to each block in the flow chart. This continues until sufficient detail exists to determine whether the design meets the specifications after evaluation.

To select the optimal design, it is necessary to analyze and evaluate the possible solutions. For ease in analysis, it is usually easiest to use computer software. For example, National Instrument's *Multisim*, a circuit analysis program, easily analyzes circuit problems and creates the layout for a printed circuit board. For mechanical components, the use of Dassault Systèmes SolidWorks Corp. *Solidworks* allows for computer-aided-design analysis and 3D drawings. Other situations require that a potential design project solution be partially constructed or breadboarded for analysis and evaluation. After analysis of all possible solutions, the optimal design

selected is the one that meets the specifications most closely.

### ***Construction and Evaluation of the Device***

After selecting the optimal design, the student then constructs the device. The best method of construction is often to build the device module by module. By building the project in this fashion, the student is able to test each module for correct operation before adding it to the complete device. It is far easier to eliminate problems module by module than to build the entire project and then attempt to eliminate problems.

Design projects are analyzed and constructed with safety as one of the highest priorities. Clearly, the design project that fails should fail in a safe manner, without any dramatic and harmful outcomes to the client or those nearby. An example of a fail-safe mode of operation for an electrical device involves grounding the chassis, and using appropriate fuses; if ever a 120-V line voltage short circuit to the chassis should develop, a fuse would blow and no harm to the client would occur. Devices should also be protected against runaway conditions during the operation of the device and during periods of rest. Failure of any critical components in a device should result in the complete shutdown of the device.

After the project has undergone laboratory testing, it is then tested in the field with the client. After the field test, modifications are made to the project, and the project is given to the client. Ideally, the project in use by the client should be evaluated periodically for performance and usefulness after the project is complete. Evaluation typically occurs, however, when the device no longer performs adequately for

the client, and it is returned to the university for repair or modification. If the repair or modification is simple, a university technician may handle the problem. If the repair or modification is more extensive, another design student may be assigned to the project to handle the problem as part of his or her design course requirements.

### ***Documentation***

Throughout the design process, the student is required to document the optimal or best solution to the problem through a series of written assignments. For the final report, documenting the design project involves integrating each of the required reports into a single final document. While this should be a simple exercise, it is often a most vexing and difficult endeavor. Many times during the final stages of the project, some specifications are changed, or extensive modifications to the ideal paper design are necessary.

Most universities require that the final report be professionally prepared using desktop publishing software. This requires that all circuit diagrams and mechanical drawings be professionally drawn. Illustrations are usually drawn with computer software.

The two-page reports within this publication are not representative of the final reports submitted for design course credit; they are summaries of the final reports. A typical final report for a design project is approximately 30 pages in length, and includes extensive analysis supporting the operation of the design project. Photographs of the device may be included in the final report but mechanical and electrical diagrams are often more useful in documenting the device.





# CHAPTER 2

## BEST PRACTICES IN SENIOR DESIGN

*John Enderle and Brooke Hallowell*

This chapter presents different approaches to the design course experience. For example, at Texas A&M University, the students worked on many small design projects during the two-semester senior design course sequence. At North Dakota State University, students worked on a single project during the two-semester senior design course sequence. At the University of Connecticut, students were involved in a web-based approach and in distance learning in a collaborative arrangement with Ohio University.

### **Duke University**

The Devices for the Persons with Disabilities course is offered as an elective to seniors and graduate students through the Biomedical Engineering Department at Duke University. The course has been supported since September 1996 by grants from the National Science Foundation, and is offered each fall. The course is limited to 12 students and four to six projects to provide a team atmosphere and to ensure quality results.

The course involves design, construction and delivery of a custom assistive technology device; typically in one semester. At the start of the semester, students are given a list of descriptions for several possible projects that have been suggested by persons with disabilities and health care workers in the local community. Students individually rank order the list, and for their top three selections, describe why they are interested and what skills they possess that will help them be successful. Projects are assigned to teams of one to three students based on these interests and expected project difficulty. Soon thereafter, students meet with the project's supervisor and client. The supervisor is a health care professional, typically a speech-language pathologist or occupational or physical therapist, who has worked with the client. Student teams then formulate a plan for the project and present an oral and written project proposal to define the problem and their expected approach. In the written proposal, results

of a patent and product search for ideas related to the student project are summarized and contrasted with the project.

Each student keeps an individual laboratory notebook for his or her project. Copies of recent entries are turned in to the course instructor for a weekly assessment of progress. During the semester, students meet regularly with the supervisor and/or client to ensure that the project will be safe and meet the needs of the client. Three oral and written project reports are presented to demonstrate progress, to provide experience with engineering communications, and to allow a public forum for students to receive feedback from other students, supervisors, engineers, and health care professionals.

Course lectures are focused on basic principles of engineering design, oral and written communication, and ethics. In addition, guest lectures cover topics such as an overview of assistive technology, universal design, ergonomics and patent issues. Field trips to a local assistive technology lending library, and to an annual exposition featuring commercial assistive technology companies provide further exposure to the field.

Students present their projects in near-final form at a public mock delivery two weeks before their final delivery, which provides a last chance to respond to external feedback. Final oral presentations include project demonstrations. Each project's final written report includes a quantitative analysis of the design, as well as complete mechanical drawings and schematics. At the end of the semester, students deliver their completed project to the client, along with a user's manual that describes the operation, features, and specifications for the device.

For projects requiring work beyond one semester, students may continue working through the spring semester on an independent study basis. A full-time summer student provides service on projects already delivered.

## University of Massachusetts-Lowell

The capstone design experience at University of Mass-Lowell is divided into two three-credit courses. These courses are taken in the last two semesters of undergraduate studies and for the most part involve the design of assistive technology devices and systems. The program costs are supported in part by a five-year grant from the National Science Foundation. Additional funding comes from corporate and individual donations to the assistive technology program at University of Mass-Lowell. Both courses are presented in each semester of a traditional academic year. The combined enrollment averages between 40 and 50 each semester.

The major objective of the first course is for each student to define a major design to be accomplished prior to graduation and ideally within the timeframe of the second course. The process for choosing a design project begins immediately. However, there are other activities that take place concurrently with the search for a project. The most significant of these is a team effort to generate a business plan for securing venture capital or other forms of financing to support corporate development of a product oriented towards the disadvantaged community. The instructor chooses a number of students to serve as CEOs of their company. The remaining students must present oral and written resumes and participate in interviews.

The CEO of each company must then hire his or her employees and the teams are thus formed. Each team is expected to do the following:

- Determine a product,
- Name the company,
- Determine the process for company name registration,
- Generate a market analysis,
- Determine the patent process,
- Generate a cost analysis for an employee benefit package,
- Generate information on such terms as FICA, FUTA, SS, 941, MC, IRA, SRA, I9, and other terms relative to payroll deductions and state and federal reporting requirements,
- Meet with patent attorneys, real estate agents, members of the business community, bankers, and a venture capitalist,
- Demonstrate understanding of the cost of insurance and meet with insurance agents to discuss health and life insurance for employees

and liability insurance costs for the company, and

- Explore OSHA requirements relative to setting up development laboratories.

Students carry out these tasks using direct person-to-person contact and the vast amount of information on the Internet.

The teams are also required to understand the elements of scheduling and must produce a Gant chart indicating the tasks and allotted times to take their product through development and make ready for manufacture. A cost analysis of the process is required, and students are expected to understand the real cost of development, with overhead items clearly indicated.

Much of the subject material described above is covered in daily classroom discussions and with guest speakers. During the process of generating the team business plan, each team is required to present two oral reports to the class. The first is a company report describing their company, assigned tasks, their product, and a rationale for choosing their product.

The second is a final report that is essentially a presentation of the company business plan. Technical oral and written reports are essential components of the first course. Two lectures are presented on the techniques of oral presentations and written reports are reviewed by the college technical writing consultants. All oral presentation must be made using PowerPoint or other advanced creative tools.

Early in the course, potential capstone projects are presented; students are required to review current and past projects. In some semesters, potential clients address the class. Representatives from agencies have presented their desires and individuals in wheelchairs have presented their requests to the class. Students are required to begin the process of choosing a project by meeting with potential clients and assessing the problem, defining the needs, and making a decision as to whether or not they are interested in the associated project. In some cases, students interview and discuss as many as three or four potential projects before finding one they feel confident in accomplishing. If the project is too complex for a single student, a team is formed. The decision to form a team is made by the instructor only after in-depth discussions with potential team

members. Individual responsibilities must be identified as part of a team approach to design. Once a project has been chosen, the student must begin the process of generating a written technical proposal. This document must clearly indicate answers to the following questions:

- What are the project and its technical specifications?
- Why is the project necessary?
- What technical approach is to be used to accomplish the project?
- How much time is necessary?
- How much will the project cost?

The final activity in this first course is the oral presentation of the proposal.

The second course is concerned with the design of the project chosen and presented in the first course. In the process of accomplishing the design, students must present a total of five written progress reports, have outside contacts with a minimum of five different persons, and generate at least three publications or public presentations concerning their project. Finally, they demonstrate their project to the faculty, write a final comprehensive technical report, and deliver the project to their client.

### Texas A&M University

The objective of the NSF program at Texas A&M University is to provide senior bioengineering students an experience in the design and development of rehabilitation devices and equipment to meet explicit client needs identified at several off-campus rehabilitation and education facilities. The students meet with therapists and/or special education teachers for problem definition under faculty supervision. This program provides significant real-world design experiences, emphasizing completion of a finished product. Moreover, the program brings needed technical expertise that would otherwise not be available to not-for-profit rehabilitation service providers. Additional benefits to the participating students include a heightened appreciation of the problems of persons with disabilities, motivation toward rehabilitation engineering as a career path, and recognition of the need for more long-term research to address the problems for which today's designs are only an incomplete solution.

Texas A&M University's program involves a two-course capstone design sequence, BIEN 441 and 442. BIEN 441 is offered during the fall and summer semesters, and BIEN 442 is offered during the spring semester. The inclusion of the summer term allows a full year of ongoing design activities. Students are allowed to select a rehabilitation design project, or another general bioengineering design project.

The faculty members at Texas A&M University involved with the rehabilitation design course have worked in collaboration with the local school districts, community rehabilitation centers, residential units of the Texas Department of Mental Health and Mental Retardation (MHMR), community outreach programs of Texas MHMR, and individual clients of the Texas Rehabilitation Commission and the Texas Commission for the Blind. Appropriate design projects are identified in group meetings between the staff of the collaborating agency, the faculty, and the participating undergraduate students enrolled in the design class. In addition, one student is employed in the design laboratory during the summer to provide logistical support, and pursue his or her own project. Each student is required to participate in the project definition session, which enriches the overall design experience. The meetings take place at the beginning of each semester, and periodically thereafter as projects are completed and new ones are identified.

The needs expressed by the collaborating agencies often result in projects that vary in complexity and duration. To meet the broad spectrum of needs, simpler projects are accommodated by requiring rapid completion, at which point the students move on to another project. More difficult projects involve one or more semesters, or even a year's effort; these projects are the ones that typically require more substantial quantitative and related engineering analysis.

Following the project definition, the students proceed through the formal design process of brainstorming, clarification of specifications, preliminary design, review with the collaborating agency, design execution and safety analysis, documentation, prerelease design review, and delivery and implementation in the field. The execution phase of the design includes identifying and purchasing necessary components and materials, arranging for any fabrication services that may be necessary, and obtaining photography for project reports.



Throughout each phase of the project, a faculty member supervises the work, as do the university supported teaching assistants assigned to the rehabilitation engineering laboratory. The students also have continued access to the agency staff for clarification or revision of project definitions, and review of preliminary designs. The latter is an important aspect of meeting real needs with useful devices. The design team meets as a group to discuss design ideas and project progress, and to plan further visits to the agencies.

One challenging aspect of having students responsible for projects that are eagerly anticipated by the intended recipient is the variable quality of student work, and the inappropriateness of sending inadequate projects into the field. This potential problem is resolved at Texas A&M University by continuous project review, and by requiring that the projects be revised and reworked until they meet faculty approval.

At the end of each academic year, the faculty member and the personnel from each collaborating agency assess which types of projects met with the greatest success in achieving useful delivered devices. This review has provided ongoing guidance in the selection of future projects. The faculty members also maintain continuous contact with agency personnel with respect to ongoing and past projects that require repair or modification. In some instances, repairs are assigned as short-term projects to currently participating students. This provides excellent lessons in the importance of adequate documentation.

Feedback from participating students is gathered each semester using the Texas A&M University student questionnaire form as well as personal discussion. The objective of the reviews is to obtain students' assessment of the educational value of the rehabilitation design program, the adequacy of the resources and supervision, and any suggestions for improving the process.

### **North Dakota State University**

All senior electrical engineering students at North Dakota State University (NDSU) are required to complete a two-semester senior design project as part of their study. These students are partitioned into faculty-supervised teams of four to six students. Each team designs and builds a device for a particular

individual with a disability in eastern North Dakota or western Minnesota.

During the early stages of NDSU's participation in projects to aid persons with disabilities, a major effort was undertaken to develop a complete and workable interface between the NDSU electrical engineering department and the community of persons with disabilities to identify potential projects. These organizations are the Fargo Public School System, NDSU Student Services and the Anne Carlson School. NDSU students visit potential clients or their supervisors to identify possible design projects at one of the cooperating organizations. All of the senior design students visit one of these organizations at least once. After the site visit, the students write a report on at least one potential design project, and each team selects a project to aid a particular individual.

The process of a design project is implemented in two parts. During the first semester of the senior year, each team writes a report describing the project to aid an individual. Each report includes an introduction, establishing the need for the project. The body of the report describes the device; a complete and detailed engineering analysis is included to establish that the device has the potential to work. Almost all of the NDSU projects involve an electronic circuit. Typically, devices that involve an electrical circuit are analyzed using PSpice, or another software analysis program. Extensive testing is undertaken on subsystem components using breadboard circuit layouts to ensure a reasonable degree of success before writing the report. Circuits are drawn for the report using OrCAD, a CAD program. The OrCAD drawings are also used in the second phase of design, which allows the students to bring a circuit from the schematic to a printed circuit board with relative ease.

During the second semester of the senior year, each team builds the device to aid an individual. This first involves breadboarding the entire circuit to establish the viability of the design. After verification, the students build printed circuit boards using OrCAD, and then finish the construction of the projects using the fabrication facility in the electrical engineering department. The device is then fully tested, and after approval by the senior design faculty advisor, the device is given to the client. Each of the student design teams receives feedback throughout the year

from the client or client coordinator to ensure that the design meets its intended goal.

Each design team provides an oral presentation during regularly held seminars in the department. In the past, local TV stations have filmed the demonstration of the senior design projects and broadcast the tape on their news shows. This media exposure usually results in viewers contacting the electrical engineering department with requests for projects to improve the life of another individual, further expanding the impact of the program.

Design facilities are provided in three separate laboratories for analysis, prototyping, testing, printed circuit board layout, fabrication, and redesign or development. The first laboratory is a room for team meetings during the initial stages of the design. Data books and other resources are available in this room. There are also 12 workstations available for teams to test their designs, and verify that the design parameters have been met. These workstations consist of a power supply, a waveform generator, an oscilloscope, a breadboard, and a collection of hand tools.

The second laboratory contains computers for analysis, desktop publishing and microprocessor testing. The computers all have analysis, CAD and desktop publishing capabilities so that students may easily bring their design projects from the idea to the implementation stage. A scanner with image enhancement software and a high-resolution printer are also available in the laboratory.

The third laboratory is used by the teams for fabrication. Six workstations exist for breadboard testing, soldering, and finish work involving printed circuit boards. Sufficient countertop space exists so that teams may leave their projects in a secure location for ease of work.

The electrical engineering department maintains a relatively complete inventory of electronic components necessary for design projects, and when not in stock, has the ability to order parts with minimal delay. The department also has a teaching assistant assigned to this course on a year-round

basis, and an electronics technician available for help in the analysis and construction of the design project.

There are occasionally projects constructed at NDSU (and at other universities) that prove to be unsafe or otherwise unusable for the intended individual, despite the best efforts of the student teams under the supervision of the faculty advisors. These projects are not officially documented.

## University of Connecticut

In August 1998 the Department of Electrical & Systems Engineering (ESE) at the University of Connecticut (UConn), in collaboration with the School of Hearing, Speech and Language Sciences at Ohio University, received a five-year NSF grant for senior design experiences to aid persons with disabilities. An additional five-year grant was awarded in 2005. These NSF projects are a pronounced change from previous design experiences at UConn, which involved industry sponsored projects carried out by a team of student engineers. The new Biomedical Engineering Program at UConn has now replaced the ESE Department in this effort.

To provide effective communication between the sponsor and the student teams, a web-based approach was implemented.<sup>6</sup> Under the new scenario, students work individually on a project and are divided into teams for weekly meetings. The purpose of the team is to provide student-derived technical support at weekly meetings. Teams also form throughout the semester based on needs to solve technical problems. After the problem is solved, the team dissolves and new teams are formed.

Each year, 25 projects are carried out by the students at UConn. Five of the 25 projects are completed through collaboration with personnel at Ohio University using varied means of communication currently seen in industry, including video conferencing, the Internet, telephone, e-mail, postal mailings, and video recordings.

Senior design consists of two required courses, Design I and II. Design I is a three-credit hour course in which students are introduced to a variety of subjects. These include: working in teams, design

<sup>6</sup> Enderle, J.D., Browne, A.F., and Hallowell, B. (1998). A WEB Based Approach in Biomedical Engineering

Design Education. Biomedical Sciences Instrumentation, 34, pp. 281-286.

process, planning and scheduling (timelines), technical report writing, proposal writing, oral presentations, ethics in design, safety, liability, impact of economic constraints, environmental considerations, manufacturing, and marketing. Each student in Design I:

- Selects a project to aid an individual after interviewing a people with disabilities,
- Drafts specifications,
- Prepares a project proposal,
- Selects an optimal solution and carries out a feasibility study,
- Specifies components, conducts a cost analysis and creates a time-line, and
- Creates a paper design with extensive modeling and computer analysis.

Design II is a three-credit-hour course following Design I. This course requires students to implement a design by completing a working model of the final product. Prototype testing of the paper design typically requires modification to meet specifications. These modifications undergo proof of design using commercial software programs commonly used in industry. Each student in Design II:

- Constructs and tests a prototype using modular components as appropriate,
- Conducts system integration and testing,
- Assembles a final product and field-tests the device,
- Writes a final project report,
- Presents an oral report using PowerPoint on Senior Design Day, and
- Gives the device to the client after a waiver is signed.

Course descriptions, student project homepages and additional resources are located at <http://www.bme.uconn.edu/bme/ugrad/bmesdi-ii.htm>.

The first phase of the on-campus projects involves creating a database of persons with disabilities and then linking each student with a person who has a disability. The A.J. Pappanikou Center provides an MS Access database with almost 60 contacts and a short description of disabilities associated with the clients in each. The involvement of the Center was essential for the success of the program. The A.J. Pappanikou Center is Connecticut's University Affiliated Program (UAP) for disabilities studies. As such, relationships have been established with the Connecticut community of persons affected by

disabilities, including families, caregivers, advocacy and support groups and, of course, persons with disabilities themselves. The Center serves as the link between the person in need of the device and the design course staff. The Center has established ongoing relationships with Connecticut's Regional Educational Service Centers, the Birth to Three Network, the Connecticut Tech Act Project, and the Department of Mental Retardation. Through these contacts, the Center facilitates the interaction between the ESE students, the client coordinators (professionals providing support services, such as speech-language pathologists and physical and occupational therapists), individuals with disabilities (clients), and clients' families.

The next phase of the course involves students' selection of projects. Using the on-campus database, each student selects two clients to interview. The student and a UConn staff member meet with the client and client coordinator to identify a project that would improve the quality of life for the client. After the interview, the student writes a brief description for each project. Almost all of the clients interviewed have multiple projects. Project descriptions include contact information (client, client coordinator, and student name) and a short paragraph describing the problem. These reports are collected, sorted by topic area, and put into a Project Notebook. In the future, these projects will be stored in a database accessible from the course server for ease in communication.

Each student then selects a project from a client that he or she has visited, or from the Project Notebook. If the project selected was from the Project Notebook, the student visits the client to further refine the project. Because some projects do not require a full academic year to complete, some students work on multiple projects. Students submit a project statement that describes the problem, including a statement of need, basic preliminary requirements, basic limitations, other data accumulated, and important unresolved questions.

Specific projects at Ohio University are established via distance communication with the co-principal investigator, who consults with a wide array of service providers and potential clients in the Athens, Ohio region.

The stages of specification, project proposal, paper design and analysis, construction and evaluation,

and documentation are carried out as described earlier in the overview of engineering design.

To facilitate working with sponsors, a web-based approach is used for reporting the progress on projects. Students are responsible for creating their own Internet sites that support both html and pdf formats with the following elements:

- Introduction for the layperson,
- Resume,
- Weekly reports,
- Project statement,
- Specifications,
- Proposal, and
- Final Report.

### **Teamwork**

Student learning styles differ among team members. Gender, cultural factors, personality type, intelligence, previous educational background, academic achievement, and previous experience in teams may influence the strengths and weaknesses that individuals bring to team membership. Research pertaining to differences in cognitive style characterized by field dependence versus independence helps to shed light on individual differences among team members and how those differences may affect team interactions<sup>7,8</sup>. There is strong empirical evidence in numerous disciplines suggesting that students may benefit from explicit training to compensate for or enhance the cognitive

style with which they enter an educational experience, such as a senior design course.<sup>9,10,11</sup>

Research on effective teamwork suggests that key variables that should be attended to for optimal team performance include:

- Explicit sharing of the group's purpose among all team members,
- Concerted orientation to a common task,
- Positive rapport among team members,
- Responsiveness to change,
- Effective conflict management,
- Effective time management, and
- Reception and use of ongoing constructive feedback.

According to the literature on cooperative learning in academic contexts,<sup>12,13</sup> the two most essential determiners for success in teamwork are positive interdependence and individual accountability. Positive interdependence, or effective synergy among team members, leads to a final project or design that is better than any of the individual team members may have created alone. Individual accountability, or an equal sharing of workload, ensures that no team member is overburdened and also that every team member has an equal learning opportunity and hands-on experience.

Because students are motivated to work and learn according the way they expect to be assessed, grading of specific teamwork skills of teams and of individual students inspires teams' and individuals' investment in targeted learning outcomes associated with

<sup>7</sup> Tinajero, C., & Paramo, M. F. (1997). Field dependence-independence and academic achievement: A re-examination of their relationship. *British Journal of Educational Psychology*, 67, 2, 199-212.

<sup>8</sup> Witkin, H.A., & Goodenough, D.R. (1981). *Cognitive Styles: Essence and Origins*. International Universities Press, Inc., NY.

<sup>9</sup> Deming, W. (1986). *Out of the crisis: quality, productivity, and competitive position*. Cambridge, Massachusetts: Cambridge University Press.

<sup>10</sup> Katzenbach, J. & Smith, D. (1993). *The wisdom of teams: creating the high-performance organization*.

Boston, Massachusetts: Harvard Business School Press.

<sup>11</sup> Larson, C. & LaFasto, F. (1989). *Teamwork: what must go right, what can go wrong*. Newbury Park, California: SAGE Publications.

<sup>12</sup> Cottell, P.G. & Millis, B.J. (1994). Complex cooperative learning structures for college and university courses. In *To improve the Academy: Resources for students, faculty, and institutional development*. Stillwater, OK: New Forums Press.

<sup>13</sup> Jaques, D. (1991). *Learning in groups*, 2nd edition. Guilford, Surrey, England: Society for Research into Higher Education.

teamwork. Teamwork assessment instruments have been developed in numerous academic disciplines and can be readily adapted for use in engineering design projects.

Clearly targeting and assessing teamwork qualities may help to alleviate conflicts among team members. In general, most team members are dedicated to the goals of the project and excel beyond all expectations. When there is a breakdown in team synergy, instructors may sometimes be effective in facilitating conflict resolution.

Timeline development by the team is vital to success, eliminates most management issues, and allows the instructor to monitor the activities by student team members. Activities for each week must be documented for each team member, with an optimal target of five to ten activities per team member each week. When each team member knows what specific steps must be accomplished there is a greater chance of success in completing the project.

### ***History of Teams in Senior Design at UConn Projects Before the NSF Program***

Before the NSF-sponsored program, senior design was sponsored by local industry. During these years, all of the students were partitioned into four-member teams whereby student names were selected at random to choose a particular sponsored project. The projects were complex, and team members were challenged to achieve success. All of the students met each week at a team meeting with the instructor. During the first semester, lectures on teaming and communication skills were given, as well as team skills training. No timelines were used and general project goals were discussed throughout the two semesters. A teaching assistant was used in the course as an assistant coach to help the students in whatever manner was necessary. In general, multidisciplinary teams were not formed since the student backgrounds were not the criteria used to select team members.

Procrastination, a lack of enthusiasm and poor planning were common themes among the students. Most teams encountered significant difficulties in completing projects on time. Conflict among team members was more frequent than desired, and in some extreme encounters, physical violence was threatened during lab sessions. Many students complained that the projects were too difficult, scheduling of team meetings was too challenging,

their backgrounds were insufficient, they had difficulty communicating ideas and plans among team members, and they did not have enough time with outside activities and courses. A peer evaluation was used without success.

### **NSF Projects Year 1**

During year one of the NSF senior design program, students worked individually on a project and were divided into teams for weekly meetings. The level of project difficulty was higher than previous years. The purpose of the team was to provide student-derived technical support at weekly team meetings. Students were also exposed to communication skills training during the weekly team meetings, and received feedback on their presentations. In addition, timelines were used for the first time, which resulted in greater harmony and success. The course improved relative to previous years. Many students continued working on their projects after the semester ended.

Throughout the year, students also divided themselves into dynamic teams apart from their regular teams based on needs. For example, students implementing a motor control project gathered together to discuss various alternatives and help each other. These same students would then join other dynamic teams in which a different technology need was evident. Dynamic teams were formed and ended during the semester. Both the regular team and dynamic teams were very important in the success of the projects.

Overall, students were enthusiastic about the working environment and the approach. Although students seemed content with being concerned only with their individual accomplishments, and completing a project according to specifications and on time, this approach lacked the important and enriching multidisciplinary team experience that is desired in industry.

### NSF Projects Year 2

During the second year of the NSF senior design program, seven students worked on two- and three-person team projects, and the remaining students in the class worked in teams oriented around a client; that is, a single client had three students working on individual projects. These projects required integration in the same way a music system requires integration of speakers, a receiver, an amplifier, a CD player, etc. In general, when teams were formed, the instructor would facilitate the teams' multidisciplinary nature. Two teams involved mechanical engineering students and electrical engineering students. The others were confined by the homogeneity of the remaining students. All of the students met each week at a team meeting with the same expectations as previously described, including oral and written reports. Dynamic teaming occurred often throughout the semester.

While the team interaction was significantly improved relative to previous semesters, the process was not ideal. Senior Design is an extremely challenging set of courses. Including additional skill development with the expectation of success in a demanding project does not always appear to be reasonable. A far better approach would be to introduce team skills much earlier in the curriculum, even as early as the freshman year. Introducing teamwork concepts and skills earlier and throughout the curriculum would ensure an improved focus on the project itself during the senior design experience.

### Timelines

At the beginning of the second semester, the students are required to update their timelines to conform to typical project management routines wherein the student focuses on concurrent activities and maps areas where project downtimes can be minimized. This updated timeline is posted on a student project web page and a hard copy is also attached to the student's workbench. This allows the professor or instructor to gauge progress and to determine whether the student is falling behind at a rate that will delay completion of the project.

Also during the second semester, the student is required to report project progress via the web on a weekly basis. Included in this report are sections of their timeline that focus on the week just past and on the week ahead. The instructor may meet with students to discuss progress or the lack thereof.

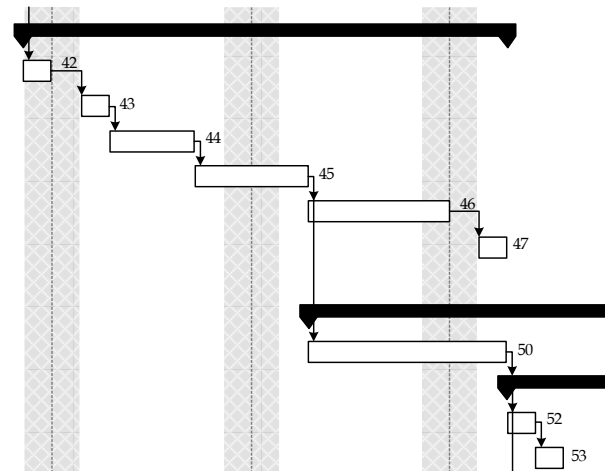


Fig. 2.1. Shown above is a section of a typical timeline. The rectangular boxes represent certain tasks to be completed. These singular tasks are grouped into larger tasks, represented by thick black lines. The tasks are numbered to correspond to a task list that is not shown. The thin lines that descend from task to task are the links. Notice that task 42 must be completed before task 43 can be started. Also, task 45 must be completed before task 46 and 50 can be started. However, task 46 and 50 are concurrent, along with task 47, and can therefore be completed at the same time. No link from task 47 shows that it is out of the critical path.

### Theory

The Senior Design Lab utilizes what is perhaps the most easily understood project-planning tool: the timeline. The timeline, or Gantt chart (see Fig. 2.1), displays each task as a horizontal line that shows the starting and ending date for each task within a project and how it relates to others.

The relation of one task to another is the central part of a timeline. The student lists tasks and assigns durations to them. The student then "links" these tasks together. Linking is done in the order of what needs to happen first before something else can happen. These links are known as dependencies. An example of this is a construction project. The foundation must be poured before you can start to erect the walls. Once all dependencies are determined, the end date of the project can be determined. This line of linked dependencies is also known as the critical path.

The critical path, the series of tasks in a project that must be completed on time for the overall project to stay on time, can be examined and revised to advance



the project completion date. If, after linking tasks, the timeline does not result in the required or desired completion date, it is recast. For example, sequential activities may be arranged to run in parallel, that is, concurrently to the critical path whenever this is practicable. An example of this is performing certain types of design work on sub-assembly B while injection mold parts are being manufactured for item A, which is in the critical path. In the case of the Senior Design Lab, the student would schedule report writing or familiarization of certain software packages or equipment concurrently with parts delivery or parts construction. Parallel planning prevents downtime – time is utilized to its fullest since work is always underway. The project completion date is also advanced when assigned durations of critical path tasks are altered. Concurrent tasks should be clearly delineated in the timeline for each project.

It is the planning and mapping of concurrent tasks that make the timeline a project-planning tool. In the modern working world time is a most valuable resource. The timeline facilitates time loading (resource management) by helping the project manager schedule people and resources most efficiently. For example, optimum time loading keeps a machining center from being overloaded one day and having zero work the next day. The timeline schedules “full time busy” for people and equipment, allowing for maximum pay-off and efficiency. In the machining center example, less than optimum time loading would delay any tasks that require usage of the center because a greater number of tasks are assigned than can be accomplished in the amount of time scheduled. Tasks would slide, resulting in delayed projects. The same idea of time loading is also applied to personnel resources. Less than optimal time loading could result in absurd schedules that require employees to work excessive hours to maintain project schedules.

A timeline also allows for updates in the project plan if a task requires more time than expected or if a design method turns out to be unsatisfactory, requiring that new tasks be added. These extra times or new tasks that outline the new design track are logged into the timeline with the project completion date being altered. From this information, the project manager can either alter durations of simpler tasks or make certain tasks parallel to place the new completion date within requirements.

The timeline also acts as a communication tool. Team members or advisors can see how delays will affect the completion date or other tasks in the project. Project progress is also tracked with a timeline. The project manager can see if the tasks are completed on time or measure the delay if one is present. Alterations to amount of resources or time spent on tasks are implemented to bring the project plan back on schedule. Alterations are also made by removing certain tasks from the critical path and placing them into a parallel path, if practical.

One major advantage of successful project planning using the timeline is the elimination of uncertainty. A detailed timeline has all project tasks thought out and listed. This minimizes the risk of missing an important task. A thoughtfully linked timeline also allows the manager to see what tasks must be completed before its dependent task can start. If schedule lag is noticed, more resources can be placed on the higher tasks.

#### **Method**

Discussed below is a method in which a timeline can be drawn. The Senior Design Lab utilizes Microsoft Project for project planning. Aspects such as assigning work times, workday durations, etc. are determined at this time but are beyond the scope of this chapter.

Tasks are first listed in major groups. Major groupings are anything that is convenient to the project. Major groups consist of the design and/or manufacture of major components, design type (EE, ME or programming), departmental tasks, or any number of related tasks. After the major groups are listed, they are broken down into sub-tasks. If the major group is a certain type of component, say an electro-mechanical device, then related electrical or mechanical engineering tasks required to design or build the item in the major group are listed as sub-groups. In the sub-groups the singular tasks themselves are delineated. All of the aforementioned groups, sub-groups, and tasks are listed on the left side of the timeline without regard to start, completion, or duration times. It is in this exercise where the project planner lists all of the steps required to complete a project. This task list should be detailed as highly as possible to enable the project manager to follow the plan with ease.

The desired detail is determined by the requirements of the project. Some projects require week-by-week



detail; other projects require that all resource movements be planned. It is also useful to schedule design reviews and re-engineering time if a design or component does not meet initial specifications as set out at project inception. Testing of designs or component parts should also be scheduled.

The second step in timeline drawing is the assignment of task duration. The project planner assigns time duration to each task, usually in increments of days or fractions thereof. If, for example, a task is the manufacturing of a PC Board (without soldering of components), the planner may assign a half-day to that task. All durations are assigned without regard to linking.

The next step is task linking. Here the planner determines the order in which tasks must be completed. Microsoft Project allows linking with simple keyboard commands. The planner links all tasks together with a final completion date being noted. It is in this step where the planner must make certain decisions in order to schedule a satisfactory completion date. Tasks may be altered with respect to their duration or scheduled as concurrent items. The critical path is also delineated during the linking exercise. Once a satisfactory completion date has been scheduled due to these alterations, the planner can publish his or her timeline and proceed to follow the work plan.

### ***Weekly Schedule***

Weekly activities in Design I consist of lectures, student presentations and a team meeting with the instructor. Technical and non-technical issues that impact the design project are discussed during team meetings. Students also meet with clients and coordinators at scheduled times to report on progress.

Each student is expected to provide an oral progress report on his or her activity at the weekly team meeting with the instructor, and record weekly progress in a bound notebook as well as on the web site. Weekly report structure for the web page includes: project identity, work completed during the past week, current work within the last day, future work, status review, and at least one graphic. The client and coordinator use the web reports to keep up with the project so that they can provide input on the progress. Weekly activities in Design II include team meetings with the course instructor, oral and written progress reports, and construction of the project. As

before, the Internet is used to report project progress and communicate with the sponsors. For the past two years, the student projects have been presented at the annual Northeast Biomedical Engineering Conference.

## **Other Engineering Design Experiences**

Experiences at other universities participating in this NSF program combine many of the design program elements presented here. Still, each university's program is unique. In addition to the design process elements already described, the program at the State University of New York at Buffalo, under the direction of Dr. Joseph Mollendorf, requires that each student go through the preliminary stages of a patent application. Naturally, projects worthy of a patent application are actually submitted. Thus far, a patent has been issued for a "Four-Limb Exercising Attachment for Wheelchairs" and another patent has been allowed for a "Cervical Orthosis."



# CHAPTER 3

## MEANINGFUL ASSESSMENT OF DESIGN EXPERIENCES

*Brooke Hallowell*

The Accrediting Board for Engineering and Technology (ABET)<sup>14</sup> has worked to develop increasingly outcomes-focused standards for engineering education. This chapter is offered as an introduction to the ways in which improved foci on educational outcomes may lead to: (1) improvements in the learning of engineering students, especially those engaged in design projects to aid persons with disabilities, and (2) improved knowledge, design and technology to benefit individuals in need.

### Brief History

As part of a movement for greater accountability in higher education, U.S. colleges and universities are experiencing an intensified focus on the assessment of students' educational outcomes. The impetus for outcomes assessment has come most recently from accrediting agencies. All regional accrediting agencies receive their authority by approval from the Council for Higher Education Accreditation (CHEA), which assumed this function from the Council on Recognition of Postsecondary Accreditation (CORPA) in 1996. The inclusion of outcomes assessment standards as part of accreditation by any of these bodies, (such as North Central, Middle States, or Southern Associations of Colleges and Schools, and professional accrediting bodies, including ABET), is mandated by CHEA, and thus is a requirement for all regional as well as professional accreditation. Consequently, candidates for accreditation are required to demonstrate plans for assessing educational outcomes, as well as evidence

that assessment results have led to improved teaching and learning and, ultimately, better preparation for beginning professional careers. Accrediting bodies have thus revised criteria standards for accreditation with greater focus on the "output" that students can demonstrate, and less on the "input" they are said to receive.<sup>15</sup>

### "Meaningful" Assessment Practices

Because much of the demand for outcomes assessment effort is perceived by instructors as time consuming bureaucratic chore, there is a tendency for many faculty members to avoid exploration of effective assessment practices. Likewise, many directors of academic departments engage in outcomes assessment primarily so that they may submit assessment documentation to meet bureaucratic requirements. Thus, there is a tendency in many academic units to engage in assessment practices that are not truly "meaningful".

Although what constitutes an "ideal" outcomes assessment program is largely dependent on the particular program and institution in which that program is to be implemented, there are at least some generalities we might make about what constitutes a "meaningful" program. For example:

An outcomes assessment program perceived by faculty and administrators as an imposition of bureaucratic control over what they do, remote from any practical implications... would not be considered "meaningful." Meaningful

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<sup>14</sup> Accrediting Board for Engineering and Technology. Criteria for Accrediting Engineering Programs 2010-2011. ABET: Baltimore, MD.

<sup>15</sup> Hallowell, B. & Lund, N. (1998). Fostering program improvements through a focus on

educational outcomes. In Council of Graduate Programs in Communication Sciences and Disorders, Proceedings of the nineteenth annual conference on graduate education, 32-56.

programs, rather, are designed to enhance our educational missions in specific, practical, measurable ways, with the goals of improving the effectiveness of training and education in our disciplines. They also involve all of a program's faculty and students, not just administrators or designated report writers. Furthermore, the results of meaningful assessment programs are actually used to foster real modifications in a training program.<sup>16</sup>

## Outcomes Associated with Engineering Design Projects

Despite the NSF's solid commitment to engineering design project experiences and widespread enthusiasm about this experiential approach to learning and service, there is a lack of documented solid empirical support for the efficacy and validity of design project experiences and the specific aspects of implementing those experiences. Concerted efforts to improve learning, assessment methods and data collection concerning pedagogic efficacy of engineering design project experiences will enhance student learning while benefiting the community of persons with disabilities.

## Agreeing on Terms

There is great variability in the terminology used to discuss educational outcomes. How we develop and use assessments matters much more than our agreement on the definitions of each of the terms we might use to talk about assessment issues. However, for the sake of establishing common ground, a few key terms are highlighted here.

### *Formative and Summative Outcomes*

Formative outcomes indices are those that can be used to shape the experiences and learning opportunities of the very students who are being assessed. Some examples are surveys of faculty regarding current students' design involvement, on-site supervisors' evaluations, computer programming proficiency evaluations, and

classroom assessment techniques.<sup>17</sup> The results of such assessments may be used to characterize program or instructor strengths and weaknesses, as well as to foster changes in the experiences of those very students who have been assessed.

Summative outcomes measures are those used to characterize programs, college divisions, or even whole institutions by using assessments intended to capture information about the final products of our programs. Examples are student exit surveys, surveys of graduates inquiring about salaries, employment, and job satisfaction, and surveys of employers of our graduates.

The reason the distinction between these two types of assessment is important is that, although formative assessments tend to be the ones that most interest our faculty and students and the ones that drive their daily academic experiences, the outcomes indices on which most administrators focus to monitor institutional quality are those involving summative outcomes. It is important that each academic unit strive for an appropriate mix of both formative and summative assessments.

### *Cognitive/Affective/Performative Outcome Distinctions*

To stimulate our clear articulation of the specific outcomes targeted within any program, it is helpful to have a way to characterize different types of outcomes. Although the exact terms vary from context to context, targeted educational outcomes are commonly characterized as belonging to one of three domains: cognitive, affective, and performative. Cognitive outcomes are those relating to intellectual mastery, or mastery of knowledge in specific topic areas. Most of our course-specific objectives relating to a specific knowledge base fall into this category. Performance outcomes are those relating to a student's or graduate's accomplishment of a behavioral task. Affective outcomes relate to personal qualities and values that students ideally gain from their experiences during a particular

<sup>16</sup> Hallowell, B. (1996). Innovative Models of Curriculum/Instruction: Measuring Educational Outcomes. In *Council of Graduate Programs in Communication Sciences and Disorders, Proceedings of the Seventeenth Annual Conference on Graduate Education*, 37-44.

<sup>17</sup> Angelo, T. A., & Cross, K. P. (1993). *Classroom assessment techniques: A handbook for college teachers*. San Francisco: Jossey-Bass.

educational/training program. Examples are appreciation of various racial, ethnic, or linguistic backgrounds of individuals, awareness of biasing factors in the design process, and sensitivity to ethical issues and potential conflicts of interest in professional engineering contexts.

The distinction among these three domains of targeted educational outcomes is helpful in highlighting areas of learning that we often proclaim to be important, but that we do not assess very well. Generally, we are better at assessing our targeted outcomes in the cognitive area (for example, with in-class tests and papers) than we are with assessing the affective areas of multicultural sensitivity, appreciation for collaborative teamwork, and ethics. Often, our assessment of performative outcomes is focused primarily on students' design experiences, even though our academic programs often have articulated learning goals in the performative domain that might not apply only to design projects.

### *Faculty Motivation*

A critical step in developing a meaningful educational outcomes program is to address directly pervasive issues of faculty motivation. Faculty resistance is probably due in large part to the perception that outcomes assessment involves the use of educational and psychometric jargon to describe program indices that are not relevant to the everyday activities of faculty members and students. By including faculty, and perhaps student representatives, in discussions of what characterizes a meaningful assessment scheme to match the missions and needs of individual programs we can better ensure a sense of personal identification with assessment goals on the part of the faculty. Also, by agreeing to develop outcomes assessment practices from the bottom up, rather than in response to top-down demands from administrators and accrediting agencies, faculty member skeptics are more likely to engage in assessment efforts.

Additional factors that might give faculty the incentive to get involved in enriching assessment practices include:

- Consideration of outcomes assessment work as part of annual merit reviews,
- Provision of materials, such as sample instruments, or resources, such as internet sites to simplify the assessment instrument design process

- Demonstration of the means by which certain assessments, such as student exit or employer surveys, may be used to make strategic program changes.

These assessment practices may be used to a program's advantage in negotiations with administration (for example, to help justify funds for new equipment, facilities, or salaries for faculty and supervisory positions).<sup>14</sup>

With the recent enhanced focus on educational outcomes in accreditation standards of ABET, and with all regional accrediting agencies in the United States now requiring extensive outcomes assessment plans for all academic units, it is increasingly important that we share assessment ideas and methods among academic programs. It is also important that we ensure that our assessment efforts are truly meaningful, relevant and useful to our students and faculty.

### *An Invitation to Collaborate in Using Assessment to Improve Design Projects*

Readers of this book are invited to join in collaborative efforts to improve student learning, and design products through improved meaningful assessment practices associated with NSF-sponsored design projects to aid persons with disabilities. Future annual publications on the NSF-sponsored engineering design projects to aid persons with disabilities will include input from students, faculty, supervisors, and consumers on ways to enhance associated educational outcomes in specific ways. The editors of this book look forward to input from the engineering education community for dissemination of further information to that end.

ABET's requirements for the engineering design experiences provide direction in areas that are essential to assess in order to monitor the value of engineering design project experiences. For example, the following are considered "fundamental elements" of the design process: "the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation" (p. 11). Furthermore, according to ABET, specific targeted outcomes associated with engineering design projects should include:

- Development of student creativity,
- Use of open-ended problems,
- Development and use of modern design theory and methodology,



- Formulation of design problem statements and specifications,
- Consideration of alternative solutions, feasibility considerations,
- Production processes, concurrent engineering design, and
- Detailed system descriptions.

The accrediting board additionally stipulates that it is essential to include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impact. ABET's most recent, revised list of similar targeted educational outcomes is presented in the Appendix to this chapter. We encourage educators, students and consumers to consider the following questions:

- Are there outcomes, in addition to those specified by ABET, that we target in our roles as facilitators of design projects?
- Do the design projects of each of the students in NSF-sponsored programs incorporate all of these features?
- How may we best characterize evidence that students engaged in Projects to Aid Persons with Disabilities effectively attain desired outcomes?
- Are there ways in which students' performances within any of these areas might be more validly assessed?
- How might improved formative assessment of students throughout the design experience be used to improve their learning in each of these areas?

Readers interested in addressing such questions are encouraged to send comments to the editors of this book. The editors of this book are particularly interested in disseminating, through future publications, specific assessment instruments that readers find effective in evaluating targeted educational outcomes in NSF-sponsored engineering design projects.

Basic terminology related to pertinent assessment issues was presented earlier in this chapter. Brief descriptions of cognitive, performative, and affective types of outcomes are provided here, along with lists

of example types of assessments that might be shared among those involved in engineering design projects.

Cognitive outcomes are those relating to intellectual mastery, or mastery of knowledge in specific topic areas. Some examples of these measures are:

- Comprehensive exams,
- Items embedded in course exams,
- Pre- and post-tests to assess "value added",
- Design portfolios,
- Rubrics for student self-evaluation of learning during a design experience,
- Alumni surveys, and
- Employer surveys.

Performative outcomes are those relating to a student's or graduate's accomplishment of a behavioral task. Some performance measures include:

- Evaluation of graduates' overall design experience,
- Mastery of design procedures or skills expected for all graduates,
- Student evaluation of final designs, or of design components,
- Surveys of faculty regarding student design competence,
- Evaluation of writing samples,
- Evaluation of presentations,
- Evaluation of collaborative learning and team-based approaches,
- Evaluation of problem-based learning,
- Employer surveys, and
- Peer evaluation (e.g., of leadership or group participation).

Affective outcomes relate to personal qualities and values that students ideally gain from their educational experiences. These may include:

- Student journal reviews,
- Supervisors' evaluations of students' interactions with persons with disabilities,
- Evaluations of culturally-sensitive reports,
- Surveys of attitudes or satisfaction with design experiences,
- Interviews with students, and
- Peers', supervisors', and employers' evaluations.

## **APPENDIX: Desired Educational Outcomes as Articulated in ABET's "Engineering Criteria for the 2011-2012 Academic Year" (Criterion 3, Student Outcomes)<sup>18</sup>**

Engineering programs must demonstrate that their graduates have:

- (a) an ability to apply knowledge of mathematics, science, and engineering
- (b) an ability to design and conduct experiments, as well as to analyze and interpret data
- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- (d) an ability to function on multidisciplinary teams
- (e) an ability to identify, formulate, and solve engineering problems
- (f) an understanding of professional and ethical responsibility
- (g) an ability to communicate effectively
- (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- (i) a recognition of the need for, and an ability to engage in life-long learning
- (j) a knowledge of contemporary issues
- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

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<sup>18</sup> ABET, Engineering Accreditation Commission (2011-12). Criteria for Accrediting Engineering Programs. ABET: Baltimore, MD, p. 3.





# CHAPTER 4

## USING NSF-SPONSORED PROJECTS TO ENRICH STUDENTS' WRITTEN COMMUNICATION SKILLS

*Brooke Hallowell*

Based on numerous anecdotes offered inside and outside of engineering, age-old stereotypes that engineers lack communication skills may have some basis in fact. However, current work environments for most new graduates in a host of professional biomedical engineering contexts, place such heavy expectations for, and demands on, excellence in oral and written communication that engineers' lack of communication skills can no longer be tolerated as a trade-off for their strengths in science and mathematics. Evolving requirements for communication with interdisciplinary team members, clients, patients, consumers, employers, and the public require that educators of engineers work hard to ensure that students reach a standard of excellence in communication before they enter the workforce. This chapter is offered to provide specific guidance on principles and resources for enriching written communication skills in biomedical engineering students through their NSF-sponsored design project experiences.

### **A Formative Focus**

As discussed in the previous chapter, a formative focus on academic assessment allows educators to use assessment strategies that directly influence students who are still within their reach. A solid approach to formative assessment of writing skills involves repeated feedback to students throughout educational programs, with faculty collaboration in reinforcing expectations for written work, use of specific and effective writing evaluation criteria, and means of enhancing outcomes deemed important for regional and ABET accreditation. Given that most students in the NSF-sponsored Senior Design Projects to Aid Persons with Disabilities programs are already in their fourth year of college-level study, it is critical to recognize that previous formative writing

instruction is essential to their continued development of writing skills during the senior year. Model strategies for improving writing presented here in light of senior design projects may also be implemented at earlier stages of undergraduate learning.

### **Clarifying Evaluation Criteria**

Student learning is directly shaped by how students think they will be assessed. Regardless of the lofty goals of excellence instructors might set forth in course syllabi and lectures, if specific performance criteria are not articulated clearly and assessed directly, then students are unlikely to reach for those same goals. To enhance writing skills effectively through the senior design experience, specific evaluation criteria for writing quality must be established at the start of the senior design experience. Clear expectations should be established for all written work, including related progress reports, web page content, and final reports. Although the examples provided here are oriented toward writing for annual NSF publications, the basic assessment process is ideally applied to other areas of written work as well.

### **Elements of Writing to be Assessed**

What aspects of writing quality are important in writing about senior design projects? The list of specific ideal aspects varies among instructors. Still, consideration of guidelines already proposed may help to streamline the development of finely tuned assessment instruments to shape and evaluate student writing. Each year, the editors of this annual publication on senior design projects send guidelines for manuscript publication to principal investigators on NSF-sponsored Engineering Senior Design Projects to Aid Persons with Disabilities grants.

Those guidelines form the basis for the elements of writing on which writing projects may be evaluated.

A sample grading form, based on the most recent version of those guidelines at the time of this publication, may be found in Appendix A. Explicit writing criteria are specified, and a means for explicit scoring according to those criteria is provided. Instructors may use such a form to evaluate drafts and final project reports. Specific item descriptions and the relative weighting of the value of performance in specific areas may be modified according to instructor preferences. Application of such scoring systems to student course grades will ensure greater student accountability for meeting explicit writing standards.

General categories for analyzing writing performance for project reports include: 1) form and formatting, 2) accompanying images, 3) grammar, spelling, punctuation, and style, 4) overall content, and 5) content within specific sections.

Form and formatting concerns are related primarily to students following of explicit instructions regarding page limitation, spacing, margins, font size, indentations, and headings. Items related to images include the type, quality, relevance and formatting of photographs and drawings used to illustrate reports. Issues of grammar, spelling, punctuation, and style may be largely addressed through adherence to specific conventions for each of these areas. Thorough proofreading and use of computerized checks for spelling and grammar, although frequently recommended by instructors, are not as likely to be carried out by students who are not expecting to be assessed for performance in these important areas.

Areas of overall content evaluation for senior design reports include aspects of writing that are often among the most problematic for undergraduate engineers. One such area is that of using appropriate language when referring to individuals with disabilities. Reports submitted for NSF publications often include terms and descriptions that may be considered offensive by many, such that the editors of this annual publication often engage in extensive rewriting of sections including client descriptions. It is most likely that students engaged in projects for persons with disabilities are wholeheartedly supportive of their clients, and use such terms out of naiveté rather than any ill intent. Still, the words we

use to communicate about other people powerfully influences readers' perceptions of them, especially in cases in which readers may be unfamiliar with the types of conditions those people are experiencing. Using appropriate language is of paramount importance to our joint mission of enabling individuals to live fully and with maximum independence. It is thus critical that instructors provide clear instruction and modeling for appropriate language use in writing about disabilities. In cases where instructors may have outdated training concerning language use in this arena, it is critical that they seek training regarding sensitivity in language use.

Basic guidelines for writing with sensitivity about persons with disabilities are summarized briefly in Appendix B. Using person-first language, avoiding language that suggests that individuals with disabilities are "victims" or "sufferers", and avoiding words with negative connotations are three key components to appropriate language use.

Evaluation of content within specific sections of senior design project reports will help students focus on drafting, appropriately revising and editing reports. By discussing and evaluating specific criteria - such as the use of laypersons' terms in a project description, effective description of the motivation for a particular design approach, and the use of clear, concise technical language to describe a device modification such that others would be able to replicate the design - instructors may help students further hone their writing and revision skills.

## **A Hierarchy of Revision Levels**

Constructive feedback through multiple revisions of written work is critical to the development of writing excellence. Even for the accomplished writer, a series of drafts with a progressive evolution toward a polished product is essential. It is thus important that instructors allow time for revision phases for all writing assignments throughout the senior design experience.

Three basic levels of writing revision proposed by some authors include global, organizational, and

polishing revision<sup>19</sup>. Global revision involves a general overhaul of a document. Macro-level feedback to students about their general flow of ideas and adherence to assignment guidelines helps to shape an initially-submitted draft into a version more suitable for organizational revision. Organizational revision requires reshaping and reworking of the text. Helpful feedback to students at this level may involve revising of macro-level issues not corrected since the initial draft, and/or a focus on new micro-level issues of coherence, clarity, relevance, and word choice. Polishing revision entails attention to such flaws as grammatical errors, misspellings, misuse of punctuation, and specific formatting rules for the assignment. Finding patterns of errors and providing constructive feedback about those patterns may help individuals or teams of students learn efficient strategies for improving their written work.

### **Structured Critical Peer Evaluation**

Many instructors require several forms of written assignments within project design courses, including the final reports required for submission to the NSF-sponsored annual publication. Consequently, it is

impractical or impossible for many instructors to provide evaluation and feedback at three levels of revision for each written assignment. One means of promoting students' experience with critical reflection on writing is to implement assignments of structured critical evaluation of writing using reader-response strategies, with students as editors for other students' work. Students (as individuals or on teams) may be given a basic or detailed rubric for evaluating other students' written work, and explicit guidelines for providing structured constructive comments following critical evaluation.

### **Resources and Support**

Numerous excellent texts are available to promote and provide structure and guidance for the development of essential writing skills in engineering students. Some sample recommended texts are listed in Appendix C. Comments and suggestions from instructors, who have developed model writing programs for engineering design courses at any level of study, are welcome to submit those to the editors of this book, to be considered for future publication.

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<sup>19</sup> Ohio University Center for Writing Excellence Teaching Handouts [on-line] (2007). Available at: <http://www.ohio.edu/writing/tr1.cfm>

## APPENDIX A: Sample Evaluation Form for Project Reports Prepared for Annual NSF Publications on Senior Design Projects to Aid Persons with Disabilities

Item evaluated	Score/ Possible Score
<b>A. Form and formatting</b>	
Does not exceed two pages (unless authorized by instructor)	/2
10-point type size throughout the manuscript	/2
Margin settings: top =1", bottom=1", right=1", and left=1"	/2
Title limited to 50 characters on each line (if longer than 50 characters, then skips two lines and continues, with a blank line between title text lines)	/1
Text single spaced	/2
No indenting of paragraphs	/1
Blank line inserted between paragraphs	/1
Identifying information includes: project title, student name, name of client coordinator(s), supervising professor(s), university address	/2
Appropriate headings provided for Introduction, Summary of impact, and Technical description sections	/2
<b>Total points for form and formatting</b>	<b>/15</b>
<b>B. Images</b>	
Photographs in black and white, not color	/1
Photographs are hard copies of photo prints, not digital	/1
Line art done with a laser printer or drawn professionally by pen with India (black) ink	/2
Images clearly complement the written report content	/2
Photographs or line art attached to report by paperclip	/1
Photographs or line art numbered on back to accompany report	/1
Figure headings inserted within the text with title capitalization, excluding words such as "drawing of" or "photograph of"	/2
<b>Total points for images</b>	<b>/10</b>

<b>C. Grammar, spelling, punctuation, and style</b>	
Consistent tenses throughout each section of the report	/2
Grammatical accuracy, including appropriate subject-verb agreement	/2
Spelling accuracy	/2
Appropriate punctuation	/2
Abbreviations and symbols used consistently throughout (For example, " or in. throughout for "inch;" excludes apostrophe for plural on abbreviations, such as "BMEs" or "PCs"	/2
Uses the word "or" rather than a slash (/) (For example, "He or she can do it without assistance.")	/1
Numbers one through 9 spelled out in text; number representations for 10 and higher presented in digit form (except in series of numbers below and above 10, or in measurement lists)	/1
In lists, items numbered, with commas between them (for example: "The device was designed to be: 1) safe, 2) lightweight, and 3) reasonably priced.")	/1
Consistent punctuation of enumerated and bulleted lists throughout the report	/2
<b>Total points for grammar, spelling, punctuation, and style</b>	<b>/15</b>
<b>D. Overall content</b>	
Excludes extensive tutorials on specific disabilities	/2
Demonstrates appropriate language regarding individuals with disabilities	/3
Avoids redundancy of content among sections	/3
Demonstrates clear and logical flow of ideas	/3
Excludes use of proper names of clients	/3
Citation and reference provided for any direct quote from published material	/1
<b>Total points for overall content</b>	<b>/15</b>

<b>E. Section content</b>	
<b>Introduction</b>	
Includes a brief description of the project in laypersons' terms	/4
Includes problem addressed, approach taken, motivation for the approach, a summary of usual or existing solutions, and problems with these solutions	/4
<b>Summary of impact</b>	
Includes a brief description of how this project has improved the quality of life of a person with a disability	/5
Includes a quoted statement from an educational or health care specialist who supervises the client, or from a significant other	/2
Includes a description of the project's usefulness and overall design evaluation	/5
<b>Technical description</b>	
Clear, concise technical description of the device or device modification such that others would be able to replicate the design	/10
Detailed parts lists included only if parts are of such a special nature that the project could not be fabricated without the exact identity of the part	/2
Text refers to circuit and/or mechanical drawing of the device	/3
Includes analysis of design effectiveness	/5
Concludes with approximate cost of the project, including parts and supplies (not just the NSF's contribution) and excluding personnel costs	/5
<b>Total points for section content</b>	<b>/45</b>

Evaluation Summary

<b>A. Total points for form and formatting</b>	<b>/15</b>
<b>B. Total points for images</b>	<b>/10</b>
<b>C. Total points for grammar, spelling, punctuation, style</b>	<b>/15</b>
<b>D. Total points for overall content</b>	<b>/15</b>
<b>E. Total points for section content</b>	<b>/45</b>
<b>TOTAL POINTS</b>	<b>/100</b>

## APPENDIX B: A Summary of Guidelines for Writing about Persons with Disabilities

The World Health Organization (WHO) has launched world-wide efforts to modify the ways in which we refer to persons with disabilities. The WHO emphasizes that disablement is not considered an attribute of an individual, but rather the complex interactions of conditions involving a person in the context of his or her social environment. An early classification scheme proposed by the WHO, the International Classification of Impairments, Disabilities and Handicaps (ICIDH) employs the general terms "impairment", "disability", and "handicap"; a more recent scheme, the ICIDH-2, employs the terms "impairment", "activity", and "participation"; the most recent version, the International Classification of Functioning, Disability and Health (ICF), suggests that body functions and structures, activities and participation should refer to the various contextual aspects of disabling conditions one might experience.<sup>20</sup> Healthcare professionals and researchers throughout the world are following suit by de-emphasizing the reference to individuals according to medically-based diagnostic categories, focusing instead on their holistic functional concerns and what might be done to address them. Readers of this book are encouraged to join in this important movement. General guidelines are presented here.

### *Recognize the importance of currency and context in referring to individuals with disabilities*

There are always variances in the terms that particular consumers or readers prefer, and it is essential to keep current regarding changes in accepted terminology.

### *Refer to "disabilities"*

Although the very term "disability" may be considered offensive to some (with its inherent focus

on a lack of ability), it is currently preferred over the term "handicap" in reference to persons with physical, cognitive, and/or psychological challenges or "disabilities".

### *Use person-first language*

Person-first language helps emphasize the importance of the individuals mentioned rather than their disabilities. For example, it is appropriate to refer to a "person with a disability" instead of "disabled person," and to say "a child with cerebral palsy" instead of "a cerebral palsied child."

### *Avoid using condition labels as nouns*

Many words conveying information about specific disabilities exist in both noun and adjectival forms, yet should primarily be used only as adjectives, or even better, modified into nouns corresponding to conditions, as in the person-first language examples given above. For example, it is not appropriate to call an individual with aphasia "an aphasic." Although the term "an aphasic individual" would be preferred to the use of "an aphasic" as a noun, such labeling may convey a lack of respect for, and sensitivity toward, individuals who have aphasia.<sup>21</sup> A more appropriate term would be "person with aphasia." Likewise, it is not appropriate to call an individual with paraplegia "a paraplegic," or to call persons with disabilities "the disabled."

### *Avoid Language of Victimization*

Do not use language suggesting that clients are "victims" or people who "suffer" from various forms of disability. For example, say, "the client had a stroke" rather than "the client is a stroke victim." Say, "She uses a wheelchair," rather than "she is confined to a wheelchair." Say "her leg was amputated..." instead of, "the client suffered an amputation of the leg."

<sup>20</sup> World Health Organization (2007). International Classification of Functioning, Disability and Health (ICF) [on-line]. Available: <http://www.who.int/classifications/icf/en/>

<sup>21</sup> Brookshire, R.H. (1992). An introduction to neurogenic communications disorders. St. Louis: Mosby - Year Book.

***Avoid words with negative connotations***

Words that evoke derogatory connotations should be avoided. These include such words and phrases as affliction, crazy, crippled, defective, deformed, dumb, insane, invalid, lame, maimed, mute, retard, and withered.

***Encourage others in appropriate language use***

By modeling appropriate language in writing about persons with disabilities, authors take an important

step in helping others to improve in this area. It is also important to help others learn to implement guidelines such as these directly through course work and other educational experiences. Likewise, polite and constructive corrections of others using inaccurate language helps encourage more positive communication as well as more enabling positive societal attitudes, widening the arena for empowering persons with disabilities.



# CHAPTER 5

## CONNECTING STUDENTS WITH PERSONS WHO HAVE DISABILITIES

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### INTRODUCTION

For many students, participation in the National Science Foundation (NSF) projects to aid persons with disabilities is a unique experience. Often it is their first opportunity to work with individuals with disabilities. As such, not only must they meet the academic requirements of their senior design project, but in order to be successful, they must also learn about disabilities and related issues. Only when students are able to combine their scientific

knowledge with an understanding of other related humanistic factors will they be able to make significant contributions to the field. Therefore, it is imperative for engineering programs participating in the NSF projects to ensure that students have the opportunity to gain the necessary awareness and social competencies needed. Specifically, students need to have a basic understanding of philosophical attitudes toward disability as well as an understanding of assistive technology and how to communicate effectively with persons with

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<sup>22</sup> Portions of “The Engineering Perspective” were presented at the 40th Annual Rocky Mountain Bioengineering Symposium, April 2003, Biloxi, MS (Barrett, 2003)

disabilities. This awareness and understanding will not only enable students to have a more meaningful experience, but also ensure a more meaningful experience for the individuals with whom they will be working.

Students must also understand the engineering aspects of their project. The engineering aspects may be viewed from two different levels: the programmatic aspects of the project and the engineering details of their specific project. At the program level, projects must be properly scoped for difficulty and required expertise. At the individual project level the projects must meet specific requirements but also must be safe and reliable. Senior design faculty as well as participating students have the joint responsibility of ensuring that these engineering aspects are met.

In this chapter we will discuss these diverse yet related aspects of National Science Foundation engineering senior design projects to aid persons with disabilities. We will first examine the social constructs of disability, followed by the proper language of disability. We will then investigate assistive technology and universal design principles. This chapter will conclude with a discussion of the engineering aspects for a successful design experience.

### *Models of Disability*

There are three predominant social constructs of disability. These models define the source or problem of disability and determines the ways to best address the related issues. The oldest model is the moral model, which posits that disability is caused by moral lapse or sin. It explains disability as a supernatural phenomenon or act of god that serves as punishment and represents the consequences of perceived wrongdoing. It brings shame to the individual and in cultures that emphasize family and/or groups over the individual, the shame spreads to the family and/or group. The person or family carries the blame for causing the disability. In a tenuously more auspicious interpretation of the moral model, disability is perceived as a test of faith (i.e. "God only gives us what we can bear") or as a mystical experience in which one sense may be impaired but others are heightened and the adversity of the disability provides increased emotional and spiritual strength often recognized by the belief that "with the grace of God" the disability can be overcome.

Given the limitations of the moral model, the medical model began to emerge in the mid- 1800s as a result of developing science and improved humanistic medicine. In this model, disability is recognized as a medical problem that resides within the individual. It is a dysfunction, defect, or abnormality that needs to be fixed. The ambition is to restore normality and cure the individual. It is a paternalistic model that expects an individual to assume the role of a victim or sick person and avail themselves to medical professionals and services. The individual is a passive participant. However, as medicine and professionals have advanced in their knowledge and understanding, this model has given way to a more person-centered version, often referred to as the rehabilitation model, in which disability is analyzed in terms of function and limitations. In this paradigm, a more holistic approach is taken. The individual is a more active participant and his or her goals are the basis for therapeutic intervention. The emphasis is on functioning within one's environments. A variety of factors are assessed in terms of barriers and facilitators to increased functioning. This model recognizes disability as the corollary of interaction between the individual and the environment. The individual is recognized as a client and the emphasis is based on assisting the individual in adjusting or adapting. It is important to note that, although this model derives from a systems approach, the primary issues of disability are still attributed to the individual.

In the last 30 years, another model has emerged: the social model of disability, which is also referred to as a minority group model and/or independent living model. Its genesis resides within the disability rights movement and proclaims that disability is a social construction. Specifically, the problem of disability is not within the individual, but within the environment and systems with which the individual must interact. The barriers that prevent individuals with disabilities from participating fully and equally within society include prejudice, discrimination, inaccessible environments, inadequate support, and economic dependence.

While it is beyond the scope of this chapter to view these constructs in detail, an awareness of these models enables one to examine one's own beliefs and attitudes toward disability. It also helps students understand that they will encounter both professionals and persons with disabilities whose beliefs are rooted in any one (or combination of) these

identified constructs. Although it may not be readily evident, these beliefs will impact how students approach their projects, their ability to see beyond the disability and consider other related factors, and their ability to establish meaningful relationships with the individuals they are trying to assist. Therefore, it is highly recommended that all engineering programs establish collaborative partnerships with other disability professionals in order to provide students with an awareness of disability issues. Potential partners include other programs within the university, especially those with disability studies programs, state assistive technology projects, and independent living centers.

### *Language of Disability*

Terminology and phrases used to describe many people (those with and without disabilities) have changed over time. Many words and phrases are embedded in the social constructs and ideologies of our history and the changes in terminology reflect the paradigm shifts that have occurred over time. For example, the terms Native American or African American have changed with the Zeitgeist and no longer reflect the often derogatory words or phrases that preceded them. Although there is often disdain for those that advocate political correctness, it is important to realize that words and expressions can be powerful and that they do, in fact, communicate attitudes, perceptions, feelings, and stereotypes. They can be oppressive or empowering. The changes in language that have occurred represent an acceptance of diversity and a respect for differences which ultimately impact social change. As professionals and educators, we are in fact, agents of change, and it is our responsibility to recognize the power of language and to use it befittingly in our conversations, discussions and writings.

In regard to disability, the use of person first language (i.e. always putting the person before the disability) recognizes the person first and foremost as a unique individual. In contrast, referring to someone by his or her disability defines them by a single attribute and limits the ability to distinguish who they are as a person from the disability, which in fact they may consider to be a very minute characteristic. For example, the statement “The stroke victim’s name is Joe” conjures up a very different image from “Joe is a great musician who had a stroke last year”, or “she can’t ski; she is paralyzed and confined to a wheelchair” versus “she loves to ski and uses a sit ski device because she has paraplegia and is a wheelchair

user.” Putting the person before the disability demonstrates respect and acknowledges the person for who he or she is, not for what he or she does or does not have. Although it may seem awkward when one first begins to use person first language, it will become natural over time, it will demonstrate respect, and it will have a positive societal impact. For guidelines on person-first language, a keyword internet search will reveal many resources. For detailed guidelines on writing, see Chapter 4.

### *Assistive Technology and Universal Design*

Assistive Technology (AT) is a general term that describes any piece of equipment or device that may be used by a person with a disability to perform specific tasks and to improve or maintain functional capabilities, thus providing a greater degree of independence, inclusion, and/or community integration. It can help redefine what is possible for people with a wide range of cognitive, physical, or sensory disabilities. AT can be simple or complex. It can include off-the-shelf items as well as special designs. Devices become AT through their application. This technology may range from very low-cost, low-tech adaptations (such as a battery interrupter to make a toy switch accessible) to high-tech, very expensive devices (such as a powered mobility equipment and environmental controllers).

AT can include cognitive aids, aids to assist with walking, dressing, and other activities of daily living, aids to augment hearing or vision, adaptive recreation devices, augmentative communication aids, and alternate computer access. Services related to Assistive Technology may include evaluation for appropriate equipment and systems, assistance with purchasing or leasing devices, and selecting, defining, fitting, adapting, applying, maintaining, repairing, or replacing equipment and systems. In addition, services could include training and technical assistance for individuals and their families, and/or other professionals. Assistive Technology may be used at home, in the workplace, in the classroom and in the community to provide creative solutions in assisting individuals as they go about their activities of living, learning, working, and playing.

Universal Design (UD) refers to a concept or philosophy for designing and delivering products and services that are usable by people with the widest possible range of functional capabilities. This includes products and services that are directly

usable (without requiring assistive technology) and products and services that are made usable with assistive technology.

As noted earlier, the social model of disability focuses on the environment as the most significant barrier preventing people with disabilities from full contribution to all aspects of society. As such, the concepts of universal design have significant potential for remedy (see reference section for resources specific to universal design). The basic premise of universal design is to create access, in terms of the mass marketplace as well as community and information environments, for as many people as possible, regardless of age, size, or ability.

It is estimated that approximately thirty million people have a disability or functional limitation due to injury, illness or aging (Vanderheidin, 1990). With the advances in modern medicine and the emerging inroads in health promotion and disease prevention, people are living longer. Nearly everyone will experience some type of functional limitation during the course of a lifetime. Given such broad prevalence of disability in the general population, the need for universal design becomes self-evident.

The underlying principles of universal design (UD) are available for review at [www.design.ncsu.edu](http://www.design.ncsu.edu), The Center for Universal Design, North Carolina State University. These basic principles provide the philosophical interface between functional limitations/disability and best practices in design. In fact, universal design principles can often simplify the adaptation or even eliminate the need for specialized design created specifically for the individual person. Conversely, when prototype devices are necessary, if they adhere to principles of UD, it is much more likely that the device will also be able to be adopted by others and that the technology will be able to be transferred to other applications. When assistive technology is necessary to support access and/or use of the built environment, products, or information, the understanding that any design must first and foremost respect personal dignity and enhance independence without stigmatizing the individual is critical. This is clearly a quality of life issue for everyone. Working with an individual who has disabilities to develop assistive technology requires the engineer to actively collaborate, respecting the right of each person to self-determination and self-control (Shapiro, 1993).

In general, the areas of functional limitation most amenable to benefit from the concepts of universal design (and assistive technology where necessary) are in the broad categories of: communication, mobility, sensory, manipulation, memory, and cognition. All design should consider and address varying human abilities across each of these domains. The goal of universal design is to eliminate, as much as possible, the need for assistive technologies because the focus of all design is inclusive rather than restrictive. Historically, designs were often based on the young, able-bodied male. With the advent of UD, designers are redefining the user to include as many people as possible with the widest range of abilities.

There are many examples of how assistive technologies have been adopted by the general population. For example, at one time the use of closed captioning was limited to individuals who were hard of hearing or deaf. Today, captioning can be seen on televisions located in public places such as restaurants, airports, and sports bars. Captioning is also used by many people in their own homes when one person wishes to watch TV while another does not. Other examples include ramps, curb cuts and automatic door openers. Initially designed for individuals who were wheelchair users, it was quickly realized they also benefited delivery personnel, people with strollers, people with temporary injuries, cyclists, etc. In addition, many items related to computer access such as voice recognition, are now employed in a variety of computer and telecommunication applications. When UD principles are employed, the whole environment, in the broadest sense becomes more humane and maximizes the potential contribution of everyone, not just those with disabilities.

As senior design students explore their options for projects, an awareness of disability issues, existing assistive technologies and universal design principles will ensure that their projects incorporate state-of-the-art practices. A list of valuable resources is included at the end of this chapter.

### *The Engineering Perspective*

To provide for a successful Engineering Senior Design Projects to Aid Persons with Disabilities Program, projects must be successful at both the program level and the individual project level. In this section we discuss aspects of a successful program and use the University of Wyoming's program as a case study.

To be successful at the academic program level, a program must successfully address the following aspects:

- Provide a team approach between assistive technology professionals and engineering participants,
- Receive appropriate publicity within assistive technology channels,
- Provide projects that have been properly scoped for difficulty, student team size, and required student expertise, and
- Have mechanisms in place to address the safety aspects of each project and the legal aspects of the program.

To address these needs, the College of Engineering partnered with four other programs to identify the specific needs of the individual. Specifically, the college joined with the Wyoming Institute for Disabilities (WIND) assistive technology program, Wyoming New Options in Technology (WYNOT) (including their Sports and Outdoor Assistive Recreation (SOAR) project) and the university's special education program.

With this assembled team of professionals, specific duties were assigned to the team members. The WYNOT Project Director served as the coordinator with the community to identify specific assistive technology needs. This was accomplished using a short project application to identify the desired assistive device and the special needs of the individual. Project proposals were initiated by the individual with a disability, his or her family members, caregivers, or teachers, or any of the service agencies in the state of Wyoming. WYNOT was also the key player in the promotion of the Biomedical Engineering Program and Research to Aid Persons with Disabilities (BME/RAPD). Marketing included featured articles in the WYNOT newsletter, posting of project information on the WYNOT website, development of a project website (<http://www.eng.uwyo.edu/electrical/faculty/barr ett/assist/>), public service announcements, and statewide and nationwide press releases.

The WYNOT project director and the engineering PI met on a regular basis to evaluate the suitability of the submitted projects. Specifically, each requested project was reviewed to ensure it was sufficiently challenging for a year-long senior design project. Also, the required engineering expertise was scoped

for each project. Once a project was determined to be of suitable scope for an undergraduate design project, the PI coordinated with the appropriate engineering department(s) to publicize the project in the senior design course. This process is illustrated in Fig. 5.1. Overall, an individual with a disability was linked with a student engineering team, which was to provide a prototype custom designed assistive device specific to his or her needs.

Since these projects involve the use of human subjects, students were required to complete an Institutional Review Board (IRB) study prior to initiating a specific project. These studies were completed and submitted to the IRB per federal and university guidelines. Furthermore, projects were delivered to the recipients only after extensive testing. At that time the recipient or his or her legal guardian signed a "Hold Harmless" agreement. This agreement was reviewed and approved by the university's legal office.

At the individual project level, students must:

- Be educated on assistive technology awareness,
- Be committed to delivering a completed, quality project,
- Be aware of available expertise to assist with the technical aspects of the project,
- Work closely with the individual who will be using the project, and
- Provide adequate time in the project schedule for testing and remanufacture if required.

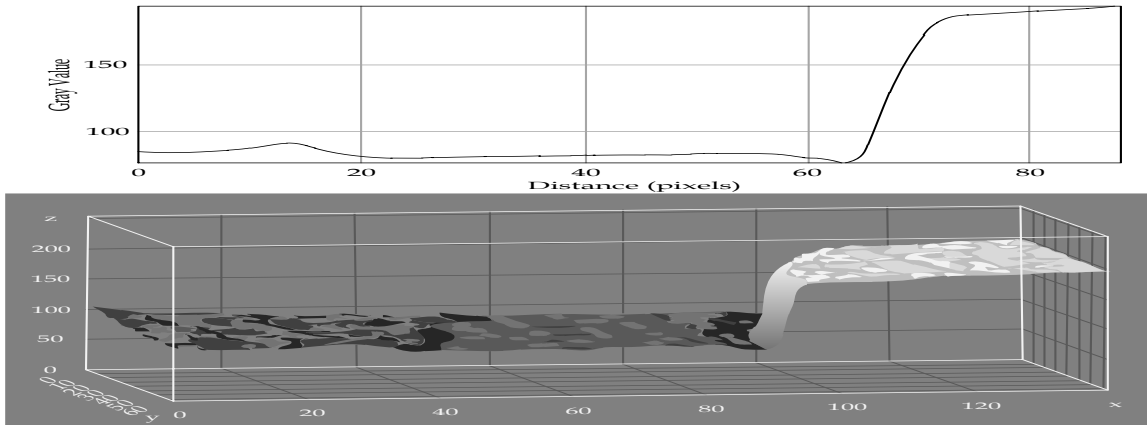


Fig. 5.1. Program Flow for Undergraduate Design Projects to Aid Wyoming Persons with Disabilities (Barrett, 2003).

To assist the students in developing these aspects of the project, the PI met with each senior design course at the beginning of the semester. The PI reviewed the purpose of the program, described potential projects, and also emphasized the importance of delivering a completed project. Students were encouraged to meet individually with the PI if they wanted more information about a specific project. At these follow-up meetings, the students were given all available information about the project and a point of contact to obtain more information from the requesting assistive technology agency or individual. Students were encouraged to contact these individuals to begin developing a relationship between the project user and designer.

Many of the projects were interdisciplinary in nature typically involving both mechanical and electrical engineering students. Faculty advisors for the senior design courses set up several “get acquainted” sessions at the local pizza parlor for students to get to know each other and also to review potential projects.

WYNOT also provided training to the engineering students regarding assistive devices and services. This training was provided to all students in the senior design course regardless if they were participating in the assistive technology program. This provided disability awareness to the state’s next generation of engineers.

### ***Expected Benefits***

It is a challenge to get a program of this type initiated; however, the potential benefits far outweigh these challenges. Here is a list of potential benefits:

- Provide engineering students multi-disciplinary, meaningful, community service design projects,
- Provide persons with disabilities assistive devices to empower them to achieve the maximum individual growth and development and afford them the opportunity to participate in all aspects of life as they choose,
- Provide engineering students education and awareness on the special needs and challenges of persons with disabilities, and
- Provide undergraduate engineering students exposure to the biomedical field of engineering.

This quote from a student who participated in the program best sums up the expected benefit:

“As an undergraduate student in the college of engineering, this project personally affected my life in many ways. It not only challenged me to think creatively and to be able to come up with an original design, but it also allowed me to see at a young age how the work I do can better other lives. I am proud to have been a part of this project and to know that something that I helped design and build is allowing people from around the state of Wyoming to be educated about disabilities (Barnes, 2003).”

### **Resources**

#### ***Resources on Disability:***

The Family Village is a website maintained by the Waisman Center at the University of Wisconsin-Madison,

<http://www.familyvillage.wisc.edu/index.htmlx>

The Library section allows individuals to search for specific diagnoses or general information on numerous disabilities.

The ILRU (Independent Living Research Utilization) <http://www.ilru.org/ilru.html> program is a national center for information, training, research, and technical assistance in independent living. The directory link provides contact information for all Independent Living Centers in the country and US territories.

### ***Resources on Assistive Technology:***

The National Institute on Disability Rehabilitation and Research,

<http://www.ed.gov/offices/OSERS/NIDRR/>

funds the state Assistive Technology projects as well as Rehabilitation Engineering Research Centers (RERC). The state projects are excellent resources on a variety of AT issues and the RERC's conduct programs of advanced research of an engineering or technical nature in order to develop and test new engineering solutions to problems of disability. Information on these centers is available through the NIDRR website by searching their project directory for Rehabilitation Engineering Research Centers. These centers specialize in a variety of areas including mobility, communication, hearing, vision, spinal cord injury, recreation, prosthetics and orthotics, and wireless technologies to name just a few. These are excellent resources to learn more on state-of-the-art engineering projects to assist individuals with disabilities.

Another valuable source is the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) <http://www.resna.org/>. This is a transdisciplinary organization that promotes research, development, education, advocacy, and the provision of technology for individuals with disabilities. In addition, by using the technical assistance project link on the home page, one can locate all of the state assistive technology projects and obtain contact information for his or her particular state or territory.

For specific product information, <http://www.assistivetech.net/> as well as [http://www.abledata.com/Site\\_2/welcome.htm](http://www.abledata.com/Site_2/welcome.htm) are excellent resources.

### ***Resources on Universal Design:***

The Center for Universal Design, North Carolina State University, <http://www.design.ncsu.edu/cud>.

The Trace Research and Development Center, University of Wisconsin-Madison, <http://www.trace.wisc.edu>.

The Center for Inclusive Design and Environmental Access (IDEA), University at Buffalo, New York, [www.ap.buffalo.edu/idea](http://www.ap.buffalo.edu/idea).

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# CHAPTER 6

## CALIFORNIA POLYTECHNIC STATE UNIVERSITY

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## FOAM WARS II: SECOND ITERATION

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*Client Coordinator: Michael Lara, Special Olympics, San Luis Obispo, CA*  
*Supervising Professor: Sarah Harding*  
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### INTRODUCTION

Persons with disabilities sometimes feel limited when it comes to recreational opportunities; Foam Wars can provide wheelchair users with an outlet to interact and engage in a group setting. The game consists of various wheelchair attachments that pits two teams of five players against each other; where the objective is to score points by launching foam balls into stationary targets placed around a typical regulation basketball court (see Figure 6.1). The team collaborated with Kinesiology students to design a new game, and then built hardware to show a proof of concept. Project goals included creating a ball retrieval system, designing for maximum portability, using commercial off-the-shelf (COTS) products, and developing a simple yet engaging game.

### SUMMARY OF IMPACT

During the school year, the Kinesiology Department helps the Special Olympics with the Friday Club. Athletes from San Luis Obispo gather to participate in various recreational activities, many of which use equipment designed and built by Cal Poly engineering students. The Foam Wars project is an attempt to create a fun, competitive game that provides the benefits of sport to athletes with disabilities. The Foam Wars II project made some substantial progress in meeting the needs of the Friday Club, but did not achieve all of its design goals. Only two prototypes were created, which means that eight additional devices would need to be manufactured to play the game.

### TECHNICAL DESCRIPTION

The team worked with Kinesiology students and Special Olympics athletes to design a game that would include five different players – two Launchers, two Retrievers, and one Goalie. Five points are awarded when a Launcher shoots a ball through one of the three goals, and a point is awarded to the Goalie's team if he or she catches one of the launched

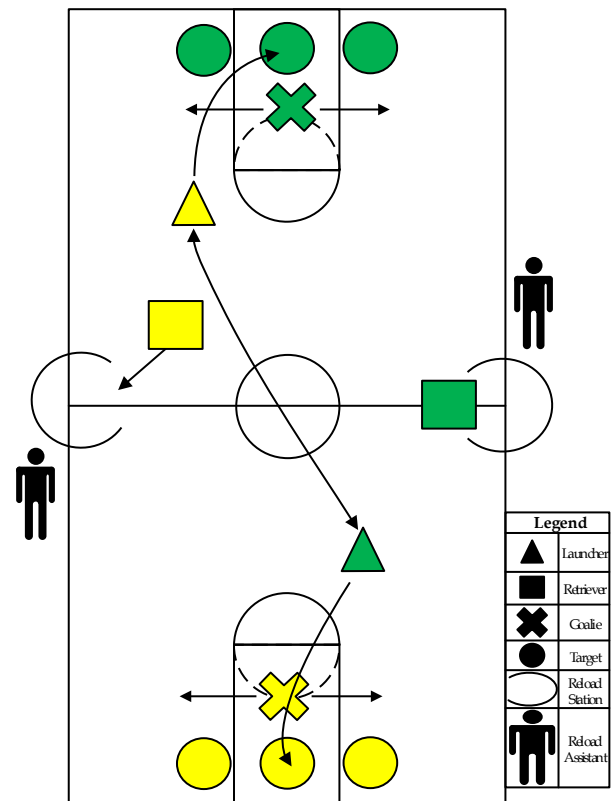


Fig. 6.1. Overhead view of the Foam Wars Game.

balls in their goalie net. To facilitate this process, the students had to design the attachments for three different positions.





Fig. 6.2. Final design of the Launcher,



Fig. 6.3. Final design of the Goalie.

The student team developed a modular approach, where the Launcher, Retriever, and Goalie use the



Fig. 6.4. Final design of the Retriever.

same basic cage design. As seen in Figure 6.2, the launchers utilize a commercial pitching machine that can throw the foam balls at speeds up to 35 mph. The goalie uses an additional attachment (see Figure 6.3) to help them defend the three goals (the hoops in Figure 6.1). Finally, the ball retrievers (see Figure 6.4) use an attachment to collect the balls and return them to the launchers. The cage is attached to the wheelchair using bungee cords, which allows different styles of wheelchair users to use the device. Each of the vertical legs of the basic cages is made from  $1\frac{1}{4}$  inch square aluminum tubing and cross pieces are constructed of  $1\frac{1}{4} \times \frac{1}{4}$  inch aluminum bars. Bolts hold the base cart together. The launcher attachment table is made from Douglas fir to minimize weight and cost, and brackets attach the launcher to the base cage. The launcher is a commercial off-the-shelf pitching machine, which is controlled using a joystick, linear actuator, motor, L298N motor driver, 12 volt batter, and Arduino UNO microcontroller board. The Launcher can vary the up and down angle of the pitching machine and when to fire. The left-to-right aiming is accomplished using the athlete's wheelchair. The goalie attachment is made from  $\frac{3}{4}$  inch PVC pipe, and the retriever is made from a commercial off-the-shelf acrylic bin. A  $3 \times 32$  inch slot is cut into the bin and covered with angled acrylic flaps to capture the balls. Finally, all of the positions are covered with netting to protect the athletes.

The cost to produce the prototypes was \$800 in materials. The estimated cost for a full five-on-five setup is \$4500.

# UNIVERSAL PLAY FRAME VI

*Designers: Justin Bazant, Cullen Crackel & Anthony Franceschi  
Client Coordinator: Michael Lara, Special Olympics, San Luis Obispo, CA  
Supervising Professor: James Widmann  
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## INTRODUCTION

The Universal Play Frame (UPF) attaches to a wide range of wheelchairs and supports a variety of adaptive recreational devices (e.g., baseball, soccer, bowling, darts, and golf). It serves as a universal attachment point to allow athletes with mobility impairments to participate in various sports and activities. The goals of the UPF VI project are to decrease attachment time, increase stability and safety, improve all-terrain mobility, and decrease storage volume. Previous models were based on only two wheels and typically fit onto the front of different wheelchairs with clamps. They were sometimes difficult to attach and were often not as stable as necessary. The UPF VI team decided to design a frame that is self-supporting and attaches to the wheelchair using cargo straps.

## SUMMARY OF IMPACT

The UPF VI solves many of the problems associated with previous versions. Large, free-moving wheels allow maximum mobility and allow users to traverse more difficult terrain than previous versions. The rear portion of the UPF is easily removed, allowing the athletes to “roll into” the frame. The assistant can then reattach the back of the frame and use the cargo buckles to attach the frame to the wheelchair. This version of the UPF is the first to incorporate a frame that fully surrounds the athlete, providing for greater stability and easier attachment. The cargo buckles allow the chair to be easily attached to the frame, and the athlete is able to maneuver quite easily with the new design. Michael Lara, Coordinator from Special Olympics, stated that “this device exceeded expectations and adapts to all wheelchair types. This latest version has reduced the set up time to go from one wheelchair to another tremendously!”

## TECHNICAL DESCRIPTION

Telescoping aluminum tubes (~1.25 inch diameter) are used for the primary vertical supports to allow



Fig. 6.5. Previous version of the UPF.



Fig. 6.6. Current design of the UPF VI.

some adjustability in the height of the attachment plate. The shorter vertical stabilizer (constant length) is made of 1 x 1/2 inch aluminum bar and is attached to the telescoping tube by a custom collar. The mechanism was designed so that the table top remains horizontal for any height the user chooses. The sides of the frame are also constructed from telescoping aluminum tubes to allow the length of the UPF to be adjustable, while the front and back are made of rectangular aluminum tubing. The project

sponsor requested that the team change to 12 inch jogger wheels mid-design. These wheels use a magnetic mating system to insert into the frame, making assembly and breakdown easy. Their larger diameter does, however result in the attachment plate being too high for some of the users. This was fixed by a follow-on General Engineering senior design project (see next report).

The frame collapses easily for storage, and it is possible for the user to insert stationary legs into the wheel posts so that different users can simply wheel into the back of the frame and use the UPF for attachments that do not have to move with the athlete (the rear cross support is removable).

The CAD model for the UPF is shown in Figure 6.7, and a model of the device fully collapsed is shown in Figure 6.8.

The cost to produce the prototype was \$1240 in materials.

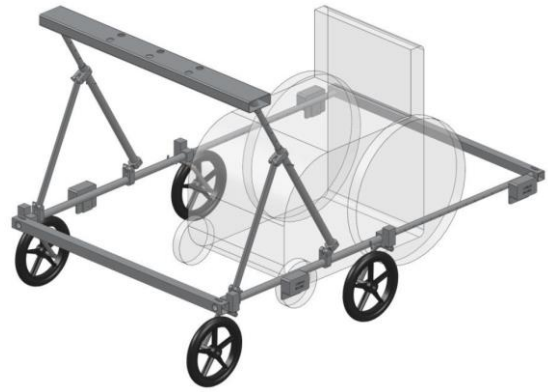


Fig. 6.7. Solid CAD model of deployed UPF VI .



Fig. 6.8. Solid CAD model of collapsed UPF VI.



## UNIVERSAL PLAY FRAME VI.2

*Designers: Ryan Westphal, with assistance from Mary Gentilucci (MECH), Marian Watson (KINE) & Tyler Holt (KINE)*

*Client Coordinator: Michael Lara, Special Olympics, San Luis Obispo, CA*

*Supervising Professor: Brian Self*

*General Engineering and Mechanical Engineering Departments*

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### INTRODUCTION

As described in the previous project, the Universal Play Frame (UPF) is a device designed for the Friday Club by Mechanical Engineering and Kinesiology students at California Polytechnic State University, San Luis Obispo. In collaboration with Special Olympics, Friday Club is a Cal Poly Kinesiology organization in which students organize physical activities for athletes of all ages with varying disabilities. The UPF is designed to support several devices to allow athletes in all types of wheelchairs to participate in various sports and activities. There have been six different UPF models, each improving upon issues encountered by their predecessors.

The designers of the UPF VI did not meet all of the goals they originally set out to accomplish. The adjustable table where the devices attach rests higher off the ground than initially planned because the wheels were changed at the last minute by the sponsor. The increased height of the table causes the attachments to be at or above eye-level of the athletes, blocking their view and causing potential safety hazards. Also, the cargo buckles that attach the wheelchairs to the frame were not properly designed (one of the four buckles broke off the frame shortly after completion). The placement of the buckles could be altered in order to improve the response of the frame when maneuvering. The goals of the UPF VI.2 were 1) to lower the minimum table height to approximately 30" while maintaining a maximum height of approximately 40" and 2) to improve upon the cargo buckle system.

### SUMMARY OF IMPACT

The UPF VI.2 appears to have finally met the needs of the Friday Club and Special Olympics. The team was able to change the height of the table to one that is more appropriate for the various attachments, and to permit optimal movement by choosing new attachment locations for the buckles. The



Fig. 6.9. Original geometry of the UPF VI.2



Fig. 6.10. Modified geometry of the UPF VI.2.

Kinesiology students who work with the Friday Club indicated that the modifications to the device greatly enhanced the ergonomics and maneuverability of the UPF.

### TECHNICAL DESCRIPTION

The UPF VI.2 was a modification of the previous UPF version. The General Engineering Department often has individual senior design projects, and Ryan Westphal chose the modification of the UPF for his. Mary Gentilucci, a Mechanical Engineering student



who received credit for one unit of independent study, helped Ryan design and manufacture the UPF VI.2. Two Kinesiology students, Marian Watson and Tyler Holt, worked with the team to determine user requirements and to provide initial design feedback.

The students came up with several options for modifying the length of the vertical support tubes, and performed stress analyses to make sure that their modified design would withstand the applied forces. Using an applied vertical load on the table of 100 lbs. (which is twice the weight of any current attachments), the calculated max pin shear stress was 1263.3 psi. This resulted in a factor of safety of 1.9. After the redesign, two welds on the slide joint were ground off and the support pieces shortened. The

slide joint was then re-welded and the UPF was reassembled.

The original UPF VI team welded the cargo buckles to the frame. This was not strong enough, and it was difficult to securely weld the buckles onto the thin-walled aluminum tubes. The cargo buckle welds were ground off and were relocated to add support and maneuverability. The attachments were done with bolts to allow future alteration and easy replacement should one of the belts break.

Because the UPF VI.2 was simply a modification of the UPF VI, only the additional bolts for the cargo buckles needed to be purchased. The entire modification supply cost was only \$10.



Fig. 6.11. Final UPF VI.2.

# THE WIIBFIT

Designers: Seth Black, Craig Letterman, Jamie Nease, Canh Sy, Mike Tran  
 Client Coordinator: Paul Mortola, Central Coast Assistive Technology Center, San Luis Obispo, CA  
 Supervising Professor: Dr. Chris Lupo  
 Computer Engineering  
 California Polytechnic State University  
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## INTRODUCTION

This project's primary intent is to develop a form of exercise for people with quadriplegia, using the Nintendo Wii system. Wii-B-Fit takes the Wii's engaging and fun game play and adapts it to meet user defined requirements. It is difficult for people with quadriplegia to participate in suitable forms of exercise. In addition to the lack of exercise options, people with quadriplegia also face very limited access to video games. Although Nintendo claims the Wii targets a broad demographic, the ingenuity of the Wii's remote actually alienates people with quadriplegia. The Wii requires players to have control of their arms and upper body to make full use of the accelerometer and infrared based remote system. In order to make exercise with the Wii

possible, the ability to play the Wii must be an inherent property of the device. Thus, this project increases the accessibility of the Wii system to people with disabilities. This in turn provides those with quadriplegia the opportunity to enjoy the health benefits of physical exercise and play.

## SUMMARY OF IMPACT

In general, it is very difficult for people with quadriplegia to find suitable forms of physical activity. Using the Wii and a customized Wiimote, the WiiBfit system makes the Wii accessible to people with quadriplegia and provides a fun form of exercise. The clear impact and potential of this system can be summarized by one user's blog entry (this user is shown in Figure 6.13 using the device).

## Block Diagram

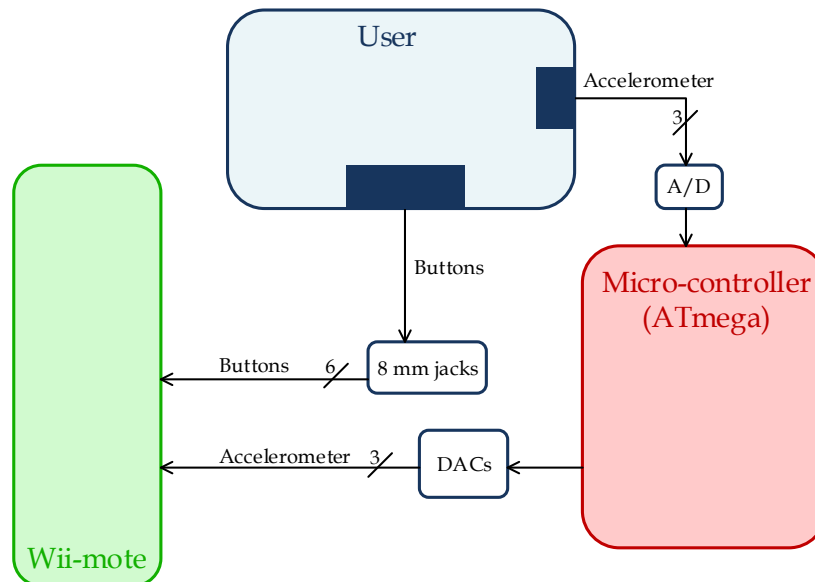


Fig. 6.12. Block Diagram of the WiiBfit.



Fig. 6.13. The client using the WiiBfit

“After my accident, I never expected to be able to play my Wii games. But now, despite my disability, I can play my Wii whenever I want. I can even use it as a physical therapy tool, which is great. It's nice to be able to have fun and exercise at the same time. Now,

when I'm using it, I forget that I'm actually exercising.”

## TECHNICAL DESCRIPTION

The design objectives were to 1) allow the user to play at least two Wii games, 2) be lightweight and durable, 3) include hands-free operation, 4) be easy to learn and fun to use, 5) mimic functionally of Wii-mote, 6) incorporate exercise, 7) not limit head motion, and 8) not make the user feel self-conscious while playing.

The overall system design (shown in Figure 6.12) uses an ATMEGA1284P microcontroller to intercept the accelerometer readings, amplify them to sufficient values, and to output them back to the remote. The accelerometer is embedded in an ordinary baseball hat to allow user inputs to the system. The athlete uses a large push button and a puff sensor for the most commonly used buttons on the remote ('A' and 'B'). The team has also provided connections for adaptive buttons for each of the four D-Pad buttons. This way, the client may choose any switches they would like to be used for menu control and for directional control in games. There is also a flex switch and four push buttons so that the client has a variety of switches from which to choose.

The team successfully tested the system with both Wii Tennis and Wii Bowling. The system was lightweight, although additional packaging work will need to be done for full implementation. The software algorithm must be fine-tuned for each individual user, and some training for the athlete is necessary before they can play the game. Future iterations could include a sensitivity adjustment to allow different users to adjust “on the fly.”

The cost to produce the prototype was \$1,016 in materials.

# ADAPTED BOCCE BALL

*Designers: Steven Erickson, William Haley, & Taylor Vaughan*  
*Client Coordinator: Michael Lara, Special Olympics, San Luis Obispo, CA*  
*Supervising Professor: James Widmann*  
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## INTRODUCTION

It has been said more people play Bocce than any other sport besides soccer and golf. With roots back to 5000 B.C., Bocce is also the oldest known sport in world history. The game begins by throwing out the pallino, a 2.4" diameter ball. The first player tries to throw his Bocce ball, which weighs about 2.2 lbs. and is about 4.25" in diameter, as close to the pallino as possible. Successive players then try to get their Bocce ball closest to the pallino. Full rules and other information can be found at [www.bocce.com](http://www.bocce.com). Currently this historic game is inaccessible to those with mobility impairments.

## SUMMARY OF IMPACT

The Adapted Bocce Ball project allows people with disabilities to obtain the social and physical benefits of participating in the sport, and allows them to compete with other athletes with and without mobility impairments. Michael Lara, the regional sports director for Special Olympics, has stated that the device (shown in Figure 6.14) "met expectations and now allows wheelchair users to participate in the game of bocce. This also challenges the user to figure out the distances using the device, the same as one not using the device."

## TECHNICAL DESCRIPTION

Design goals for the project were transportability (including electrical power), 60 ft. maximum range, lifetime of 20,000 cycles, maximum of 3 lbs. user input force, ability to create backspin on the bocce ball, and a reload time of 20 seconds. A full Solid Model of the system is shown in Figure 6.15.

The balls are launched using compressed air, which is supplied by two air tanks that are 1 foot long, have a diameter of 4 inches, and a total volume of 300 in<sup>3</sup>. The piping system has two PVC barrels, one for launching the pallino and another for the bocce ball. A three-way valve is used to select which of the

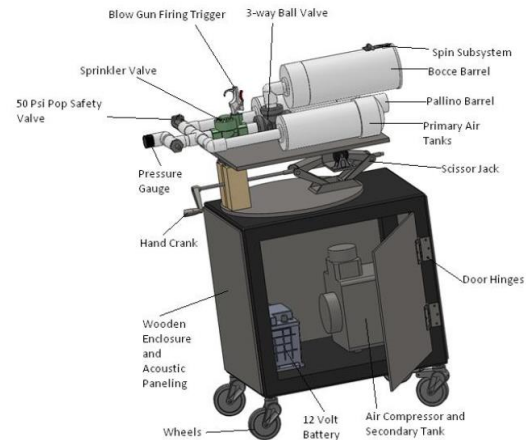


Fig. 6.14. Full solid model of the Adapted Bocce Ball Launcher.

barrels will be used. The bocce ball pipe, which requires much higher pressures, is modified because no standard pipe size is the exact diameter of the ball. Rubber inserts and metal flashing are used to create an adequate fit for the bocce ball. A deployable rubber wedge is placed in the top of the bocce pipe to allow the athlete to apply backspin to the ball. For safety, the piping system has a pop safety valve that will release pressure if the tanks exceed 50psi.

An air compressor is used to fill a 5 gallon secondary tank, which is connected to the piping subsystem. It is powered by a 12 Volt rechargeable battery, and the system can run for one hour continuously before needing to be recharged. In actual use, the compressor is used to fill the secondary tank intermittently. In testing, the device was used for three hours at the senior design expo without needing recharging. It is usually necessary to turn on the compressor every six or so launches to maintain the necessary pressure. The compressor sound level is slightly below 75 decibels at a distance of 2 feet, although again this does not run continuously.



The athlete controls the launch of the balls with three different control mechanisms. The first is the amount of pressure applied to the pipes. A calibrated pressure gage is provided to help the athlete determine how much pressure is stored in the secondary tank. The primary exercise for the athlete

is in adjusting the scissor jack. The athlete must turn a hand crank to change the angle of the pipes, thus changing how high the ball will go. Finally, the entire launch system is on a turntable that can adjust the aim from side to side.



Fig. 6.15. The Adapted Bocce Ball Launcher demonstrated at the Senior Design Expo.

# RECREATIONAL SIT SKI

*Designers: Krystina Murrietta, Tom Silva, Allen Thrift & Dan Murray*  
*Client: Mr. Jon Kreamelemeyer, Developmental Coach of the US Adaptive Ski Team, Colorado*  
*Supervising Professor: Sarah Harding*  
*Mechanical Engineering Department*  
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## INTRODUCTION

Cross country skiing has been a part of the Winter Paralympic Games since the first Paralympic Games event in Sweden in 1976. There are many fans of the Paralympic Games who would like to recreationally use sit skis. Several companies (e.g., Spokes n' Motion, Sierra Sit Ski, and Teton) make sit skis that are either custom made or come in specific sizes, but to date there is not a suitable adjustable program ski that is adjustable for different sized athletes. Although Cal Poly teams have built recreational sit skis in the past, fairly broad adjustability requirements resulted in the devices being too heavy for most athletes.

Most skiers prefer one of two positions: 1) legs stretched out in front or 2) the teacup position, where the knees are pulled up close to the torso (see Figure 6.17). A few athletes have also been using a more upright, legs tucked under position. The goal of this project is to allow different sized recreational users to cross country ski and to choose which of the two most popular sitting positions they use.

## SUMMARY OF IMPACT

An adjustable sit ski can be used in a number of cross country resorts where athletes with disabilities might want to try out cross country skiing. The ability to switch between the two positions allows people with different levels of spinal injury to participate in the sport, and the adjustability of the foot rest can accommodate athletes of different sizes. Additionally, the binding design allows the sit ski to attach to any ski with an NNN binding, allowing the athlete to switch to different skis quickly and easily. Jon Kreamelemeyer, a developmental coach with the Adapted Nordic Cross Country program, would like to use the sit ski when he travels to recruit different athletes for the Paralympic Team.

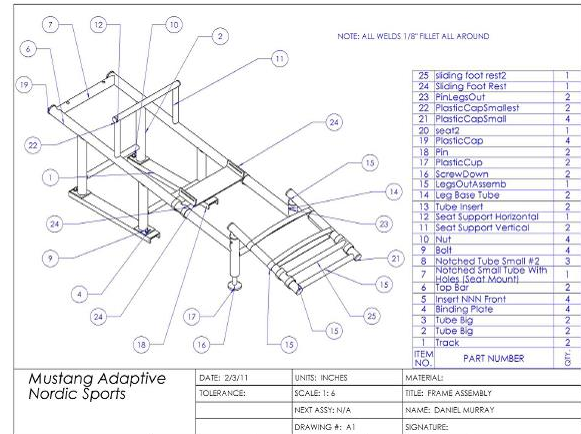


Fig. 6.16. Solid Model of Sit Ski.



Fig. 6.17. Skier in the teacup position.

## TECHNICAL DESCRIPTION

The frame is made of 6063 T5 Aluminum tubes. The aluminum frame consists of eight 1inch diameter, 1/16 inch thickness tubes and seven 5/8" diameter tubes. These tubes are welded together and plastic caps plug any open tubes. The four vertical "legs" of the frame are welded to small aluminum plates and are attached to the U-channel binding with hex screws and lock nuts. This hardware requires minimum tools and remains secure during use. A removable assembly consisting of an aluminum plate welded to a 5/8" diameter tube and attached foot restraints is used for the teacup footrest. Turn-key hose clamps secure the footrest and allow the rider to adjust his or her feet for the teacup position. Polyester seat belt webbing and plastic buckles provide comfort and security for the rider's ankles.

The modular attachment slides into the vertical tubes of the frame and is secured by rounded retainer snap safety pins. These retainer pins make the attachment and removal quick and easy since no tools are required. The attachment consists of four 1" diameter tubes and one 5/8" diameter tube. The 5/8" tube is a footrest for the legs-out position and an additional 5/8" tube can be added to the attachment in order to accommodate petite riders. This removable footrest is also secured with turn-key hose clamps.

The ski bindings on the bottom of the frame are constructed using a U-channel and a set of plastic inserts. The inserts are modeled after the bottom of a NNN ski boot. These inserts are rapid-prototyped in ABS plastic and are press-fit into place. This design only required a single binding which allows the sit ski to easily fit into standard cross country ski bindings. The ski mounts are also able to slide side-to-side to adjust the track width. The free heel design works by



Fig. 6.18. Skier with legs out front.

snapping a pin on the front of the base into the binding, like a standard boot. These pins are machine screws held to the frame with lock nuts, making them easy to replace should they ever break. The front leg on the frame has a rubber stopper on the end that can screw in or out to hold the frame in place and prevent rocking.

The large bucket seat is from Enabling Technologies. Abdomen and thigh restraints made of polyester webbing and plastic buckles are bolted to the seat. Closed-cell foam padding is used as cushioning and extra padding is provided should the rider need extra security, and can be used to raise the skier by a few inches if desired. The seat is secured to the aluminum tube with hex screws and lock nuts.

The material cost of the device, including powder coating, is \$880.



# COMPETITION SIT SKI

*Designers: Kyle Martinez, Ben Woodward, and Vinay Clauson*

*Client: Andy Soule*

*Client Coordinator: Mr. Jon Kreamelmeyer, Developmental Coach of the US Adaptive Ski Team, Colorado*

*Supervising Professor: Sarah Harding*

*General Engineering and Mechanical Engineering Departments*

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## INTRODUCTION

Andy Soule is a talented athlete who won a bronze medal in the 2010 Winter Paralympics. He has an above-knee double amputation, with full use of trunk and arm muscles. As with any elite athlete, Andy wants to have the lightest, most competitive sit ski possible to help him place even higher at future Olympic Games. The primary focus was in weight reduction, but the team also decided (based on input from Andy and his coach) that placing Andy upright with a forward lean might improve the biomechanics of Andy's poling.

## SUMMARY OF IMPACT

The sit ski was designed to push the limits of current competitive sit skis. The final product (see Figure 6.19) weighs 3.02 lbs., a remarkable accomplishment. Andy will be testing the sit ski during the upcoming season to determine if the calculated 1.5 factor of safety will prove adequate for his racing needs.

## TECHNICAL DESCRIPTION

The students developed the following design criteria:

- 1) The sit ski must weigh less than five pounds total.
- 2) The track width must be adjustable in order to conform to both American and European track widths.
- 3) Skis should connect/disconnect as easily as possible with nothing more than basic household tools.
- 4) The angle of the seat must be such that Andy feels comfortable and is able to exert maximum power during the arm stroke. A forward lean is advised.
- 5) Center of gravity must be kept low to provide excellent cornering ability and stability.

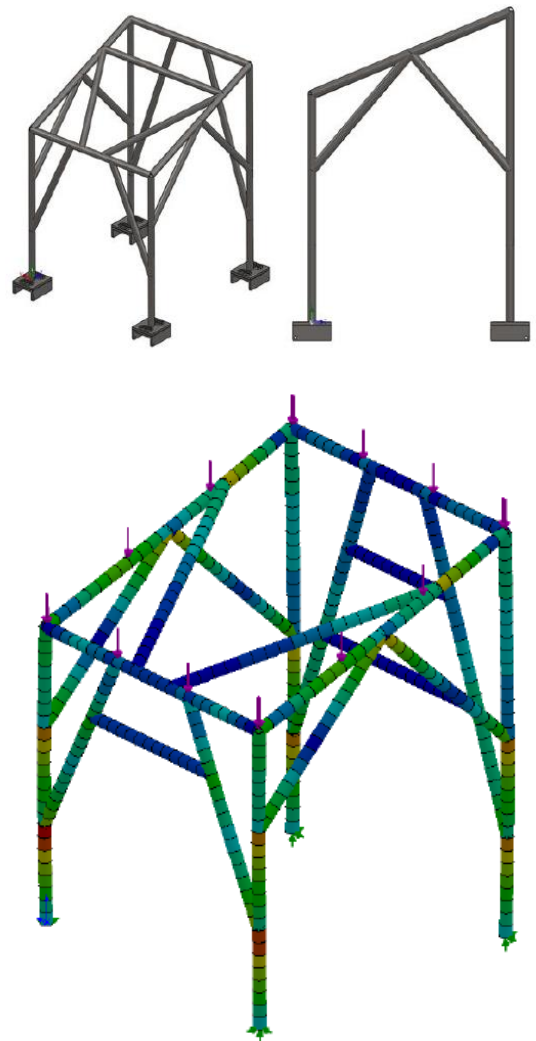


Fig. 6.19. Competition sit ski made from Titanium.

The sit ski was made from 0.375 x.019 inch Titanium tubing to maximize the strength to weight ratio. It was quite difficult to weld titanium, which requires an argon-rich environment and a welding chamber. The thin-walled tubes made welding even more

difficult – the student team recommended that future designs may want to use slightly thicker wall dimensions. Despite these difficulties the student team decided to perform all of the welding themselves. Each tube was welded to 0.125 inch thick plates that were attached to aluminum U-channels with mechanical fasteners. The U-channels served as part of the binding system for the sit ski, and four short individual channels were used to reduce weight. Stainless steel mounting pins were placed in each of the U-channels to articulate with the bindings; one front and one back binding are mounted on each of the skis for easy attachment and removal of the sit ski. Special steel fixtures were constructed to ensure proper alignment of the sit ski frame.

The seat was constructed by carving a mold out of a single piece of high density foam using both wood chisels and sandpaper to acquire the desired shape. Four separate coats of epoxy resin were then applied to the foam mold to both eliminate its porous nature

and to add rigidity. On top of the epoxy resin a layer of tool release agent was applied so that the carbon part would release from the mold cleanly. The seat was made from a pre-preg unidirectional carbon fiber utilizing an epoxy matrix that would cure at low temperature. In order to ensure that the seat would have adequate strength under the predicted loading conditions a 5-ply [90/0/90/0/90] layup was utilized.

A Solid model of the sit ski is shown in Figure 6.20. The sit ski had a safety factor of 3 when the seat was loaded with a downward distributed load of 200 lbs. The sit ski was also tested with 250 pounds placed in the seat, and with a 180 pound person in the seat leaning 45 degrees to the side. As mentioned, the final sit ski only weighed 3.02 pounds.

The total material costs for the frame, seat, molding material, and fixtures were \$1300.



Fig. 6.20. Competition sit ski made from Titanium.

# UNTETHERED RUNNING AID

Designers: Aaron Baldwin, Brian Berg, J.P. Charlesbois, Eric Cerney, J.C. Li  
 Clients: Students from the Santa Maria school district  
 Client Coordinator: Stephanie Cleary, Teacher, Santa Maria, CA  
 Supervising Professor: Dr. Lynne A. Slivoosky  
 Computer and Electrical Engineering Department  
 California Polytechnic State University  
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 San Luis Obispo, CA 93407

## INTRODUCTION

The purpose of this project is to design a system that allows people who are blind or have low vision to run completely independently from a sighted runner. The traditional methods of solving this problem typically rely on sighted runners; a physical tether, either a rope or bungee system around the waist or finger tethers, or by running alongside a sighted runner and receiving audio cues from them. Counting steps may also be used to help the users cover well known distances relatively accurately.

Several other electronic travel aids (ETA) are available – some use ultrasonic signals to detect obstacles around the user and provide audio and vibratory feedback. Different types of camera technologies have also been used, but these types of solutions are quite expensive and over-complicated for the user needs. Ms. Stephanie Cleary runs after-school activities that include groups of student runners on a 400 meter track, so the system should allow multiple simultaneous users.

## SUMMARY OF IMPACT

The student team worked on developing a wireless system consisting of (1) four sensors placed around the track, (2) a user belt (shown in Figure 6.23) consisting of wireless transmitters and tactile actuators to cue the runner, and (3) hardware and software to process the signals. A working system would provide the athletes with greater autonomy and less dependence on sighted runners. It might even be possible to have an athlete run for longer distances on the track without any other supervision. This first prototype attempted to provide navigational cues to allow the runner to stay on the track – they also recommend developing a method to allow the runners to detect and avoid other runners. Unfortunately the correlation between signal strength and distance was very weak and cannot be

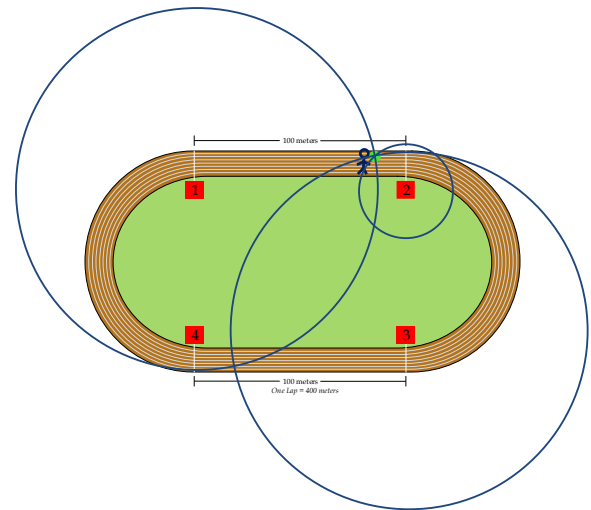


Fig. 6.21. Placement of track sensors to localize position of the runner[s].

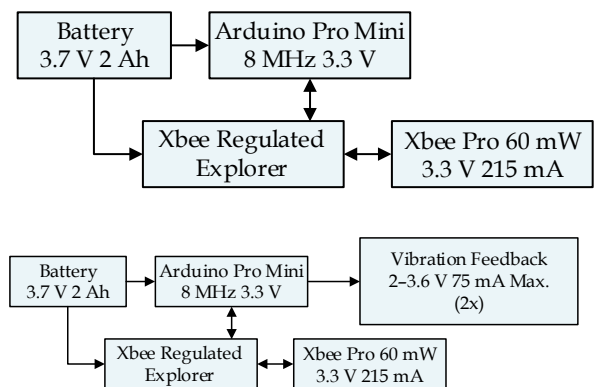


Fig. 6.22. Hardware diagrams for track sensor (top) and belt (bottom).

accurately relied upon for this system, and the team was not able to deliver a working prototype. The

background research and progress made will be useful to a follow-on team next year.

## TECHNICAL DESCRIPTION

The design objectives were to 1) allow user to run blind and untethered without the need for a sighted runner, 2) be usable by a wide variety of users, independent of vision level, 3) be small and lightweight, 4) have a long operating time, 5) have a small learning curve for users, 6) have high safety and reliability, 7) not impede normal running movement, 8) have signals to the user that are clear and independent of environment, 9) assist user in avoiding obstacles, and 10) be low cost. The system used four sensors placed around the track as shown in Figure 6.21 to try to triangulate the position of the runner(s).

The belt itself (schematic in Figure 6.22) is worn by the users, and contains an XBee Pro wireless board, an Arduino Pro Mini micro-controller, a vibration motor, and a battery pack. The wireless board allows the belt to transmit and receive signals from other belts and the track sensors. The signal then is passed to the micro-controller, which processes the signal and determines the current position of the user. The track sensor (schematic in Figure 6.22) is built around

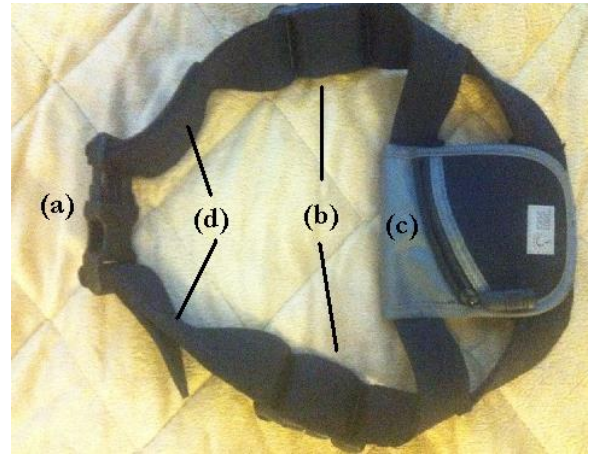


Fig. 6.23. Belt for runner, including (a) easy clipping component, (b) double adjustment straps to adjust size and location of vibration sensors, (c) pouch holding electrical components (d) location of vibration sensors.

the XBee Pro 60 mW, a wireless communications board specifically designed for embedded systems. It has a range of approximately 1 mile.

The total cost for materials and components was \$1160.



# LOW COST PROSTHETIC TEST SOCKET

*Designers: Erica Wong, Mackenzie Tageson & Karina Moraes*

*Client Coordinator: Matthew Robinson, Hanger Orthopedic Group, San Luis Obispo, CA*

*Supervising Professor: Lily Laiho*

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## INTRODUCTION

A test socket is a vital component of a prosthetic leg and is used to ensure the final prosthetic socket properly fits a patient. An incorrect fit can lead to patient pain and discomfort and may require a new socket to be constructed.

Typical steps in developing a test socket before final socket fitting in the U.S. include 1) Initial Evaluative Consultation, 2) Acquire Residual Limb Measurements and First Positive Plaster Mold, 3) Static Clear Test Socket Analysis, and 4) Dynamic Clear Test Socket Analysis. Vivak, Surlyn and polypropylene are often used for the test sockets. Vivak, a form of polyethylene terephthalate (PET), is a transparent semi-crystalline thermoplastic polymer widely used in the prosthetic industry. Surlyn is a thermoplastic copolymer made from polyethylene and methacrylic acid. Neither material, however, is readily available in Honduras and are both too expensive for use in the Clinic.

## SUMMARY OF IMPACT

Due to the high cost, using a test socket is a complete luxury for developing countries such as Honduras. Without a test socket, the clinic has no way to locate any detrimental pressure points before the final socket is cast. A low-cost, easily manufactured test socket could prevent multiple fittings for patients. This is critical when many patients have to travel long distances to reach the clinic. The technicians in the clinic were impressed by the work that the team did, but right now this is still too cost prohibitive for them to implement. This is primarily due to the time involved, since they are paid an hourly wage and this would essentially double the time they spend on each prosthesis.

## TECHNICAL DESCRIPTION

Design specifications were developed: 1) transparent, 2) less than 3 lbs., 3) bear a weight of 300

lbs., 4) fit to a tolerance of  $\pm 0.2''$ , 5) be manufactured and cured within 12 hours, and 6) allow connection to pylon adapter using either glue or screws.

During a trip to Honduras by a second team (see later report on the Piernas de Vida project), students noticed a large number of plastic bottles in piles along the road. This could be a very inexpensive source of material for the test socket, and could help utilize an underused resource. After experimenting with milk bottle caps, banana leaves combined with plaster, wax and epoxy, seaweed and epoxy, and even shrinky dink, the test socket design team decided that using PET from two or three liter bottles was the best approach.

In general this process uses vacuum assistance, a heat gun, sections of 2L or 3L bottles, and epoxy to create a test socket. The vacuum ensures that a tight fit is created with the soda bottles and the heat gun, with digital controls, allows for specific degrees of heat to be applied throughout the process. Being able to control the temperature is a vital aspect of this process due to certain materials not being able to withstand certain temperatures. The 2L bottles must be cut, then placed in overlapping sections, and then tape and epoxy used to form the final test socket. If the plaster cast of the leg is small enough, then a single 3L bottle can be used in the process. The following figures show how to complete the process to complete the test socket for the 3L bottle. (a) Attach pylon adaptor to top of mold, (b) place 3L bottle over the mold, (c) put turkey oven bag over mold and bottle, (d) wrap tightly around tube on bottom and apply vacuum (around 28 in Hg), (e) apply vacuum to bag and use heat gun (at 350 degrees F) to shrink the plastic bottle around the mold, (f) repeat the process with two additional 3L bottles (cut off tops) around the first. (g) Finally, you will take out the second and third layers, cut off the first layer bottle top so that the adapter is exposed, and then epoxy the



Fig. 6.24. Placement of pylon adapter.



Fig. 6.25. Placement of bottle over mold.



Fig. 6.26. Placement of turkey bag over mold and bottle.



Fig. 6.27. Bag tightened around vacuum hose.

three different layers together for strength and stiffness.

Tensile tests were performed on seven specimen strips of heated and seven specimen strips of unheated PET from two liter bottles.

Compressive tests were also run on sockets made from 2L and 3L bottles. Both were able to hold 300 lbs. of force, although the 2L bottle socket did show some slight jumps in force (likely due to some delamination of the multiple cut sections).

The total cost for materials to develop the process was less than \$250.



Fig. 6.28. Use of heat gun to melt plastic.



Fig. 6.29. Process is repeated for a total of three bottles.



Fig. 6.30. Final Test Socket.

# ADAPTER FOR SURFING WITH A PROSTHESIS

Designers: Josh Cutts, Ben Friesem & Natasha Nelson

Clients: Members of AmpSurf on the Central Coast

Client Coordinator: Matthew Robinson, Hanger Orthopedic Group, San Luis Obispo, CA

Supervising Professor: Lily Laiho

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## INTRODUCTION

Currently there are no specialized surfing prostheses to fulfill the need for amputees who desire to surf. Historically, amputees who surf use a normal prosthesis, occasionally with some modifications to compensate for common issues that occur with the use of a prosthesis created for everyday wear. These modifications are temporary fixes to problems encountered by the amputees while surfing on a normal prosthetic foot.

The first problem is corrosion from exposure to salt water and sunlight. Corrosion is mainly seen in connectors, such as screws, which are typically made of cheaper metals that are unable to resist the corrosive saltwater environment of surfing. The second problem is the limited ankle range of motion with normal prostheses. Ankle flexibility is extremely important in a dynamic sport such as surfing. The range of motion required is especially important for popping up, turning, and carving. The third major problem that amputee surfers experience is the lack of friction between their prosthetic foot and the surfboard; this contact is critical for allowing the surfers to pop up into a standing position and for controlling their board as they ride the wave. The most common methods to solve this friction problem are applying a material to the top of the surfboard such as a wax or a cutout foam pad, or by using a surfing boot with bottom traction.

## SUMMARY OF IMPACT

AmpSurf (ampsurf.org) is a non-profit organization that is very active on the Central Coast. A device such as this could help improve the surfing experience of a large number of people with amputations in our local area, and help introduce the sport to others. Unfortunately this design team was unable to find someone to test their product, but the client coordinator, Matt Robinson, will be finding test

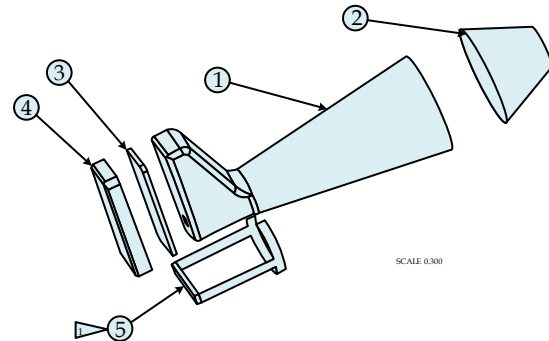


Fig. 6.31. Schematic of Surfer Boot: [1] Bilaminate leg from waders, [2] Latex neck gasket, [3] silicon insole, [4] Hyperflex sole, [5] Velcro strap.



Fig. 6.32. Surfer Boot prototype.



subjects this fall. A picture of the prototype is shown in Figure 6.32.

## TECHNICAL DESCRIPTION

The student team developed the following design specifications: 1) prevent corrosion of the metal parts of a prosthetic. The design must remain watertight during 2 hours of salt water immersion, 2) include a surface area contact material providing a coefficient of friction of at least 0.4 between the prosthetic foot and a surfboard, 3) include an adaptation that allows a 10 degree inversion angle and a 5 degree eversion angle of the ankle from the surfboard's surface, 4) take less than 2 minutes to put on and take off, 5) have a lifetime use of 2000 hours of use without losing water resistance and grip, 6) be easily adapted to multiple users, 7) have a weight less than 2 lbs., and 8) cost less than \$500.

Several off-the-shelf components were purchased for the prototype, including Cabella's Three Forks Stockingfoot Hip Waders, a Seamtite Latex neck gasket, and Hyperflex Access 3mm Round Toe Surf Boot Size 11. The leg section of the waders was made of a bilaminate of nylon denier and polyurethane; it was glued to the latex neck gasket. The sole was cut

off of the Hyperflex Surf Boot, and a silicone gel insert was sewn onto the inside of the sole. This was done to help increase the amount of inversion and eversion that the surfer could achieve. Finally, the sole was glued to the neoprene foot section of the waders.

Cotol-240, a cleansing agent, and Aquaseal, an adhesive, were used to adhere the different parts of the device together. Great care had to be taken to ensure that all seals were watertight. A lip was sewn into the joint between the bilaminate of the hip wader and the neck gasket to serve as a handle when the surfer was putting on the boot. A heel support cup with Velcro fastener was also added to the sole to help hold the prosthesis firm while surfing.

During static testing of the device, a test subject performed minimal movements in the water for 30 minutes. This was followed by dynamic testing, where the subject moved his leg for five minutes. Both tests resulted in less than 1 ml leakage of water. Don/doff tests resulted in times of 80 seconds and 35 seconds, respectively.

The total cost for materials to develop the process was \$365.

# STRIDER - STANDING WHEELCHAIR

*Designers: Matt Browning, Michael Flynn, Douglas Desfor, Mary Gentilucci*

*Client Coordinator: John Lee, San Luis Obispo, CA*

*Supervising Professor: Brian Self*

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## INTRODUCTION

For people who are restricted to a wheelchair for mobility, standing has many health benefits. Passive standing alone has the benefit of preventing pressure ulcers and improving circulation. Meanwhile, bearing weight on the legs increases lower body muscle and bone strength. Walking increases muscle strength, promotes joint mobility, and allows for a mild cardiovascular workout. Standing also has the benefit of allowing easier eye-to-eye contact and easier access to devices designed for a standing position.

There are several devices on the market which fulfill some of these requirements. Standers (e.g., the EasyStand Evolv, Permobil LifeStand Helium) allow users to transfer from a sitting to a standing position. They are generally not designed for the user to move around under his or her own power, but allow the user to gain the health benefits of passive standing. The GlideCycle PT Pro is a two-wheeled exercise device similar to a bicycle. The user sits in a seat suspended from a U-shaped frame between the two wheels. Since the device is two-wheeled it is difficult to set up autonomously by a person with limited use of their legs and is not appropriate for indoor use. The Rifton Pacer Gait and the LiteGait Mobility Device are well-designed mobility aids that fulfill the largest number of the design requirements. Unfortunately, the devices are too wide to fit through a door and do not provide a transfer seat for the user.

## SUMMARY OF IMPACT

The user, John Lee, provided a great amount of feedback on the device.

The Adult Strider is the type of walking aid that I've been wanting to develop for several years, ever since the injury that compromised my walking and left me relying on a wheelchair for my primary means of mobility. The Strider enables me to get out of my



Fig. 6.33. Front (left) and rear (right) views of the strider.

wheelchair for longer stretches of time to weight-bear and move around using my legs as my primary locomotion (instead of my arms). In addition to the weight-bearing benefits, the Strider helps me work on my standing balance, lower body strength, flexibility, posture, and endurance. Even in only 15-20 minutes, I get a good burn in my legs and lower back, as I exercise muscles that I normally under-utilize during an average day. Once I'm in the Strider, I feel very safe and secure as I move around. Thanks to the swing-away seat, I'm able to remain in the Strider for longer periods of time, as I can take breaks whenever I need to by simply perching on the seat. Merely sitting in the Strider while watching TV is better than sitting in my wheelchair, as I'm able to stretch my thigh muscles. It will take me some time to build up my endurance so that I can walk around in the Strider for longer stretches. It's worth the effort because I realize the many benefits that the Strider offers for my bone health, muscle health, even organ health. I believe that regular use of the Strider will ultimately help me maintain and hopefully even improve my physical functioning and quality of life. It feels great to be able to walk around again without fear of falling.

## TECHNICAL DESCRIPTION

The student team developed the following user requirements: 1) independent use by user, 2) safe, 2) high mobility, 4) weight bearing adjustable, 5) adjustable for different users, 6) comfortable use for 2-3 hours, 7) light, quality materials, 8) transportable by van, 9) low maintenance, 10) little to no assembly, 11) aesthetically pleasing.

The frame was primarily made from 1.5" OD X 0.125" and 1-1/4" OD X .083" 6061-T6 Aluminum circular tubing. Aluminum slip-on rail fittings (Tee with through hole, 90 degree elbow) were used at the joints of the frame because pipe bending weakened the aluminum pipes. A transfer seat was also constructed to allow the user to position him or herself into the Strider, and also to provide a resting seat. The seat was commercial-off-the-shelf, and was supported by aluminum rails. A commercially-available walker was purchased, and several parts were scavenged from the device. The wheels and

braking system were adapted for the Strider, and the seat was used for a chest pad. The user can lean against the chest pad to help propel the Strider forward; the entire front adjustable chest pad assembly can also be removed if desired. This torso support system is constructed of zinc-plated steel square tubing and corrosion-resistant aluminum.

A climbing harness (Black Diamond) was purchased to partially support the user during walking. The straps are adjustable, so the user can decide how much weight bearing he would like to have on any given day. The bottom legs are adjustable (telescoping tubes) to accommodate users of different heights. Hand brakes and arm rests are also fixed to the Strider. Almost none of the joints were welded to allow the user to take apart the device for transportability, and to allow for easy repair should any of the parts fail.

The material for the Strider cost just under \$1300.

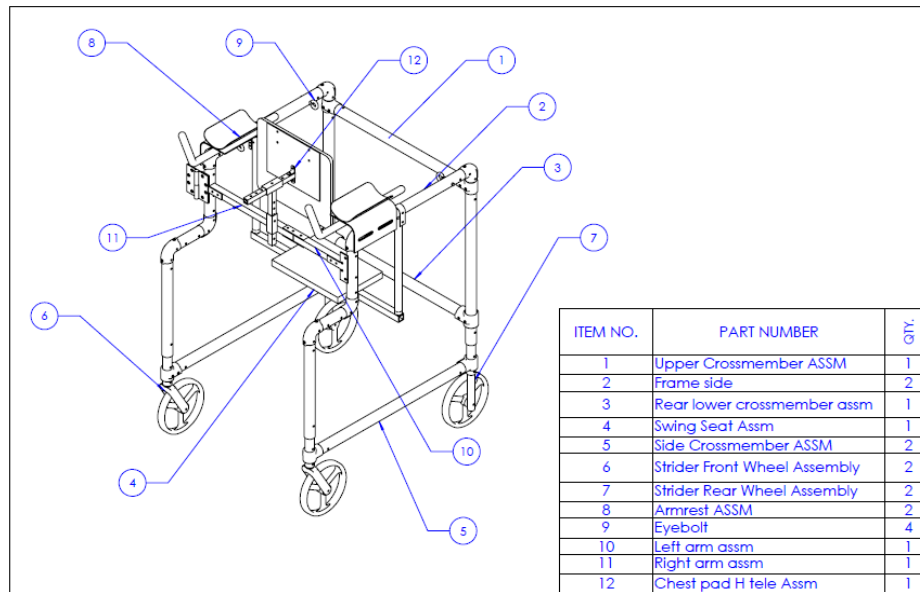


Fig. 6.34. Solid CAD model of the Strider.

# ROCK-N-BOWL

*Designers: Josh Grip, Travis Rodrigues, Richard Rozporka*

*Client: Mike Ward, San Luis Obispo, CA*

*Client Coordinator: Kevin Taylor, Kinesiology Department, Cal Poly, San Luis Obispo, CA*

*Supervising Professor: Brian Self*

*Mechanical Engineering Department*

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## INTRODUCTION

Bowling is a classic American pastime enjoyed by people of all ages, but this seemingly simple game has been difficult for people with disabilities. It is highly important to get the motion and strategy of bowling as close as possible to standard bowling. Using strategy and ball control allows people with a disability the opportunity to truly compete with a standard bowler. The Rock-N-Bowl needs to allow the athlete to curve the ball in for a strike, just like the professionals do. Also, the bowler needs to control the speed of the ball for optimal ball control.

There are several devices on the market which fulfill some of these requirements. Free-standing ramps are very simple, but do not provide spin to the ball, often move when the ball rolls down the ramp, and have limited speed variability. The IKAN Bowler is a well-designed device that has provided an enjoyable bowling experience to many bowlers with disabilities. It does not, however, allow the user to vary the spin on the ball a great deal. Spin is achieved by placing the holes of the ball to one side, limiting the options available to the user.

## SUMMARY OF IMPACT

The Rock-N-Bowler has the potential to open up the world of bowling to several local athletes. One benefit of the device is that it can be either attached to the bowler's wheelchair to add to the forward speed of the ball, or it can be set up as a stand-alone device and allow different bowlers to wheel up to it. The spinning mechanism allows the athlete to experiment with different hooking speeds and add to the enjoyment of the game. Alternatively, the athlete can use the Rock-N-Bowler as a simple ramp bowler. Mike Ward, the customer, seemed quite happy with the device when he tested it at the Senior Design Expo. The Rock-N-Bowler will be kept at Mustang Lanes where anyone is free to use it.



Fig. 6.35. Spin Controller.

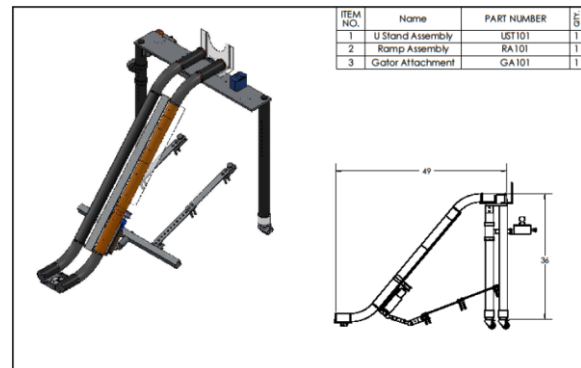


Fig. 6.36. Solid CAD model of the Rock-N-Bowler.

## TECHNICAL DESCRIPTION

The student team determined the following user requirements: 1) the end product should be able to "throw" the ball close to the normal speed of a bowling ball, and it must curve the ball to enhance the bowling experience, 2) the user interface should be within a six inch range of motion around the customer's hand, 3) the device needs to easily attach to a wide variety of different wheelchair designs, and be easily adaptable to go from one chair to another, 4) a personal assistant must be able to install it

unassisted, so the device cannot be too heavy or cumbersome to prevent a single person from installing it, 5) the device must be easily transportable so that it can be used at multiple bowling alleys; therefore, the device must come apart and fit in a car or truck.

The legs of the frame were constructed of PVC, and locking casters were attached to allow the device to act as a stationary bowler when desired. The top of the frame was constructed from aluminum and supported the controller and ball holder. The controller was made from a linear potentiometer, and simple circuitry was designed to allow the user to control the speed of the drill motor by moving the large handle shown in Figure 6.35

The curved portions of the ramp were also made of PVC. One of the rollers was made of Delrin to allow easy turning and low friction, while the powered roller was made of polyurethane. Steel rods attached to bearings and aluminum brackets provide structural support to each of the rollers. A drill motor and pulley were used to spin the roller; a small groove was machined into the polyurethane roller for the belt. A mechanism consisting of telescoping steel tubes and heavy duty pivot locking hinges was designed to attach the device to a variety of different wheelchairs. This attachment mechanism can be adjusted in height, width, and length to accommodate different users.

The material for the Rock-N-Bowler cost just under \$1230.



Fig. 6.37. Team with completed Rock-N-Bowler.



# THE QUADRICYCLE – HAND AND FOOT CYCLE

*Designers: Marissa Chin, Parker Drennan, Spencer Nelson, Kevin Reidy*

*Client: Scott Davis, San Luis Obispo, CA*

*Client Coordinator: Kevin Taylor, Kinesiology Department, Cal Poly, San Luis Obispo, CA*

*Supervising Professor: Sarah Harding*

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## INTRODUCTION

Daily tasks can be a challenge for people with physical disabilities, and one of the most important of those is getting a sufficient amount of exercise. The senior design team was tasked with designing and manufacturing a hand and foot powered cycle to be used for exercise and mobility by Scott Davis of Atascadero, California. The main objective of the project is to build a cycle that Mr. Davis can power predominantly by hands and upper body strength, but also allow a cycling motion and some power input by foot in order to get a full body exercise.

Mr. Davis has a C5 level spinal cord injury which is approximately at the deltoid/bicep height. Due to the location of his injury, he had very limited use of his arms and legs. He spent several months at a program called Project Walk and through rigorous rehabilitation he was able to regain a significant amount of upper body and leg muscle control. In order to achieve an appropriate amount of daily exercise, a hand and foot powered cycle is ideal for Mr. Davis. While there are many companies who design and manufacture hand cycles and recumbent cycles, there are few that produce a product that meets Mr. Davis' needs. The two that are closest to his needs are the BerkelBike Pro and the All Body Workout (ABW) Trike. The main design feature that will differentiate the cycle from anything else on the market today is that it will allow parallel hand and foot power, adapted specifically to Mr. Davis' abilities.

## SUMMARY OF IMPACT

Mr Davis is very happy with the final design of the bike, but has made a few small alterations after the product was delivered. It was very difficult for him to get in and out of the bike because of the positioning of the hand cranks, therefore one of our mechanical engineers made some modifications for him as part of

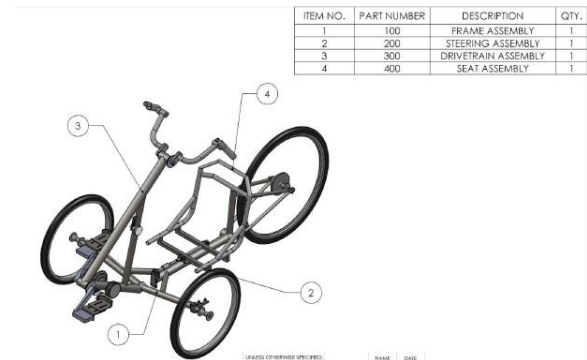


Fig. 6.38. CAD model of Quadricycle.

an independent study course. These changes have allowed Mr. Davis to exercise his upper body, while providing some passive (and slight active) motion for his lower extremities.

## TECHNICAL DESCRIPTION

The student team determined the following user requirements: 1) powered mainly by hands, specifically in a circular, synchronized, prone pedaling motion; the feet must move in a cycling motion as well and allow for parallel cycle power, 2) gears should be similar to a normal bike, with a low underdrive gear for hills and starting out, 3) easy to (dis)assemble and able to fit in a car, 4) weigh less than 50 lbs., 5) turning radius of < 12 ft., 6) width < 25 inches.

The frame material is 4130 chromoly steel. This alloy is commonly used in bicycle and recumbent frames since it provides adequate stiffness and strength, while maintaining low manufacturing cost. All components such as cranksets, spindles, bottom brackets, chain, derailleurs, shifters, wheels, and hubs are off-the-shelf components and can be purchased at any bicycle retailer. The hand pedal material chosen was 6061 T-6 aluminum for its high strength to weight ratio and excellent weldability.



The seat frame material is made of T6-6061 Aluminum, and the seat was made of lightweight foam.

The front wheels are 20 inch TerraTrike replacement wheels and tires. Since the team is using TerraTrike hub mount replacement spindles, these wheels are an appropriate match. The rear wheel is a standard 26 inch mountain bike wheel; the 26 inch size provides additional high gearing to help attain a higher top speed. Any three-wheeled vehicle with two wheels in the front requires steering geometry compensation for maximum stability during turns. As the vehicle executes a turn, the inside wheel makes a smaller radius arc than the outer wheel and as a result the angles that the wheels make relative to the chassis are different. Compensation can be made to account for this and is commonly referred to as Ackerman

compensation. For the Quadricycle, this compensation is performed by locating the tie rod mounting points appropriately.

The chain is routed from the hands to the feet on the left side through two chain rings of equal size. On the right side, the chain is routed from a 3 speed chain ring on the foot crank to an 8 speed cassette on the rear driving wheel. With the selected cassette and chain ring, the Quadricycle will be able to achieve a low gear ratio of 22:34 and a high gear ratio of 44:11. This means that in low gear, the user will be able to transmit approximately 130 ft-lb of torque if 150 lb. of force is given at the hand and foot pedals combined. In high gear, the user will be able to travel at a speed of approximately 28mph with a 90rpm cadence.

The total cost of the device was \$2675.



Fig. 6.39. Client with the completed Quadricycle.

# PIERNAS DE VIDA - DEVELOPING A LOW-COST PROSTHETIC FOOT

*Designers: Jennifer Van Donk, Justin Lekos, Sarah Baker, Kevin Yamauchi, Adam Paicely*

*Client: Vida Nueva Clinic, Choluteca, Honduras*

*Client Coordinator: Matthew Robinson, Hanger Orthopedic Group, San Luis Obispo, CA*

*Supervising Professor: Brian Self*

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## INTRODUCTION

Walking is such a part of everyday life in the developing world that it is frequently taken for granted. Transportation is often limited, and it is not uncommon for people to walk several miles every day to get to and from work, the grocery store, etc. A growing number of people, however, have severe disabilities due to traumatic, dysvascular, and congenital defects. There are 300,000-400,000 known landmine-related amputees worldwide, of whom 20% are children. In total, it is estimated that there are up to 500,000 total amputees worldwide, and that 5,000-10,000 are added to this number each year. Many of the amputees in Honduras are working men that were injured in mine explosions or train accidents. These men are often the main provider for the family and after an amputation they lose work because they are unable to perform the tasks required for their jobs. Therefore, a prosthetic leg, that can allow them to earn a living, is critical. In addition to empowering individuals to continue working, a well-designed prosthetic leg can improve a patient's self-image. Dealing with persons with physical impairments in any culture can be uncomfortable for both the patient and those interacting with the patient. There are many cultural stigmas attached with those who have disabilities, including viewing them as inferior and incapable. Piernas de Vida (the senior design team) hopes to fight back against stigmas held against persons with physical impairments and design products that can help break social and cultural barriers.

## SUMMARY OF IMPACT

Many clinics and organizations have been established in the developing world to attempt to treat those with lower limb impairments. One success story is the Vida Nueva clinic in Choluteca, Honduras, seen in



Fig. 6.40. The Vida Nueva Clinic in Choluteca, Honduras.



Fig. 6. 41. Different PolyStack prototypes.

Figure 6.40. Since it opened in 2003, the clinic has provided 369 new prostheses, 1278 orthoses, and performed 21 repairs. The clinic treats approximately 70 patients per year, including both children and adults. Vida Nueva prides itself on providing prostheses to patients who normally cannot pay. They also maintain close relationships with their patients to ensure proper fit and to provide follow-up care. However, because Vida Nueva is funded entirely by international aid organizations and other private donations, the clinic typically has to turn

away 10-20 people per year because they do not have funds for the necessary components. Currently Vida Nueva purchases most of its hardware from the US or Switzerland. Their typical costs are \$550 for an above knee and \$350 for a below knee prosthesis. Considering that the estimated per capita gross domestic product is \$1829, the cost for these prostheses is beyond the reach of most Hondurans. If Vida Nueva could manufacture high quality, lower cost prostheses within the country it could potentially help them to serve a larger population base as well as spur on the local economy by allowing individuals with disabilities to return to the workforce.

## TECHNICAL DESCRIPTION

During the Fall quarter, the entire team took a weekend trip to the clinic to perform a needs assessment and further develop relationships with the technicians (prosthetists), Walter and Roque, as well as several of the clinic's patients. They spent two days in the clinic and during this time had the opportunity to interview several patients who were receiving new prostheses or were in for regular adjustments. From these interviews, the team learned more about their stories and better understood their specific needs. They also observed Walter and Roque at work fitting patients with prostheses and discussed their thoughts about problems with the current designs. This trip was instrumental for all parties involved because it provided inspiration and enthusiasm. One teammate, Kevin, said that "Our trip to Honduras showed [him] how fortunate we are to have grown up in a country with bountiful resources" and he "left Honduras with a feeling of responsibility to use the knowledge [he] has gained in school to help others." Also, the trip provided the information about the needs, technical abilities, and available supplies at Vida Nueva that would have been extremely hard to attain otherwise.

Using information from this trip, the team developed the following user requirements: 1) manufacturable in house, 2) reproduce natural gait, 3) low cost, 4) minimal deterioration, 5) long replacement interval, 6) low weight, and 7) aesthetically pleasing.

The team brainstormed several different designs, and performed structural analysis on their top concepts. After testing different design concepts, the students decided that the PolyStack Foot was the best alternative. This foot, pictured in Figure 6.41, is composed of multiple layers of material fastened with a bolt that simultaneously acts as the ankle. A



Fig. 6.42 PolyStack being tested on the Instron machine.

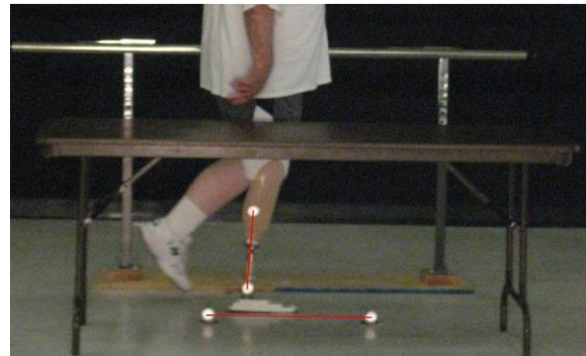


Fig. 6.43. Gait analysis on subject walking with the PolyStack.

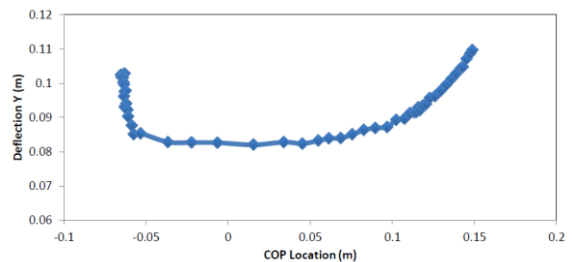


Fig. 6.44. Rollover shape from gait analysis.

second pin is inserted through the layers in front of the bolt to provide rotational stability. The layered design will allow for controlled flexion, and by joining the layers at different locations could provide a variety of gait responses. This also gives clinicians control over the foot behavior and allows them to vary the response according to individual patient needs.



Originally, the team was hoping to make the layers out of polyethylene terephthalate (PET) recycled from plastic bottles to form the layers. They noticed piles of bottles virtually everywhere in Honduras, so knew that it is a prevalent material and available at fairly low costs. However, the plastic must be melted into sheets, and this alone presents significant challenges.

Led by the Materials Engineer on the team, the students discussed and tested several viable options including compression molding (where plastic flakes are placed into a mold and compressed at high heat and high pressure into a flat sheet) and extruding (where flakes are placed into a machine that heats them and then compresses them out through a rectangular die to form films). The challenging task is to create these processes on a scale that can be replicated at clinics throughout the developing world. Unfortunately the team was unable to develop a suitable process for creating the recycled PET during the past school year, so they utilized their backup material, Delrin.

This material is an ideal alternative because it shares similar material properties to PET and is the same material used in the LeTourneau M1 knee. The greatest downside to Delrin is that it is not available in-country; however the layer foot would fulfill the low cost requirement. Similar to PET, Delrin is easy to work with. The construction process was as follows: 1) use a jig saw to cut out the pieces from the big sheet of Delrin, 2) measure out the locations for the holes using a square, center punched the hole, and then drill out the holes with a drill press (a hand drill can also be used), 3) insert the ankle bolt and install the pin with a mallet. The prototypes took approximately 2 ½ hours to build.

As can be seen in Figure 6.41, several different thicknesses (0.5 in, 0.375 in, and 0.25 in) were originally made for testing. The foot was placed in an Instron test machine and loaded to 4000 Newtons (see Figure 6.42). All of the feet were able to withstand the load, so the team then did human testing in San Luis Obispo.

Before each trial the patients were allowed to walk a few paces to become accustomed to the foot. They then walked across the force plate while both the force plate software and the video camera collected data. Each foot (0.5 inch, 0.375 inch, and 0.25 inch layer thickness) was tested with the force plate on



Fig. 6.45. One of the patients wearing the modified PolyStack.

two different patients three times for a total of 18 runs. Two runs of data were also collected for each patient on their standard prosthesis for comparison.

The testing equipment included a force plate from the Cal Poly Kinesiology Department and a long-zoom digital video camera. The force plate records the location of the Center of Pressure (COP) of the foot during gait as well as the magnitude and direction of the ground reaction force on the foot. Simultaneously, the video camera captures kinematic data from markers placed on the shank and on the ankle of the patient during gait. These two sets of data are then matched to produce an accurate rollover shape, as seen in Figure 6.46.

After each prototype foot the patients were asked a series of qualitative questions about their experience. Both patients had similar responses and helpful feedback. The following were questions asked in the survey: 1) Did you feel more or less balanced on this prosthesis when you were standing/walking? 2) Did you feel the foot turn inward or outward at all? 3) Was the foot heavier or lighter than your standard prosthesis?

Patient 1, because he was much heavier, felt most comfortable on the 0.5 inch foot. There was considerable deflection in the toe from this foot under his weight, however little to no deflection in the heel. Patient 2 responded best to the 0.375 in foot. Their comments alone made it clear that there was a

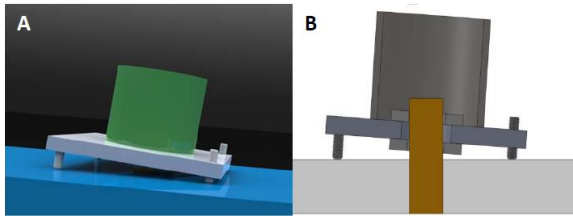


Fig. 6.46. A solid model [A] and section view [B] of the pylon cup adapter. The pylon is inserted into the cup and the four set screws allow two axes of rotations (inversion/eversion and flexion/extension).

correlation between weight and appropriate thickness. Patient 1 frequently commented that the foot “felt out of whack.” It was clear that he was not accustomed to the foot, and did not find it particularly comfortable. Both patients felt that the heel strike was significantly too hard and there was little to no give. We observed the toe was too compliant on the thinner feet, so the patients felt as though they were “falling forward”, “going downhill,” or being “thrown forward.”

The team was pleasantly surprised at how much flexing there was. They did not believe there would be much deflection, however all three feet showed considerable compliance, and some even exhibited too much deflection. From the results of the test, their primary suggestion was to shift the bottom layer back in order to improve deflection in the heel and reduce the deflection in the toe. Unfortunately, you can only shift the bottom layer out a few centimeters. If the heel protrudes too far behind the ankle it will not induce natural walking motion.

Three additional prototypes were constructed for testing at the Vida Nueva Clinic. 1) 0.375” modified: In this design the middle layer was shifted forward to be in line with the top layer. This was done to soften the heel and stiffen the toe. Each layer was 0.375 inches thick. 2) 0.25” modified: Same design as above but using 0.25 inch layers. 3) 0.1875” modified: Same design, but using 0.1875 inch layers. In Figure 6.47, one of these prototypes is shown on a Vida Nueva patient.

The prototypes were then taken to the Vida Nueva Clinic in Honduras, and a series of subjective tests were performed. Several of the lighter patients commented that even on the 0.1875” modified the toe was a bit stiff.

Walter, the Vida Nueva technician, made several suggestions, including cutting the toe a bit shorter or using an even thinner layer in the middle. Another concern was the overall length of the foot. Many of the patients were shorter and would not normally use a 26 cm foot. Their complaint was that they were unable to reach the toe flexion point in the foot in their natural gait because it was so far forward. The team has not yet tested out scaling the feet down, so it is unclear how the foot will perform if all of the layers are shortened.

One individual mentioned that he felt some energy return as he walked forward. A second patient stated that using the 0.1875 modified foot felt considerably smoother than the ICRC foot he had been using, even though it was a bit too long for his height. He felt very comfortable on this foot, and walked around with confidence, even testing out the hills and steps in the dirt area behind the clinic. He also brought in his bike and rode around a few laps with ease.

The technician Walter, who currently uses a Flex Foot, also tested out the 0.1875 inch PolyStack. He said he liked the feel of the foot, though the pylon was a little long so it was hard to get an accurate feel. He mentioned that the heel felt a little stiff and commented that it would be a good idea to potentially use a different material for the heel than the rest of the foot.

The total estimated cost for the foot is \$17.70.

Two different trips to Honduras were paid by a generous grant from Boeing and funds from the Cal Poly chapter of the Engineering World Health Club. The team spent under \$750 for materials and fixturing costs for the project.

Finally, the team also spent considerable time in developing an ankle adapter to help the clinic use different donated feet that they receive. Often these feet have different attachment mechanisms, and it can be difficult to fit them onto different pylons. The preliminary design is shown in Figure 6.45. Because the bolt from the PolyStack is attached directly to the current Vida Nueva pylons using their current adapters, this ankle adapter was not rigorously tested.

Perhaps the most beneficial outcome of the project is the strong relationship formed between the students and the Vida Nueva Clinic. The clinic personnel were warm, talented, and open to new designs and

solutions to their design problems. The student team had various Skype video conferences to discuss their ideas and to get feedback from the technicians and clinic supervisor. The students went to Honduras on their own for the prototype testing, and brought an additional student who will continue the project next year.

Matt Robinson, a local certified Orthotist and Prosthetist, will continue to advise the project (he

travelled with the team on the fact finding trip and is fluent in Spanish). Next year's team will be formed from students in the Cal Poly chapter of Engineering World Health. Many of the students involved in the club have expressed great interest in prosthesis design, and this momentum will contribute to the success of the project in future years. This interest and the continued strong design work by our students will help sustain our relationship with Vida Nueva.



Fig. 6.47. Cal Poly Piernas de Vida Senior Design Team and personnel at the Vida Nueva Clinic.



# CHAPTER 7

## DUKE UNIVERSITY

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# DRUM ROLL, PLEASE : A CUSTOMIZED DRUM KIT

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## INTRODUCTION

Our client is a 12-year old boy with TAR syndrome, which causes him to have short arms with limited strength and reach. The goal of this project was to modify a drum kit so he could play comfortably. Modifications included custom drumsticks for each hand, a drumstick-actuated cymbal damper, a contoured and padded seat, extensions for the tom drums to move them closer to his body, and a third leg on the bass drum to prevent tipping due to the tom extensions. With these modifications, the client can comfortably play all of the components in the drum kit.

## SUMMARY OF IMPACT

The customized drum kit enables our client to indulge in his love of music and learn to play a musical instrument. "Before, I was always the triangle player," our client told us. His mother commented, "The drum kit has provided [him] with a cool activity to interact with his friends and increase his hand strength and coordination. He enjoys being able to do something that his peers do without being "different". He loves music and this project enabled him to do more than sing, as finding a way for him to play an instrument was hard for us. This project gave him the opportunity to do something he never would have been able to do."

## TECHNICAL DESCRIPTION

The Customized Drum Kit (Figure 7.1) includes adaptations to the drum seat, drumsticks, tom extensions, cymbal damper, and the addition of a third bass drum leg. The drum seat is constructed from a 10" wide, saddle-shaped contoured piece of 2" thick wood covered by two layers of foam, upholstered by a mattress pad and black velvet fabric. The manufacturer's mount is screwed into the bottom of the seat via four 1/4-20 wood screws. The resulting product is comfortable and supportive.



Fig. 7.1. Customized Drum Kit.

Custom drumsticks are provided for each hand. The left-hand drumstick is the standard 16" inches in length. Approximately 1" from the large end, a 3" diameter ball gives the client additional support for gripping. Three quarters of an inch past the ball toward the small end, the stick is narrowed from the original diameter of 0.55" down to 0.4", over a length of 3/4", giving the client a more secure gripping surface. The right-hand drumstick is lengthened by 4 inches by combining two drumsticks together. One stick is cut and the end lathed to 0.4" for 2" in length. The other stick is cut and the end drilled out to accept the "dowel" from the other stick. The two pieces are glued together. The end of this drumstick is wrapped in athletic tennis tape to facilitate grip.

The toms are the drums that sit on top of the bass drum. The tubes that normally connect them to the bass drum are extended via a tube connector. The new length of the extension can be adjusted between 4-16 inches. Because the longer moment arm increases the stress on the joint of the arm of the tom connector, a support tube is connected from the tube connector down to the support clamps of the bass drum. This vertical tube releases the stress on the joint.

The tom extensions move the center of mass of the bass/tom combination closer to the user, making the assembly more likely to tip. A third bass drum leg prevents tipping. This third leg consists of a 3" long aluminum rod that connects to a 1" stopper via a 1.5" long, 1/4-20 threaded rod, and thereby allowing adjustable height. The aluminum rod attaches to one side of a hinge with two 1/4-20 round head bolts. The other side of the hinge attaches to a metal strip residing securely between two bass drum support clamps.

The cymbal damper system attaches to the cymbal stand via a 1.8x2x1.2" aluminum support block, which secures onto the stand with a 1/4-20 threaded eye screw. Two 8" aluminum levers attach to the block such that they can pivot as the client pushes on a striking pad attached between the levers on one end. Two dampers, made from tennis balls, dampen the cymbal vibrations when the client does so. A spring attached between the damper levers and the support block returns the system to the starting position after actuation. Total cost of the modifications is about \$90.



Fig. 7.2. Client using custom drum kit.

# ROCKSTAR GUITAR STAND

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*Client Coordinator: Nancy Curtis*

*Supervising Professor: Larry Bohs*

*Department of Biomedical Engineering*

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## INTRODUCTION

Our client is an adult male who loves music and playing his guitar; however, due to cerebral palsy, he cannot hold the guitar and play it at the same time. The Rockstar Guitar Stand provides a safe and durable attachment for our client's wheelchair that supports his electric guitar as well as his keyboard. The apparatus attaches to the wheelchair armrests, and allows the guitar platform to adjust in height and angle for the most comfortable playing position.

## SUMMARY OF IMPACT

Our client loves music and has a dream of being a rock star. The Rockstar Guitar Stand enables him to play the guitar independently once his aide sets it up. The device also securely holds his keyboard, which previously had to be set on a table in front of his wheelchair. Our client described the device as "cool" and "wonderful." His aide commented, "[He] asks for, and uses the Guitar Stand daily, either for his guitar or the piano. Having the guitar stand lets him pursue a very strong passion of his in a very real and independent way... it encourages his independence with communicating by adding meaningful activities for him to ask for during the day; playing the guitar and piano helps him find common ground with peers that may have a more difficult time realizing that [he] shares the same interests, and it has led to new friendships; finally, it helps him with his self-esteem and confidence, and with actualizing his own identity, he is the person he wants to be- The Rock Star!"

## TECHNICAL DESCRIPTION

The Rockstar Guitar Stand (Figure 7.3) comprises three sections: the permanent section, the horizontal section, and the vertical section. The permanent section consists of two front brackets, two rear brackets, and two aluminum bracket tubes. The horizontal section consists of two aluminum rods, two bottom connectors, and a lower horizontal tube. The vertical section consists of two vertical tubes, two



Fig. 7.3. Rockstar Guitar Stand.

top connectors, an upper horizontal tube, a Variloc Plastic Hinge, a C-shaped guitar neck support, a Variloc Stainless Steel Hinge, and a guitar body support surface.

The permanent section components attach to the wheelchair under the armrests. Two custom-made aluminum front brackets attach to the vertical armrest posts using two  $\frac{1}{4}$ -20, 1.25" long socket cap screws. Two aluminum rear brackets attach similarly. Two aluminum bracket tubes, each 0.75" in diameter and 14" in length, extend through the holes of the front and rear brackets.

The horizontal section includes 0.6875" diameter, 26" long aluminum rods that slide into the aluminum bracket tubes. These rods secure to the aluminum bracket tubes using 1" long T-handle quick release pins, which insert through both sets of tubes. The aluminum rods attach to the two bottom connectors, which connect the aluminum rods to the lower horizontal aluminum tube. The lower horizontal aluminum tube is 0.75" in diameter and 22" in length.

The vertical section attaches to the horizontal section via the bottom connectors. Two vertical tubes insert into the appropriate holes in the bottom connectors,



where they are secured using 1.5" long T-handle quick release pins. The vertical tubes attach to two top connectors, which, like the top connectors, are milled from solid aluminum blocks. The top right connector attaches to a Variloc Plastic Hinge, which allows simple, locking adjustment in angle. A foam-padded, C-shaped guitar neck support extends from the top of the plastic hinge. The top left connector

attaches to a Variloc Stainless Steel Hinge. This hinge attaches to the guitar body support surface, which consists of a black wooden block on which the back of the guitar body rests. A metal J-shaped rod extends down from the block to support the bottom of the guitar body. Figure 7.4 shows the client using the Rockstar Guitar Stand. The cost of the components is approximately \$290.



Fig. 7.4. Client using Rockstar Guitar Stand.

# BIKE STABILITY DEVICE

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## INTRODUCTION

Our client has difficulty stabilizing herself on her bike due to cancer related treatments and surgeries. The goal of this project is to create a device to provide stability during intervals of starting and stopping throughout a bike ride. The Bike Stability Device includes a rotational system and a wheel support system. The final prototype provides stability for the client and has the ability to rotate. A future project will address rider actuation so the rider can move the wheels off the ground as desired.

## SUMMARY OF IMPACT

The bike stability device will enable our client to realize her dream of riding her bike again. Since she is stable once moving, having the ability to deploy and retract the wheels will give her the freedom and feel of cycling she desires.

## TECHNICAL DESCRIPTION

The Bike Stability Device (Figure 7.5) consists of two systems: a rotational system and a wheel support system. The rotational system includes two sealed ball bearings rotating on a  $\frac{3}{4}$ " diameter aluminum rod. The aluminum rod mounts into a triangular plate that is welded to a commercial bike rack, so that the rod protrudes horizontally. One bearing is pressed into a wheel support plate at the distal end of

the rod, while the other fits into a stopper plate at the proximal end of the rod. The support plate is oriented vertically downward, while the stopper plate is oriented vertically upward. Both plates are made from  $\frac{1}{2}$ " thick aluminum. The wheel support plate is linked to the stopper plate via two  $\frac{1}{4}$ " thick aluminum linkage plates mounted on the front and back edges, altogether forming a rectangle of  $\frac{1}{4}$ " aluminum for stiffness. Two shaft collars hold the bearings in place on the rod. Two angular braces of  $\frac{1}{4}$ " aluminum between the support and stopper plates further strengthen the system.

An extension spring attaches from the top of the stopper plate to the bike rack, biasing the system towards the down position at rest. A stopper plug, welded into the triangular plate, contacts the stopper plate to prevent rotation of the wheel support plate past vertical.

A wheel support system provides stability during leaning. The axle of each 12.5" diameter pneumatic wheel screws into the support plate as well as a T-shaped section, which reinforces the support plate and limits bending. Each wheel attaches via ball bearings to its axle. The support plate rotates about the previously described rotation system. Cost of parts for the device was approximately \$320.





Fig. 7.5. Bike Stability Device.



Fig. 7.6. Client using Bike Stability Device.

# WHEELCHAIR LEAFBLOWER

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## INTRODUCTION

Our client, a woman who uses a manual wheelchair, wanted to remove leaves that fall in her yard. A previous student design used a battery powered blower, which did not provide adequate power or duration. The Wheelchair Leaf blower includes a commercial gas-powered leaf blower that attaches behind the wheelchair seat. A flexible hose mounts to the wheelchair air port, and a throttle switch at the end of the hose allows her to easily vary the blower power. The hose end rests securely in a holster while she is traveling. The hose is long enough so that she can blow leaves with either her left or right hand, with a good range of motion. A custom starting station allows her to pull the cord to start the blower. With the Wheelchair Leaf blower, our client can now clear her yard of leaves independently.

## SUMMARY OF IMPACT

The Wheelchair Leaf blower restores independence in a part of life that our client enjoys: yard work. According to our client, she is very happy with the device and intends to use it regularly. She said, "This [device] is my favorite piece of adaptive equipment ever. I really love being outdoors, and this is going to make everything better."

## TECHNICAL DESCRIPTION

The Wheelchair Leaf blower (Figure 7.8) comprises a Stihl 86 CE hand-held leaf blower, an HDPE mount, a flexible hose, a throttle extension switch, a holster assembly, and a starting station. The Stihl 86CE leaf blower was selected for its blend of power, light weight, and ease of use. It has a 190 mph air speed rating, while weighing only 9.7 lbs. The leaf blower mounts to a 11"x16", 1/2" thick piece of high-density polyethylene (HDPE) using short sections of 1/16" insulated cable attached to eye screws in the HDPE and looped over three sections of the blower: one around the nozzle, one around the handle, and one around the base. Hooks fashioned from aluminum sheet attach the HDPE mount to the wheelchair rear frame member. A conduit clamp attaches the lower



Fig. 7.7. Client starting the Wheelchair Leaf blower.

portion of the mount to the tip-stopper on the bottom of the wheelchair, making the leaf blower system stable when starting and traveling.

A 3' long, 3" diameter flexible plastic duct hose attaches to the blower output port, and terminates in a fan-shaped piece of rigid plastic at the blowing end. Between the flexible hose and the rigid end is a commercial throttle extension switch, which provides a handle and an easy way for the user to vary the blower power from idle to maximum output. The switch includes a locking mechanism so the user can keep the blower at maximum without continuously squeezing the trigger. An extended cable, made using bicycle derailleur cable and housing, connects the trigger switch to the throttle lever on the leaf blower using a custom bracket on the HDPE mount.

Zip ties tether the cable to the blower hose so they move in tandem as the user flexes the hose while blowing.

A custom holster assembly holds the leaf blower hose end while traveling. The holster includes a 1" L-bracket that attaches the assembly to a slot previously mounted below the wheelchair seat. The holster arm, constructed using parts modified from a microphone stand and camera tripod, terminates in an 8" long piece of schedule 40 black PVC, cut lengthwise to create a U-shaped channel in which the hose end fits snugly. A Velcro strap keeps the hose end from vibrating out of the channel. The holster assembly keeps the hose end at a slightly downward and outward angle, so that the user can lock the throttle switch at maximum power while wheeling her chair with both hands, thereby blowing leaves while traveling.

The starting station includes a 3' long arm made from pressure treated wood, attached to an oak tree in the client's back yard.

A polypropylene rope loops over a 3" diameter plastic pulley at the top outer end of the arm, and terminates on the tree side in a 3" wide, two-pronged hook created from aluminum sheet. Three pieces of 2x4" pressure treated wood, staked to the ground, locate the optimal parking area for starting. To start the blower, the user backs into the parking area, and then reaches behind the chair to attach the rope hook to the pull-cord handle of the leaf blower. She then grasps knots in the rope, shown in Figure 7.7, and pulls quickly to start the blower. After unhooking the pulley rope, she is ready to begin blowing leaves. Testing revealed that the user can generate more force using knots in the rope than with a handle on the rope end, since she can then pull with both arms in a more fluid motion. The cost of the components for the device is approximately \$520.



Fig. 7.8. Wheelchair Leaf blower.



# HAND-POWERED MOBILITY DEVICE

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## INTRODUCTION

Children with spina bifida experience partial or complete paralysis of the lower extremities, often requiring an upper extremity powered mobility device in order to travel. In the United States, these devices are either easy to purchase at a local store or to build using a variety of commonly found materials. In countries like Kenya, however, materials are both scarce and expensive given the average income. As a result, young children in Kenya with spina bifida often rely on oversized wheelchairs, if any mobility device at all, to move around. The goal of this project was to develop a hand powered mobility device sized for children aged 2-5 years old that was cheaper than current alternatives, and that could be easily constructed from materials found in Kenya. The device features wheels that children can spin by hand to propel themselves, as well as a reclining seatback that allows the child to lie down while moving. Using this hand powered mobility device provides young children with spina bifida a more convenient, fun, affordable and easier-to-use mobility device.

## SUMMARY OF IMPACT

The device provides a durable, sustainable, and low-cost mobility solution for Kenyan children with spina bifida. By providing them with the ability to travel independently, this chair allows children to comfortably navigate their homes and engage in their communities. During testing with a local client with spina bifida, the client's mother commented, "This device is safe and is easy for my son to turn. I think the wheels work better than his [expensive] wheelchair."

## TECHNICAL DESCRIPTION

The Hand-Powered Mobility Device has three main technical features: reclining seat back, wheel locking mechanism, and hand-powered propulsion.

The main frame of the device is constructed from wood to keep it feasible and sustainable for people to



Fig. 7.9. Client using the Hand-Powered Mobility Device.

construct it in Kenya. The frame of the device consists of two U-shaped wooden frames attached together with a second plank of wood to provide more strength and support to the joints.

The seatback reclines using two door hinges that attach to the main frame. A T-bar, attached to the rear main frame using a small hinge, supports the seat back at a 100° upright position, or can be disengaged to change to a 180° reclining position. Two L-brackets attached to the seatback provide a "stopper" to secure the T-bar in place in the upright position. Velcro straps prevent the T-bar from moving out of the L-brackets on rough terrain.

The wheel-locking mechanism keeps the device stationary while the user enters and exits the device. Two door latches attached to the bottom of the device are released into the wheel spokes to lock the wheels in position.

The child propels the device by manually spinning two 12" pneumatic bicycle wheels. A common axle, connected to the bottom frame via one L-bracket on each side, provides stability for the cantilevered wheels. Three caster wheels, two in the front and one in the rear, provide stability and make the device easy to turn.

Leg guards attached to the front frame keep the clients' legs from sliding off the device, and an adjustable seat belt keeps the user securely fastened. Removable, Velcro-secured Cushions add comfort and prevent pressure sores on the clients' back and legs. Finally, spoke guards on both sides of each wheel protect the client from possible finger injuries that could arise from spinning spokes. Cost of parts for the device was about \$290.



Fig. 7.10. Hand-Powered Mobility Device.

# EASYSHRINK: A DEVICE FOR SAFELY APPLYING SHRINK WRAP

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## INTRODUCTION

The goal of this project was to create a device that enables employees with disabilities at OE Enterprises, Inc. to safely and reliably apply shrink wrap to vitamin supplement bottles. EasyShrink physically isolates the heat gun from its user using a wooden insulating box. A metal control box with a push button and knob creates easy activation of the automated turntable for a set time interval. This device empowers employees to perform the shrink wrapping task without fear of injury.

## SUMMARY OF IMPACT

Employees at OE have been eager to use EasyShrink because it makes shrink wrapping safe and easy. "Nobody is afraid of using [the EasyShrink]. Actually, everybody wants to use this," said James Hurst, an OE staff member who oversees the shrink wrapping task. "This is the best thing. It's helped us out a lot, and we want another one." Regardless of size, the device can shrink wrap each bottle within 20 seconds. Since its introduction, the EasyShrink has increased total bottle output from 250 a day to 700 a day. In addition, multiple employees can perform the task with ease, and a few veterans now work independently without supervision.

## TECHNICAL DESCRIPTION

EasyShrink (Figure 7.12) consists of three key components: a wooden insulating box, a metal controller box, and an automated turntable, all of which mount on a consolidating platform of plywood. The insulating box (13"x8<sup>5</sup>/<sub>8</sub>"x10<sup>3</sup>/<sub>4</sub>") isolates the high-temperature Master Appliance heat gun from the user. The heat gun rests on a stabilizing wooden block (3.5"x1.5"x1.5"), and its nozzle protrudes into a 5" long, 2" diameter aluminum heat sleeve. The heat sleeve fits snugly into an aperture in the box facing the motorized turntable, allowing hot air flow to be directed outside. A hinge on the top of the box allows for insertion and removal of the heat



Fig. 7.11. An employee shrink wraps a nutritional supplement bottle using the EasyShrink.

gun. The heat gun's power cord connects to a 3-prong outlet on the metal controller box (9"x5"x6"). Handles affixed to the box sides make the device easy to lift and transport.

The controller box attaches to the side of the insulating box. On top are a turntable activation button and a timing knob to set the desired time for shrink wrap application. When the user pushes the button, the heat gun and turntable are both activated for the time set by the timing knob. A modified Velleman interval timer provides a one-shot interval adjustable up to 35 sec, and an Omron AC relay powers the heat gun and turntable for that interval. A main power cable extends from the controller box to a surge protector, providing an emergency switch to shut off the entire system if necessary.

The turntable rests on a rectangular wooden platform. A DC gear motor, rotating at 12.5 RPM, mounts to a wooden box on the platform. A circular motor mount of 1.5" diameter attaches to an 11" diameter wooden turntable.



Countersunk holes in the turntable allow stabilizing pins to hold different sized bottles upright. Three circular disks accommodate different bottle sizes. Bottles are wrapped upside-down, so these disks are slightly smaller than the respective bottle lids. Wrapping upside-down allows all bottles to be

wrapped without adjusting the height of the heat gun or turntable. The disks remain centered using protruding screws mounted in the turntable and respective holes on the bottom of each disk. The replacement cost for the device is \$230.

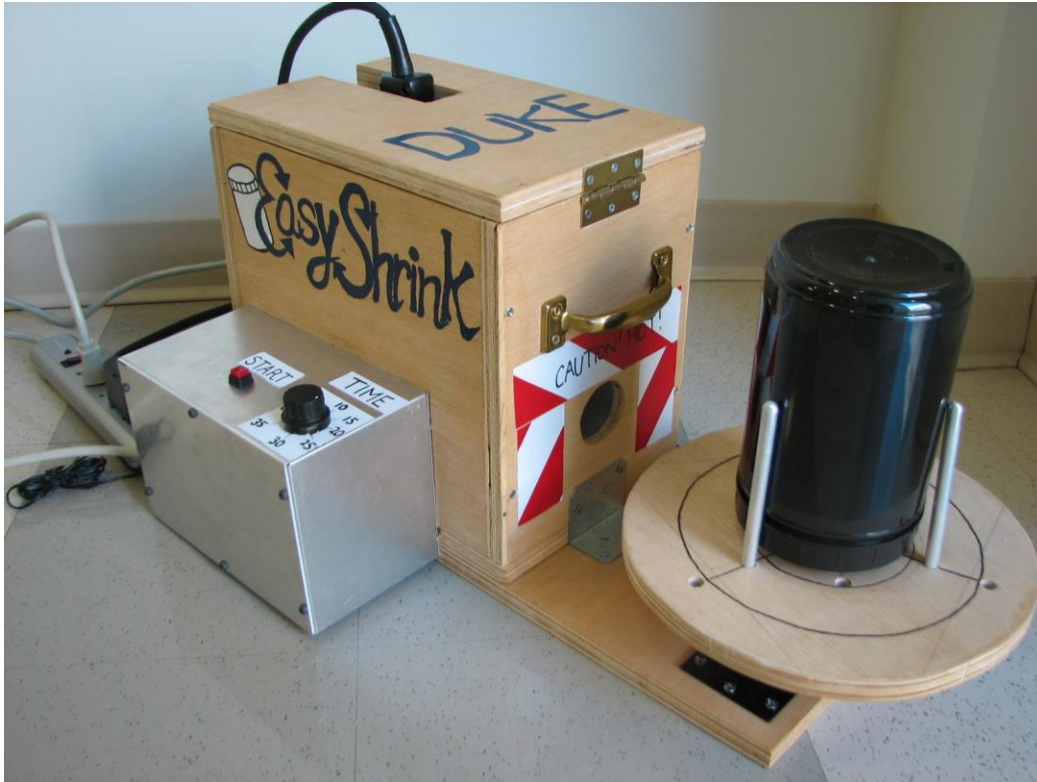


Fig. 7.12. EasyShrink.

## PORTABLE SUNSHADE

*Designers: Henry Hwang, John Lee, Tamara Louie, Nicholas Ong*  
*Client Coordinator: Kimi Dew, Goodwill Industries of Eastern North Carolina (GIENC)*  
*Supervising Professor: Larry Bohs*  
*Department of Biomedical Engineering*  
*Duke University*  
*Durham, NC 27708*

### INTRODUCTION

The nature facilities at the Goodwill Industries of Eastern North Carolina (GIENC) are used to produce gardening products and to provide pleasant gardening experiences for people with disabilities. During the hot summer months, staff members and people with disabilities work at these facilities under direct sunlight. The goal of this project was to provide a portable sunshade device to GIENC. The device consists of a sixty square foot UV-resistant shade attached to a frame of galvanized steel, mounted on four wheeled poles for mobility. When the device is deployed, the users can work in a shaded area and enjoy a respite from the sun's light and heat.

### SUMMARY OF IMPACT

The portable sunshade allows our clients to enjoy gardening under the shade during summer. The supervisor at GIENC commented, "The portable sunshade creates a space for shade while our groups of adults with disabilities are working in the raised planters and other places on the farm tolerating more time outside and providing UV protection for a large number of people. It is also a mobile device that makes it handy to move about easily with just a couple of people."

### TECHNICAL DESCRIPTION

The Portable Sunshade (Figure 7.13) includes a mesh tarp, a sunshade canopy, aluminum supports, four 90° connectors, four lockable wheels, four aluminum disks, and handles. The mesh tarp is a commercially available product from Tarp Cover Sales. It is a black polypropylene mesh tarp with 100% UV protection and 73% shading. The tarp attaches to the sunshade canopy using bungee cords and metal grommets at 18" intervals on the tarp edges.

The sunshade canopy is modified from a commercially available product by Outdoor Canopy, with horizontal dimensions of 6' x 10' and a 7'7" height. The commercial product, which had a peaked



Fig. 7.13. Portable Sunshade.

roof, was modified to have a flat top frame by replacing the top connectors with 3-way 90° connectors. This flat roof, combined with the mesh nature of the tarp, make the device far less prone to being moved by the wind. All of the poles are made from 1 3/8" diameter galvanized steel, custom

powder-coated green for durability and aesthetics. The poles attach to connectors using eye screws.

Custom aluminum supports attach at the top corners to provide stability. These supports are made from round-edged, 3/16" thick corrosion resistant aluminum bars, each 1/5" wide and 20" long. The supports attach to the vertical poles using 1/4-20 bolts and nylon-inserted nuts.

Pneumatic 8" lockable wheels from Waxman Consumer Group attach to the footpads of the vertical poles using custom aluminum disks, each 1"

thick and 6" in diameter. The wheels provide a simple foot-actuated locking mechanism to prevent the device from rolling, and their large size makes moving over rough terrain easy. The wheels and the footpads attach to threaded holes in the bottom and top of the aluminum disks respectively, using 1/4-20 screws and threadlock. Handles made from cushioned grip tape mount at a 4' height on the vertical poles to make the device easier to transport, especially if the metal poles become hot from sun exposure. The cost for the device is approximately \$580.



Fig. 7.14. Client using Portable Sunshade.



# IRON CHEF: COOKING ADAPTATIONS

*Designers: Katie Apibunyopas, Seung Yun Lee, David Song  
Client Coordinator: Fay Tripp, OTR, Lenox Baker Hospital  
Supervising Professors: Kevin Caves and Richard Goldberg  
Department of Biomedical Engineering  
Duke University  
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## INTRODUCTION

Our client, Joshua, is a teenage boy who was diagnosed with a primary brain tumor and experienced a stroke as a result of surgery to remove the tumor. The stroke left Joshua both paralyzed on the left side of his body and cortically blind. Through physical therapy, he has been able to regain motor function in his left leg and shoulder but still has limited motion, strength and sensation in his left arm. He retained full control and strength in the right side of his body and is able to stand and walk independently. He has full cognitive comprehension and verbal abilities.

Joshua enjoys cooking, but as a result of his disabilities, has not been able to do so without the help of his mother. For this project, we developed several custom devices that enable him to prepare his three favorite dishes with minimal assistance: spaghetti and meat sauce; steak with mashed potatoes and a vegetable; and chicken quesadilla. These dishes require many different cooking tasks that are difficult for Joshua to accomplish with standard cooking utensils.

## STATEMENT OF IMPACT

While Joshua still required some supervision and assistance after initially receiving the devices, his mother was confident that with practice he would become more independent. Additionally, she reported: "Making it safe is very important and they we're able to do that. He is not going to burn himself. And the cutting board, wow, that is a device. They did an amazing job with the cutting board, making sure that it is very safe." Joshua told the team: "I love it and it's going to definitely help with my independence in the kitchen. Soon enough I will be making everyone dinner ... I'll open my own four star restaurant!"



Fig. 7.15. Client using Iron Chef

## TECHNICAL DESCRIPTION

The team created three devices to assist Joshua with cooking tasks: a modified George Foreman grill, custom modified spatula/tongs, and a custom cutting board.

A. Modified George Foreman Grill. In order to grill steak, chicken and vegetables, we selected the G4

George Foreman grill (GRP94WR), which consists of two grilling surfaces, in which the top plate folds down onto the food to be cooked. The grill comes with removable plates for easy cleaning, a large cooking surface area, and a temperature knob that allows the grill to be turned off even when plugged in. We added rubber tactile cues around the temperature knob to help him set the grill to the appropriate temperature. To use, the client puts the food on the grill, closes the lid and waits for it to cook. This eliminates the need for Joshua to flip the piece of food and, for safety reasons, limits the amount of exposed heated surface while it cooks. To provide additional safety, we added a shield made of heat resistant polyetherimide plastic. We milled a handle into the shield, and attached it to the top part of the grill with two hinges. When the grill is opened, the shield extends over the grilling surface to prevent his hand from coming in contact with the hot grill plate. In the closed position, the shield extends forward and prevents Joshua from accidentally reaching into the grill or into the hot grease that drips out. When the unit is closed, the exposed upper surface also gets hot, so we provided a heat-resistant cover, made of potholder material. This cover is attached with Velcro.

**B. Custom Spatula.** We attached two oversized, pancake spatulas to a set of barbeque tongs (Figure 7.16). With the larger surface area of the spatulas and

their ability to clamp the food in place, he will be able to easily move food on and off the grill without having to balance it. We machined grooves into the spatula heads that match the grooves of the George Foreman grill. The front edge of the top spatula was bent to make a rake-like shape to help scrape food off of the grill. The larger spatula face, which provides roughly 9 square inches of surface area, accommodates larger pieces of food such as a quesadilla.

**C: Cutting Board.** We created a modified cutting board that can be operated with one hand. The cutting board has a sliding food holder that slides in small increments towards an attached knife (Figure 7.16). This allows Joshua to slide food in fixed increments and then locate the stainless steel knife to slice the food. The cut pieces slide directly into a removable container on the other side of the knife so that Joshua can collect and carry them elsewhere in the kitchen. The knife is held in place with a removable pin to allow for washing of the knife. The pin slides in a slot over a distance of 2" and rotates about the point of the pin to allow for a slicing motion. The knife rests on a 4" block on the edge of the cutting board to allow for food to be slid under the knife into position without exposing too much of the knife blade.

The total cost of the three devices was \$375.



Fig. 7.16. Iron Chef Devices [clockwise from top left]: Modified Grill, Spatula/Tongs, and Cutting Device

# VOICE TRAINER

*Designers: Calvin Lee, Joe Hoerner, Morgan Fox*  
*Client Coordinator: Meredith Nye, SLP, CCC, Duke University Medical Center*  
*Supervising Professors: Kevin Caves and Richard Goldberg*  
*Department of Biomedical Engineering*  
*Duke University*  
*Durham, NC 27708*

## INTRODUCTION

People with Parkinson's disease (PD) often develop speech and voice disorders. Our client, an older woman with PD, experiences these common symptoms as she is prone to gradually lowering the volume of her voice and has little vocal endurance. Many patients with compromised speech secondary to PD, including our client, undergo the Lee Silverman Voice Treatment (LSVT), a method of therapy that seeks to improve speech and voice by focusing on improving vocal loudness.

In LSVT therapy sessions, patients are reminded to speak more loudly when their voice drops below an appropriate volume, and they also undergo various vocal loudness exercises. LSVT has been shown in multiple studies to be an effective program in treating speech and voice disorders. Therapy is intense, requiring patients to commit to four consecutive weeks of daily therapy sessions intended to habituate speaking loudly. We developed the voice trainer to support LSVT therapy by providing biofeedback on voice volume throughout the day.

## STATEMENT OF IMPACT

Our client's therapist reported: "The device will be helpful in giving patients biofeedback to help ensure they are speaking with sufficient volume. It often falls to the user's caregiver or spouse to remind the user to speak up and it is not uncommon for this to lead to resentment. This device will definitely help improve the user's quality of life."

## TECHNICAL DESCRIPTION

The team developed a microprocessor-based device that measures vocal and ambient volumes and gives feedback if the user is not speaking loudly enough. It can be worn or carried and monitors speaking volume continuously. If the speaking volume is not loud enough compared to the ambient volume, a red LED is illuminated and a vibration motor is activated.



Fig. 7.17. Client using the device.

If the speech is loud enough, a green LED is illuminated and there is no vibrational feedback.

The device uses an omnidirectional microphone to measure the speaking and ambient volume and a throat microphone to detect whether or not the user is speaking. The throat microphone used in this device is a Socom Paintball Throat Microphone (RAP4 #001981). It has an adjustable strap with a magnetic connector that provides a snug but comfortable fit. The microphone works by sensing the user's vocal vibrations, so it does not pick up sounds from other peoples' speech or ambient noise. Although signal magnitude increases with speech volume, this microphone cannot be used to reliably measure volume because signal magnitude is very sensitive to positioning and tightness of the strap. The omnidirectional microphone was taken from a Communications Ultra-Light Headset (RadioShack #19-315). Because the microphone is



omnidirectional, its signal is not sensitive to positioning. This microphone is attached to the throat microphone strap, rather than on the user's clothing, in order to ensure consistent microphone placement and to consolidate wires (Figure 7.18).

Both microphone signals are input to a custom circuit, which filters and amplifies the signals and passes them to an Arduino Mini microcontroller. This microcontroller was chosen because it is easy to program, yet powerful enough to rapidly sample and process the analog inputs. It samples the throat and omnidirectional microphones signals, determines

whether speech is sufficiently loud, and gives an appropriate output.

A small, ABS-plastic case was fabricated and the device can be kept in a pocket or clipped onto an article of clothing (Figure 7.17). The case contains the PCB, microcontroller, rechargeable 7.4V, 800mAh Polymer Lithium-ion battery, on/off switch, and feedback mechanisms. It is designed so that feedback can be easily noticed by the user; the vibration motor is positioned to maximize sensation and the LEDs are placed in a convenient location.

The total cost of the device was \$232.



Fig. 7.18. The Voice Trainer. The microprocessor and circuitry are inside the enclosure in the top of the photograph, and the throat microphone and omnidirectional microphone are at the bottom.

# VERTICAL DISPLAY STAND

*Designers: Laura Struzyna, Alexandra Sterling, AlessondraSpeidel*  
*Client Coordinator: Catherine Alguire, OT, Jen Michalenok, Lisa Stinnett, Durham Public Schools*  
*Supervising Professors: Kevin Caves and Richard Goldberg*  
*Department of Biomedical Engineering*  
*Duke University*  
*Durham, NC 27708*

## INTRODUCTION

We created a transportable, adjustable display stand for a special needs classroom in a local elementary school. Our clients have a number of different neurological disorders, including Angelman's Syndrome, spastic quadriplegic cerebral palsy, and cortical vision impairment (CVI).

To interact with and instruct the students, the teachers use a variety of educational materials including books, papers, toys, binders, as well as felt and magnetic items. It is difficult for the teachers to hold the materials in the appropriate location in front of the student and to instruct the student at the same time. Staff have tried several different commercially existing products that partially satisfy the clients' needs. Tripod easels with magnetic whiteboards are currently available, and 3M offers an adjustable monitor arm that can be swiveled, tilted, and moved vertically for optimal positioning. However, there is no single existing commercial product that is sturdy or versatile enough to incorporate and display all of the materials in a manner that is comfortable and effective for all users. To address these needs, we developed the Vertical Display Stand, which enables teachers and staff to display a variety of educational materials while the teacher is free to move around and interact with the student more easily.

## STATEMENT OF IMPACT

One of the teachers stated: "This is amazing! The design is fantastic. It gives us all of the opportunities that we are going to need in order to allow for our students to access their materials and do partner-assisted scanning. So, this is really everything we wanted to have happen for them. I am really excited to use this!" The school occupational therapist reported: "The needs and concerns were complex and challenging - they were all well addressed by the product design. Thank you for contributing to the daily education of countless students with multi-handicapping conditions!"



Fig. 7.19. Front view of the Vertical Display Stand.

## TECHNICAL DESCRIPTION

The vertical display stand design looks like an easel, as seen in Figure 7.19. It has an adjustable central board that allows for the display of the teachers' various educational materials at multiple angles. The stand is designed so that the teachers can push the clients up to it in their wheelchairs.

The structure is made of oak plywood and coated with a washable black satin polyurethane coating. The stand is about 40" wide and 60" tall. The central display board is about 40" x 25". The bottom of the board is 28.5" above the ground to allow room for the students' wheelchairs and reaches a height of 53.5" to



accommodate the vertical visual ranges of all the students.

The central display board has several unique features. The entire board can tilted in 10 degree increments, from 30 degrees forward, to 10 degrees back. The board has a built in white board door mounted on hinges to allow the teacher to sit behind the board, open the door to write on the board, then close to show the student. There is another hinged section of the display board, designed to facilitate face-to-face, partner assisted communication techniques. The entire display board is covered with black felt and there is a black felt cover for the white board that attaches with magnets that are inlaid on the display board. There is also a separate yellow felt cover that attaches with magnets to provide a high contrast background for students that need it. The magnets can also be used by the teachers to easily place items for students to make visual selections.

A set of shelf brackets is mounted to the front of the display board. We provided a narrow shelf that can be used to hold books and papers as well as a clear office folder holder that the teachers use to hold their custom made binder books.

To address specific visual impairments, the display stand includes a visor and focal task lighting. A swing away visor was installed on the top of the stand to block out the overhead lights. Two gooseneck lights, mounted to the front of the stand, provide task lighting. Both lights use low temperature, energy smart soft white bulbs. The lights are plugged into a power strip that sits out of reach of students, underneath the visor at the top left of the left A-frame base. The power strip has a six-foot cord that allows it to be plugged into a nearby outlet. Remaining outlets on the power strip can be used for other electronic devices the teachers want to use with the students.

The total cost of the device was \$447.

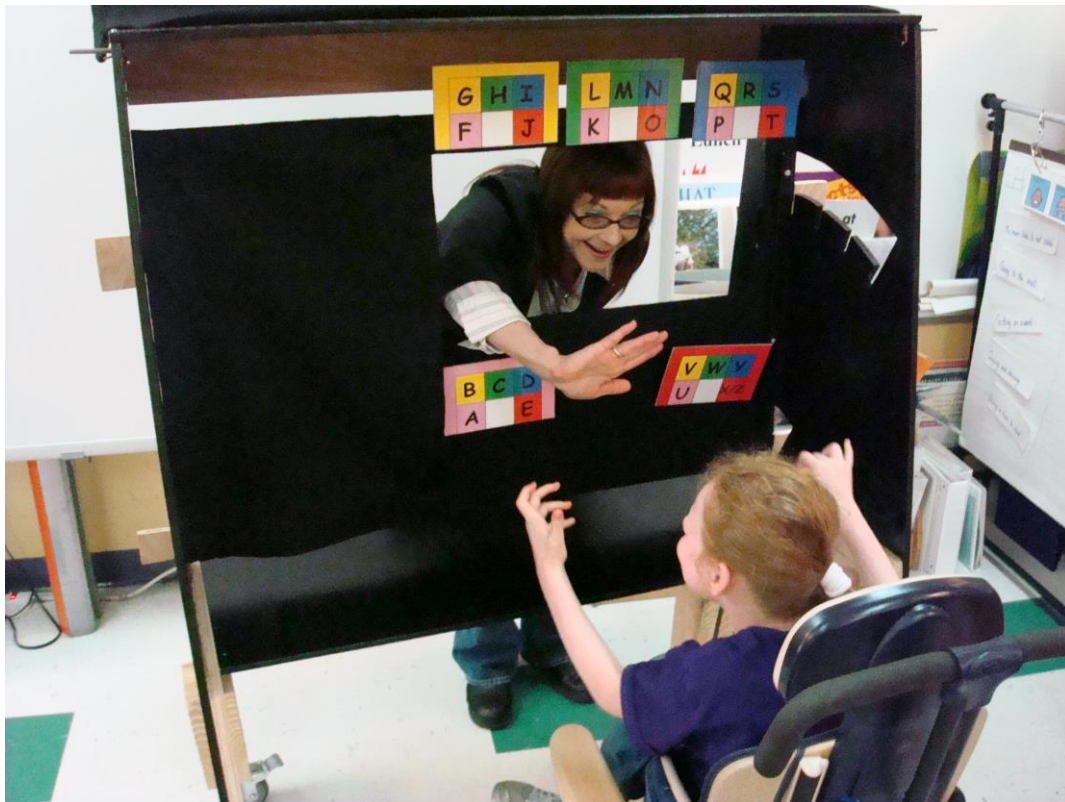


Fig. 7.20. Teacher using the device with a client.

## MOVIN ON UP

*Designers: Sam Lipman, Nicole Rothfusz, and Kelly Waldman  
Client Coordinator: Charlotte Hughes, PT, Orange County Schools  
Supervising Professors: Kevin Caves and Richard Goldberg  
Department of Biomedical Engineering  
Duke University  
Durham, NC 27708*

### INTRODUCTION

Molly is a middle school student who uses a manual wheelchair due to a spinal cord injury. She has paraplegia at the T-3 level and does not have motor control or sensation below mid-sternum, but has full movement of her head, neck, shoulders, arms, wrists, and fingers. She is strong in both pulling and pushing motions. Molly is able to maneuver her manual wheelchair independently and can transfer independently between horizontal surfaces that differ less than 2 inches in height using a depression lift in which she lifts her body weight up with her arms.

Molly is in a technology class where the other students sit on stools at elevated tables. She is currently unable to do this because the stools in the classroom do not provide adequate support and she is unable to raise and lower herself the ten inches between her wheelchair and the height of the stool. In order to work at these elevated tables, we developed a device that will enable her to raise and lower herself independently, while also providing the necessary cushioning and postural support..

### STATEMENT OF IMPACT

The physical therapist reported “Molly is excited about the device as it allows her to use the same desks as her peers and it will give [Molly] access to the lab table for years to come.” Additionally, while utilizing the device, Molly exclaimed several times: “I feel so high!” and “I’m higher than a table for once!”

### TECHNICAL DESCRIPTION

We modified a commercial drafting chair, the Global Deluxe Fabric Drafting Chair (purchased from Staples), which uses a gas spring to adjust the height of the chair over a ten-inch range. Like typical office chairs, when the user unlocks the pneumatic gas spring assembly, the chair rises when no weight is placed on the seat, and lowers when the user is seated. New adjustable armrests and support poles



Fig. 7.21. Movin On Up Chair, raised position with base in open position.

were designed so that the client can perform a depression lift, de-weight the seat and subsequently activate the pneumatic gas spring assembly to raise the chair in a series of increments. Once the client raises the chair to the desired height, the chair mechanism can slide forward along tracks, so the client can pull herself in to work at the elevated table. The device is pictured in Fig. 7.21.

We made several modifications so that Molly could de-weight herself to easily raise and lower the chair. We added a bicycle brake handle and cable to pull on

the lever mechanism that unlocks the gas spring. The brake handles attached to the right armrest and when squeezed, the brake lever pulls on the cable, which lifts the unlocking lever. The chair will go up if the client puts no weight on the seat by performing a depression lift, and down when she sits in the seat.

To facilitate the depression lift, we constructed armrests that can adjust in height. A pair of vertical, 4' long 1" square aluminum tubes support the armrests. Each tube has four 3/8" bolts driven through them to create different supporting heights for the armrests. The armrests are constructed from 2"x4" wood, which are each attached to 2"x3" rectangular tubes of 1/4" thick pieces of aluminum that are 7" in length. There is a 1 1/8" x 2" rectangular hole cut from the back of the metal tube. The vertical supporting bars fit through this hole, so that the armrests can slide up and down the supporting bars, and stay in place at the height of any of the bolts.

The modified drafting chair is mounted to a custom T-shaped wooden base constructed from two pieces

of plywood that measured 25"x28"x1/2". The plywood bases are connected via four side drawer slides, to allow the client to slide the chair up to the desk to work as close as she would like. Each pair of drawer slides can support up to 100lbs. The top base piece has six non-caster wheels that support the device when the sliders are in the open position as the client transfers in. The two wheels in the back also allow the device to be easily transported between classrooms.

For increased safety, it was necessary to prevent the base from swiveling while transferring. A locking mechanism was fashioned out of a 1 1/2"x3" rectangular aluminum tube with a 1/8" thickness. The mechanism catches a horizontal stabilizer support for the armrest poles and locks automatically when the seat is lowered to its lowest position. This prevents any swivel movement while the chair is in the lowest position and enables a safe transfer.

The total cost of the device was \$486.



Fig. 7.22. The client using the device with her physical therapist.



# POOL CHAIR

*Designers: Luke Li, Andy Pettit, Xinli Zhang*

*Client Coordinator: Jean Bridges, Lenox Baker Hospital, Duke University Medical Center, Durham NC*

*Supervising Professors: Kevin Caves and Richard Goldberg*

*Department of Biomedical Engineering*

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## INTRODUCTION

Lenox Baker Hospital offers Aquatic Physical Therapy (APT) conducted by physical therapists. Physical therapists utilize the buoyancy, viscosity, and hydrostatic pressure of the water to help support the body by diminishing the effects of gravity. The water also helps reduce stress on joints and muscles, while improving circulation due to the compressive forces of the water. The patients at Lenox Baker undergo APT to help relieve or recover from arthritis, chronic pain, balance impairments, obesity, and profound weakness.

For patients who need assistance in entering the pool, physical therapists transfer them to a water wheelchair, and then roll them down a narrow ramp into the water. The ramp includes a narrow, 180 degree turn that is difficult to maneuver. They have a commercial PVC wheelchair that can be used for patients that weigh in excess of 250 lbs., but it is difficult to maneuver for heavy patients. This is due to the force of the patient's weight on the rotating front casters, making them resistant to rotation. In addition, the pool wheelchairs are subjected to water and chlorine exposure for around 6 hours a day, leading to the constant need for repair and replacement of the tires and axles. To address all of these concerns, we developed a pool wheelchair that is easy to maneuver up and down the narrow ramp into the pool (figure 7.23). It is durable and can accommodate patients who weigh up to 400 lbs.

## STATEMENT OF IMPACT

The Physical Therapists at Lenox Baker found that the Pool Chair is safe, effective, and easy to use. One PT commented that "The firmness of the seat is perfect. If we need any extra padding for the seat we'll just use towels." And a patient stated that "the central bar you have is great. It's nice because it reminds you there are bars beneath the seat. I also like the removable arm because it gives you more flexibility in transferring into the chair... I had no problems



Fig. 7.23. The Pool Chair.

getting into or out of the chair." Finally, a PT stated that "Can we just have you make a few more?"

## TECHNICAL DESCRIPTION

Our design was based on a three-wheel frame made out of furniture-grade PVC. Preliminary research and testing showed that this would provide a much smaller turning radius than a conventional four-wheel design, making it easier to navigate the ramp at Lenox Baker. The device contains four main components: frame, front caster, rear wheels, and seat.

The frame of our water wheelchair is constructed out of furniture grade PVC (1.5" Diameter). Our design uses a base in the shape of a pentagon to incorporate our three-wheel design and provide the support necessary for a 400 lb. client. Our decision to include only three wheels required us to provide additional vertical supports. These supports, which connect the pentagon base and seat, provide our wheelchair with necessary vertical support and allow the seat to be at a comfortable height. A removable armrest was also constructed to facilitate side transfers. This modification also allows wider patients to sit comfortably in the chair. The PVC pipes and fittings

were connected using Oatey's Clear Advanced Cement. The product has been approved for use in extended water exposure situations (plumbing).

The front wheel is a stainless steel swivel caster, which is threaded into a 6" piece (1.5" Diameter) of solid PVC. This is connected to our frame using Oatey's Clear Advanced Cement. The rear wheels consist of commercial wheelchair wheels. These have solid tires, and are attached using a quick release axle and four washers. This allows the wheel to be easily and rapidly assembled and disassembled. PVC caps have been designed which cover the axle and limit water exposure.

We created a seat made of cross-hatched nylon straps and heavy-duty canvas. The nylon straps are rated for 1,000 lbs. and are sewn to the canvas. Upholstery thread approved for outdoor (water exposure) use was used to sew the straps. Nylon straps and canvas were used due to the additional safety measures a nylon seat would provide. The final cover was attached to the PVC frame using anchor rope (approved for extended water exposure) and heavy upholstery grommets.

The total cost of the Pool Chair is \$517.



Fig. 7.24. Client going down the ramp at the pool.

# BLAZING SADDLES

*Designers: Fernando Iglesia, Wade Sidley, Shin Chang*  
*Client Coordinator: Margie Muenzer, PT, North Carolina Therapeutic Riding Center*  
*Supervising Professors: Kevin Caves and Richard Goldberg*  
*Department of Biomedical Engineering*  
*Duke University*  
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## INTRODUCTION

Therapeutic horseback riding is a technique that uses the motion of riding a horse to build strength, and improve trunk tone and muscular endurance as well as balance and posture. Used in conjunction with dexterity exercises, such as holding the reigns, therapeutic riding is a powerful tool. Our client has spastic quadriplegia cerebral palsy and he uses therapeutic riding to improve his trunk strength, posture, coordination and dexterity. However, our client does not have the trunk tone to balance on the saddle without leaning forward or to one side. In addition, our client becomes very nervous when attempting to straighten his posture because he feels as if he will fall off the back of the saddle. As such, while he rides, he needs to have his legs and ankles held down by assistants to help him balance and feel safe.

In order to provide the client with more independence and safety while riding, we developed several saddle attachments. A raised, horizontal bar connects to the front of the saddle. By gripping onto this bar, the client has additional support and sits more upright while riding. A back support connects to the rear of the saddle. It provides physical support and makes the client feel safer. Both attachments are adjustable, so they can be used for other riders. In addition, the attachments are removable and do not alter the original saddle in any way.

## STATEMENT OF IMPACT

Our device enables our client, as well as other horseback riders with postural issues, to ride with greater support and confidence than afforded by conventional saddle designs. The physical therapist at the riding center said: "Without the device, he's tense through his body and he's putting a lot of weight through his arms because he's feeling pretty insecure in the saddle. With the new attachments, it lightens him up and he's able to sit up and look around a lot better and able to reach things much



Fig. 7.25. Custom attachments to provide additional support in therapeutic horseback riding; the raised horizontal bar at the front of the saddle and the backrest at the rear of the saddle.

more confidently and easily, so I think it'll really enable him to enjoy his riding and be more functional."

## TECHNICAL DESCRIPTION

Our project consists of two separate, removable attachments to a saddle that are designed to help our client with balancing and posture while horseback riding.

The raised bar attachment consists of a base, made from an aluminum plate, and an adjustable bar structure. The base slides underneath the top layer of the saddle, and the rider's weight and Velcro straps hold it in place. The bar structure consists of four bars in a rectangular shape. There are two horizontal bars, made from steel conduit pipes, and four connector joints. The two vertical bars are telescoping tubes with spring pins (adapted from crutches) that can be lifted in 1-inch intervals to accommodate a variety of horseback riders. The top bar is covered by tennis grip tape and two cut open tennis balls cover the top connector joints, which provides a gripping location and covers sharp edges for safety reasons. The result

of the design is a handlebar that is sufficiently rigid and strong enough to support the client pushing on it in order to support himself while horseback riding. There is ample padding in the saddle, so that neither the rider nor the horse can feel the metal base that is inserted in the saddle.

The backrest consists of a cushion that is mounted to a supporting structure. This structure is made from two plywood boards connected at a right angle using 4 corner brackets along the back. The cushion itself

was taken from an Otto Bock wheelchair headrest with the metal supports cut to size. The entire structure is 6" long and 9" wide. The height of the backrest can be adjusted from a minimum of 9 $\frac{1}{4}$ " to a maximum of 13 $\frac{1}{2}$ ". The backrest is designed to fit into the saddle by sliding under the back cushion. The backrest cushion can be moved up and down the metal supports it by loosening screws and manually sliding the cushion.

The total cost of this project is \$384.



Fig. 7.26. Client using the saddle attachments.







# CHAPTER 8

## LOUISIANA TECH UNIVERSITY

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# LOW-COST ARTIFICIAL HAND

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## INTRODUCTION

This project addresses the problem of limb absence. The absence of a hand is a major obstacle that has to be overcome in order for people to easily accomplish activities for daily living (ADLs). Sometimes in the past, hooks and cable system prostheses have acted as substitutes for the hand. These devices are poor substitutes for the human hand because the hand is incredibly complex, with 21 degrees of freedom, and has the ability to manipulate delicate items and lift heavy objects. There are current solutions to the problem of limb absence, but many commercially available prosthetic hands are expensive or utilize cable systems that lack automated points of motion. This is not the first attempt at this type of prosthetic; this project improves upon a previous generation from a senior design last year. Using this knowledge, we have worked to design an artificial hand which utilizes: 1) smaller, stronger motors to increase the gripping strength, 2) stronger structural materials to increase the durability, 3) a new cover design to reduce the slippage of objects during usage, and 4) a lower cost. The final product, beyond the scope of our mechanical prototype, will be an inexpensive myoelectric artificial hand capable of completing ADLs.

## SUMMARY OF IMPACT

Target consumers are persons who have amputations of the hand. The main problem that these clients face is that they are restricted or limited to almost no hand functionality. The whole goal of this project is to give our clients more independence in their lives. This device creates less frustration for a potential customer who wants to simply lead a normal life. Once the device is on the market, we believe it has the potential to be the new type of hand used by amputees.

## TECHNICAL DESCRIPTION

The primary goal stated the desire to create a prosthetic hand that is better in all mechanical areas than the previous generation. Our design increased



Fig. 8.1. The Aluminum Chassis Palm.

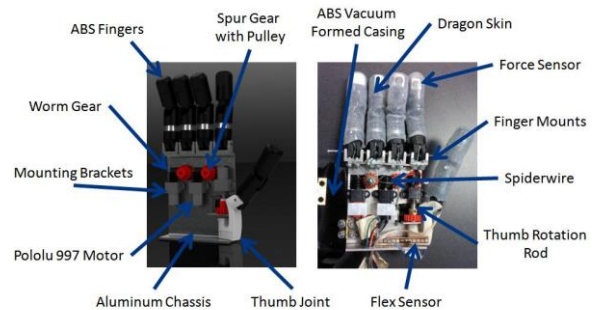


Fig. 8.2. Artificial Hand Components.

the curling force, decreased the closing time, decreased the weight, decreased the volume, decreased the cost, decreased the slippage, increased the structural strength, maintained the current gripping patterns, and was easier to repair than the previous generation. Along with these criteria a

prosthetic hand should be easy to clean, difficult to unintentionally open, and have a maximum gripping force that resembles a human hand.

The first major modification implemented was the addition of the aluminum chassis in the palm, in order to use it as a mount for all components. The chassis is easier to manufacture, and constructed more quickly than a palm constructed using a rapid prototyping printer.

An aluminum chassis also provided more rigidity at a smaller volume and lower weight. The thumb joint was modified from a SolidWorks file provided by the creators of the previous generation. It is the only remaining piece of rapid prototyped ABS plastic. To protect the interior components, we created an outer shell also made of ABS plastic. This was done using the vacuum forming technique. Creating a single mold for each half of the shell resulted in a 30 minute production time for new coverings. This was much faster compared to the hours it would take to 3D print something similar in size. Vacuum formed pieces were also much more resistant to impact damage, withstanding even the force from repeated hits with a claw hammer. The outer shell pieces were hinged to the aluminum chassis to allow for easy access to internal components. The fingers were also attached directly to the chassis, using aluminum u-brackets.

The basic design of our drive system did not change; we still used a pulley system in the same fashion seen in the previous generation. However, we were able to improve upon the system by using smaller, more powerful motors. We also changed to a smaller gear with a larger radius pulley to increase the closing speed from the previous generation. There were no changes to the type of wire used in the drive system. The wire was attached to the fingertip in the same manner as the previous generation.

The four fingers had the same number of joints as the previous generation. The thumb, however, was given an extra joint to increase dexterity. This slowed the closing speed of the thumb, but allowed it to form more complex gripping positions. The manufacturing and material components of the fingers are completely new in our design. We routed a solid block of acrylonitrile butadiene styrene (ABS)



Fig. 8.3. The Vacuum Molded Fingers.

plastic, in comparison to rapid prototyping in which the ABS is layered. This greatly increased the breaking point of the fingers. By routing the ABS, we attempted to replicate the results of injection molding, but at a price that was in our budget. Each piece of routed plastic is connected by an aluminum tube to create the full finger. Routing a solid block of ABS also reduces the cost of manufacture.

The glove design was implemented using Dragon Skin™, a form of silicon rubber. However, instead of creating a complete glove, we coated only specific areas of the palm covering and the fingers. This allowed much easier access to the interior components than the glove used in the previous generation, while maintaining the friction necessary for gripping.

Testing was segmented in several processes to determine the performance of the new hand. As expected, the design proved to be better than the previous design in multiple areas. The tests that were completed by the hand are as follows: finger strength, closing time, curl force, maximum grip force, slippage, weight, volume, cost, and grip position. Improvements in performance relative to the previous generation of hand in were not observed in the maximum grip force test and the volume test. The overall cost of the parts for this project was approximately \$195, which was \$70 dollars cheaper than the previous generation.

# AT DEER STAND

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*Client Coordinator: Mike Shipp, Center for Rehabilitation Engineering, Science & Technology*  
*Supervising Professor: Dr. Mel Corley*  
*Department of Mechanical Engineering*  
*Louisiana Tech University*  
*Ruston, LA 7127*

## INTRODUCTION

The AT (assistive technology) deer stand was developed to help enable a deer hunter without leg mobility to more fully enjoy the outdoors. This stand is fully capable of being used by any hunter that uses a wheelchair for mobility. Existing stands for these hunters are either too expensive or not mobile enough to meet the needs of clients. This stand is a box stand that is mounted onto a general flatbed trailer. It lays flat on the trailer until it is hoisted into the operational position. The deer stand is operated by a manual winch, which is used to hoist the stand into the upright position. A custom safety harness system was also designed to hold a person in a wheelchair safely in the deer stand. Also, custom stops were implemented as a way of transporting the hunter's firearm in a quiet and safe manner.

## SUMMARY OF IMPACT

The overall goal of this project was to produce a deer stand capable of being an independently operated device for someone who uses a wheelchair. This deer stand could be put on the market fairly quickly and be somewhat competitive in the outdoor industry. It gives mobility and independence to a deer hunter who uses a wheelchair. This deer stand also causes no negative environmental impact from operation as well, which may be a problem with some current solutions.

## TECHNICAL DESCRIPTION

The deer stand we designed had several specifications that we inferred from conversations with the client.

These specifications required that the stand had to be big and strong enough to hold someone in a wheelchair, the stand had to have a safety harness system, it had to have a way to safely transport a firearm, and it had to be independently operational. The safety of the consumer was stated to be the first priority of the team when we were designing this



Fig. 8.4. Safety Harness System.

deer stand. This can easily be seen by the custom safety harness system that they incorporated into the design, which is shown in Figure 8.4. The safety harness is simply made of towing straps that are mounted to the walls of the deer stand by eye bolts. They also included a system to securely and safely transport the hunter's firearm while the deer stand is being hoisted into the hunting position. This design consisted of two pieces of wood using a simple hook and eye type lock to fully secure the firearm. The final design the team decided upon was a box stand that worked on a standard manual winch system which would be mounted onto a stand and then mounted to the base of a trailer (not included). The box stand was a standard 5' x 5' x 5'. A shooter's window with a height of 12" is incorporated into the design of this deer stand.

The operational procedure started by lowering of the trailer ramp and then lowering the deer stand ramp. Once this was complete the hunter placed the firearm between the stops and secured the latch. The hunter then entered the stand and raised the deer stand ramp and put on the safety harness system. Lastly the hunter needed to winch himself into position until

the stand is in the upright position. The winching system could be raised and lowered easily while remaining fully seated in the wheelchair.

A 2200 lb. winch was selected by the designers. The winch cable is drawn through a sheave located at the bottom center of the stand where it is then routed to a lifting lug with a shackle at the vertical support arm. This type of lifting was chosen because it will lift the box stand evenly and easily. The designers decided to use a basic four-bar mechanism which can be mounted to any flatbed trailer. Using a steel frame floor that was welded together was claimed to be the only feasible option. The designers used 2" x 2" x 1/4" square tubing, 1 1/2" x 1 1/2" x 3/16" angle iron, 1/2" steel plate, and 1/2" flat bar. The system was fastened with 3/4" tractor bolts and secured to the trailer with 1/2" bolts. In the fabrication of this deer stand, the group used several different saws, a mig welding machine, a grinder, a power drill and a drill press with standard drill bits. A custom component for this deer

stand that was used in the fabrication process is a simple bracket made out of a 1/2" steel plate. These brackets were used to mount the sheave to the frame of the stand and also to connect the frame of the stand to the base of the trailer via the arms and pins of the trailer.

The group was able to safely raise the deer stand with the winch in an average time of 134.7 seconds to get it in an upright position with this design. Once the deer stand was erect it stood approximately 9.6ft from the hunter's sightline to the ground. This height of the deer stand should present no problems in the field as far as sight capabilities are concerned. However, if the customer would like a shorter or taller deer stand, a trailer compensating such height should be provided.

The total cost to build this deer stand was \$1,154.96 which included the labor of the welder that the team hired.



Fig. 8.5 Deer Stand halfway up.



# THE ELECTRIC SLIDE

*Designers: Rea Hensen, Chris Garcia, Brennon Cucullu, Katie Simmons*

*Client Coordinator: Mike Shipp*

*Supervising Professor: Dr. Patrick O'Neal*

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## INTRODUCTION

The independent use of electrical outlet connections is a problem for people with Multiple Sclerosis, Osteoarthritis /Arthritis and Parkinson's disease. The Electric Slide is designed to help ease the use of electrical outlets for these types of clients. Some devices that are currently available for this problem are known as Electronic Aids to Daily Living (EADL). However, EADLs have a significant disadvantage in that they must remain connected into a wall outlet at all times. This suggests an inherent lack of independence for the client. Every time that an electrical device needs to be moved, the client must have someone else remove the electrical cord from the outlet and then reinstall it. The Electric Slide addresses this issue with its magnetic outlet design. The Electric Slide gives anyone the ability to remove and reinstall an electrical appliance anywhere in their home.

## SUMMARY OF IMPACT

The target consumer is any individual with Multiple Sclerosis, Osteoarthritis/Arthritis and Parkinson's disease. One main problem that these clients face in common is that they have limited upper-body mobility. The whole goal of this project is to give our clients more independence in their lives. This device creates less frustration for a potential customer who wants to simply lead a normal life. Once the device is on the market, we believe it has the potential to be the new type of electrical outlet used in households everywhere.

## TECHNICAL DESCRIPTION

A magnetic connector system is what we selected for the final design of The Electric Slide. The design of The Electric Slide featured a faceplate for the outlet and an electrical cord attachment which created an easily established magnetic connection. The final design accounted for both the faceplate and cord to have user-installable adapters. The design of these adapters called for both a independent top and



Fig. 8.6. Male Bridge (top) and Female Bridge (bottom)

bottom half. This design allowed for components such as a male "bridge" and a female "bridge" to be installed in the adapters. This modular design stabilized the inner components and alleviated some issues with US standards and electrical codes by using standardized methods and parts. The two blocks combine to secure all of the electrical components in The Electric Slide. The components inside the wall adapter/faceplate were the male "bridge" (Figure 8.6) and the contacts.

The contacts were crimped onto the male "bridge". The female "bridge" (Figure 8.6) and the pins were placed inside the device for the cord adapter. As the contacts were crimped into the male "bridge", the pins were also crimped into the female "bridge". Three pins and three contacts are required for this

design. This ensured that a grounding component is associated with the standard three-prong American outlet. In summary, the male “bridge” and contacts were placed between the top and bottom halves of the faceplate adapter. The female “bridge” and pins were installed in between the top and bottom halves of the cord adapter. This design of The Electric Slide accounted for several key design specifications of the device such as size, weight, safety, and the force of loading a cord into the adapter all meeting the criteria of the client. Also, real world design specifications, such as the issues of arcing and shock, were accounted for. Arcing and grounding requirements were the main safety concerns with this device. If the pins should somehow not fully connect with the contacts, the electrical current jumps resulting in sparks. The ABS plastic that is used for the faceplate adapter has a high rating for arcing potential, therefore creating a less hazardous situation. This means that if arcing does occur, it will take several seconds before any electrical current can affect the device. To assess the potential of arcing, a testing strategy was devised by the group which created a loop-through the device. The circuit is only then complete if every pin connection is made.

The testing of this device was done by connecting a 9V battery to the faceplate adapter. A computer was

then used to monitor the amount of voltage that was received in the electrical cord. The current that flowed through the device at that time was recorded with a Data Acquisition Device (DAQ) system using the computer program LabView. If a connection was made, the voltage recorder output was equivalent to the original amount of voltage placed in the circuit. We ran the testing process 314 times and a full connection was made on 291 of those times.

This device was tested to find out exactly how much magnetic strength was needed to completely remove the electrical cord from the outlet adapter. This process was completed with a tensile testing machine to determine the exact amount of force required to remove the cord. The device was sheared from top to bottom, bottom to top, left to right, and right to left. After the test was completed, statistics confirmed that the force needed to remove the device was below 20 Newtons.

A \$500 dollar budget was given for this group to complete the project. The group produced the prototype within this constraint, and since most of the parts could be bought in bulk, the device would be relatively cheap to manufacture.

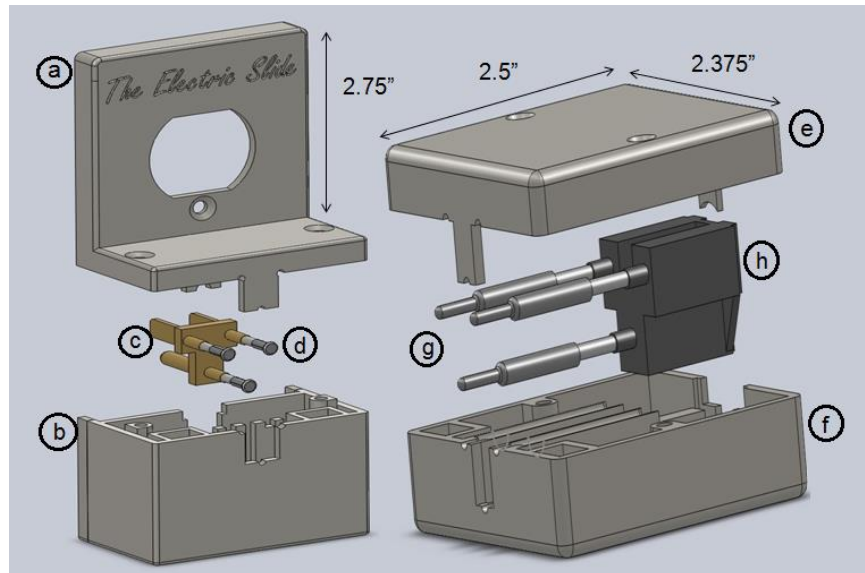


Fig. 8.7. Prototype overview. [a] Top half of faceplate adapter. [b] Bottom half of faceplate adapter. [c] Male Bridge Heyco component. [d] Contacts Etc component. [e] Top half of cord adapter. [f] Bottom half of cord adapter. [g] Contact pins Etc component. [h] Female Bridge Heyco component.

# MOBILE INDEPENDENCE AUTOMATION

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## INTRODUCTION

Scoota-Trailer Mobility Products makes a trailer to load and transport scooters and power wheelchairs designed for individuals with limited mobility. The commercially available Scoota-Trailer can be hitched to the back of a vehicle and towed around with minimal effort. Such designs accommodate individuals who feel discomfort when walking more than short distances and allow individuals with limited upper body mobility to operate a vehicle. However, this product requires some strength to load and unload scooters and power-chairs. We postulated and prototyped an adaptive design to automate the loading and unloading of scooters and power chairs onto a standard Scoota-Trailer frame. The adaptation uses a system of linear actuators which reduce the effort required to load a wheelchair to the turn of a key. In addition, this adaptive design is cost effective and will cause a relatively small increase in current market prices for the standard Scoota-Trailer.

## SUMMARY OF IMPACT

This modification of a standard Scoota-Trailer makes the loading, unloading and transportation of a powered wheelchair more convenient with less discomfort for individuals who find it difficult to walk for any more than short periods and have limited upper limb mobility. This design is intended to be an affordable, add-on package that can be marketed alongside the Scoota-Trailer for customers who feel that an automated system will be beneficial. The implementation of an automated process of opening the trailer compartment and loading/unloading a scooter or chair allows clients to enjoy a greater sense of independence and convenience without unnecessary discomfort.

## TECHNICAL DESCRIPTION

The design is constrained by a combination of the Scoota-Trailer's inside dimensions (66 inches x 37.5 inches) in the opened and closed state as well as the

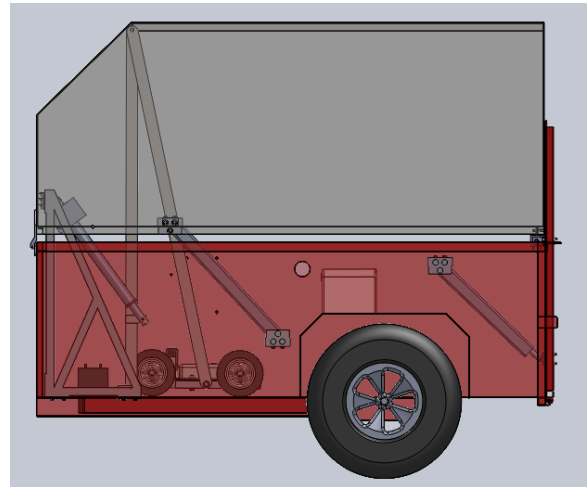


Fig. 8.8. Scooter-trailer adaptive design [transparent view of the driver side].



Fig. 8.9. Scooter-trailer adaptive design [Open rear aerial view]

dimensions of the power wheelchair or scooter that will be housed inside. The power wheelchair/scooter dimensions include height, width, length, and a maximum weight of 350 lb. Also, the maximum trailer weight is limited to 2000 lb and the tongue weight is limited to 200 lb. As it stands, the standard Scoota-Trailer alone can house scooters up to 37.4 inches wide and 65.8 inches long.

Improvements to the Scoota-trailer consisted of a system for the automated opening of the lid and ramp as well as the automated loading and retrieval of the wheelchair or scooter from a position that is as close to the ground as possible. An added feature is a battery charge system that would support multiple applications per complete charge.

The design implements linear actuators to automate the ramp and lid. For the lid, a 150lbf actuator with a 12 inch stroke and manufactured by Firgelli Automations (FA-05-12-12") is used. The lid actuator is attached to the left inner wall of the lid 1.29 inches from the bottom surface of the lid and 17.31 inches from the front (driver's end) wall of the lid. The fixed end of the actuator is fastened to the inner wall of the trailer, 7.45 inches from the trailer floor and 31.30 inches from the front wall. Fully extended, the actuator allows a 42.95° displacement of the Scoota-Trailer lid. The ramp also employs a 150lbf actuator from Firgelli Automations (FA-05-12-9") but with a 9 inch stroke. The fixed end is attached on the left wall of the trailer 17.30 inches from the floor and 53.33 inches from the front inside wall of the trailer. The ramp opens 104.80° to the ground. In Figures 8.8 and 8.9, the attachments of the linear actuators for the ramp and lid are shown.

This adaptive design prototype uses an A-frame design to carry out the loading and retrieval of the transported power chair or scooter. A pair of 400lbf linear actuators (FA-400-L-12-12", Firgelli Automations) each with a stroke length of 12 inches is used to drive the A-frame arms constructed from ASTM 500 rectangular tubing which is 1.5"x1"x0.12". A cart with an integrated EZ-Lock system (used to

attach the power chair or scooter) and four wheels are attached to the extending end of the driving arm. The other end of the driving arm is fixed to the actuator mount 10 inches from the front inner wall of the trailer. When fully extended, the driving arm spans 92 inches with the front wheel of the cart 2 inches off of the ramp. Figure 8.9 shows the entire system with the ramp and lid open and the driving arm of the retrieval system fully extended. All of the actuators used require a 12V voltage supply, while the 400lbf actuators require 10 amps each and the 150lbf actuators need 4 amps each.

This modification of the Scoota-trailer implements a control system powered by a 12 volt battery. Mounted within the trailer is a 12 volt trickle charger with an associated 12 volt plug outlet so that the design can be plugged into an AC outlet and charged. The average time required to fully charge the battery is 90 minutes from the 1.5 amp charge of the trickle charger.

The system is engaged by turning the key switch in the control box on top of the right wheel well on the outside of the trailer. This unlocks the trailer and allows the use of a two-position sustaining rocker switch, also located within the control box. The polarity of the rocker switch can be reversed to allow the opening and closing of the ramp and lid. On the inside of the trailer there is a second rocker switch mounted onto a handheld electronic enclosure. The switch controls the extension and retraction of the driving arm and EZ-Lock cart.

The location of this second switch ensures that the driving arm is not powered while the trailer is closed. A tilt switch mounted onto the driving arm breaks the circuit to the lid and ramp actuators disallowing the closing of the lid and ramp while the driving arm is extended. The control box and handheld are in easily accessible locations. The modified design loads in an average of 95 seconds.

The entire cost of the automation modification of the Scoota-Trailer was \$2453.65.

# ADAPTIVE USB DATA TRANSFER TECHNOLOGY

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## INTRODUCTION

There has been a global standardizing of basic methods in data communication in a time where technological advances are rapid and widespread. One such method, USB data transmission, has become more prevalent as computers and several independent electronic devices are being fitted with USB technology. Consistent with the trends of modern technology, USB communication devices are becoming smaller presenting possible difficulties for individuals with disabilities. Persons with rheumatoid arthritis, for instance, as well as individuals with limited upper limb mobility and fine motor function find it a tedious or even painful to use a small USB memory stick. A device has been conceptualized and prototyped to provide a method of plugging a standard USB flash drive into a USB hub for data transfer. The device requires minimal finger dexterity and upper limb motor function.

## SUMMARY OF IMPACT

This adaptive USB data transfer device has a tray to house the USB flash drive and through purely mechanical means allows the insertion of the drive into an onboard USB port for data transfer. As the primary action of plugging the drive requires less than 3lbs of force in a singular horizontal direction, the device reduces the discomfort normally associated with such an action. It provides a convenience as well as a greater sense of independence for individuals with limited upper limb mobility.

## TECHNICAL DESCRIPTION

The device is constructed of four main components. The base, female port hub, back plate and cover plate make up the functional components of the USB adaptor displayed in Figure 8.13. The USB memory stick is placed into the tray of the base plate with the male end of the USB plug toward the female port hub. A horizontal force can then be applied to the back plate, compressing the two springs of the base

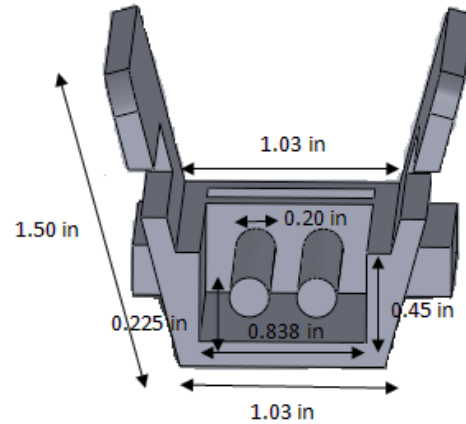


Fig. 8.10. SolidWorks representation of the Base component (without springs loaded).

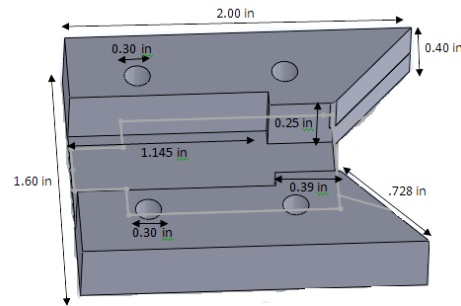


Fig. 8.11. SolidWorks Representation of the Female Port component (without screws and metal plate).

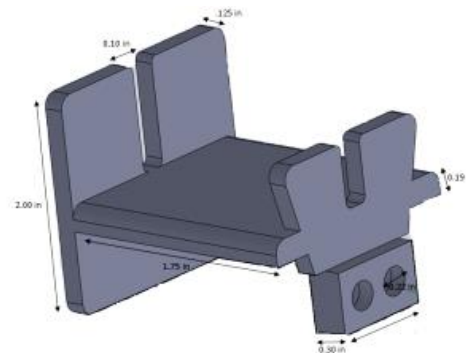


Fig. 8.12. Back plate component of the device.





Fig. 8.13. Complete assembly of adaptive USB device.

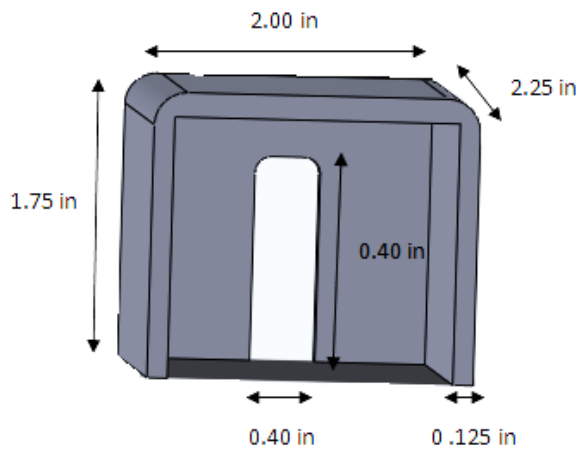


Fig. 8.14. SolidWorks representation of Cover component

component and pushing the USB drive toward the USB port until snugly inserted. The compression springs then retract the back plate for subsequent loading. A lanyard connected to the USB memory stick can be pulled horizontally away from the device to unplug and retrieve the USB memory stick.

The base component, shown in Figure 8.10, contains the tray that supports the USB flash drive and a platform for the female USB port component. Beneath

the tray are two horizontal cylinders which suspend the compression springs that support the mechanical retraction of the back plate component. The base is composed entirely of ABS plastic with the exception of the tray which is a sheet of 0.021" steel.

The female port hub, shown in Figure 8.11, houses the actual USB port of the USB cord which the drive is plugged into. It is constructed with a widened mouth to allow the USB flash drive to be guided into the port. Four screws run through a plate of 0.021" steel, the ABS plastic molding which houses the USB port and into the base support to keep the structure sturdy. Compression springs placed around each of the four screws connecting each component, allow for the adjusting of the USB port to the dimensions of the USB flash drive being used.

The back plate, shown in Figure 8.12, is a component that fits into grooves carved into the base component, beginning at the ends of the horizontal cylinders and compression springs. It is also constructed entirely of ABS plastic. When a maximum force of 2.31lbf is applied to the back plate it compresses the springs and moves the USB flash drive toward the female port. Magnetic tape serves to attract the drive into the slot (not shown). The horizontal compression springs cause the retraction of the back plate for subsequent loading and trials.

The final component (dimensions shown in Figure 8.14) is the cover plate for the female USB port hub. It is constructed purely of ABS plastic and acts as a water resistant covering for the USB female port.

This USB adaptive device project explores a mechanical solution to the problem of handling small devices. A purely mechanical solution such as this, while reducing the dexterity and strength required to insert a USB drive, may not be adequate in satisfying convenience and comfort for individuals with limited upper limb mobility and finger dexterity.

The total cost to prototype this adaptive USB technology project was \$136.88.

# VISUAL ALERT SYSTEM

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*Supervising Professors: Dr. Paul Hummel, Dr. Davis Harbour,*  
*Department of Electrical Engineering*  
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## INTRODUCTION

The inspiration for this project is a client who owns a business and has a hearing disability.

The client's business has multiple entrances and having a hearing disability makes it difficult to keep track of persons entering and exiting the building. An alert system was designed to make it easier to keep track of the opening and closing of building entrances/exits. It is primarily a visual alert system which implements radio frequency technology to communicate the opening and closing of doors.

## SUMMARY OF IMPACT

This radio frequency oriented visual alert system can be used for individuals who work indoors and may have limited hearing. When an entrance to the work building is opened a radio frequency signal is transmitted. The signal is received by a wall mounted display that subsequently indicates which door is ajar. The same transmission is also received by a personal alert system (PAS), worn by the client, that triggers an LED output indicating which door is ajar. The PAS also has a vibrating output to alert the wearer of the opening and closing of secured doors within the building. This visual alert system will improve the awareness of owners and personnel with limited hearing, thereby increasing their sense of security and management.

## TECHNICAL DESCRIPTION

The visual alert system designed has three primary components. The first is a door sensor and transmitter that detects an electrical stimulus from the opening and closing of a secured door and transmits the signal using radio frequency technology. The second component is the PAS unit which is a receiver that detects radio frequency signals and alerts the user with a page and with the lighting of the corresponding LED. The third component is another receiver, the Wall - mounted unit, which uses an LED matrix as a visual output to the user(s). The system

interface is controlled by Cerebot Nano microcontrollers developed by Digilent, Inc. The Cerebot Nano microcontroller was implemented in this system for three primary reasons; its relatively low cost, its small size, and its power conservation abilities. Each component utilizes one Cerebot Nano microcontroller to operate transmitting and receiving. The Nano runs on a reference voltage of 1.1V and as such, every component is wired to preserve the integrity of the microcontroller. The PmodFR1 from Digilent Inc. is the transceiver used to facilitate wireless radio frequency communication between each component of the visual alert system.

The door sensor system, shown in Figure 8.15, has one input and two outputs. The input is derived from a magnetic reed switch package (also from Digilent Inc.) mounted on the door and door frame to determine whether the door is opened or closed.

When the magnetic switch is open, an electrical signal is sent to the microcontroller as an input. The microcontroller records the state of the switch and outputs data to an onboard bi-indicator status LED. The Cerebot Nano toggles the status of the LED between green and red signal to denote the door closed and door ajar signals respectively. The microcontroller then sends the data to the PmodFR1 which subsequently transmits the signal in the form of a radio frequency signal. In Figure 8.16 the circuit diagram of the door sensor system is displayed.

The personal alert system, shown in Figure 8.17, was designed to alert a mobile user. Since the wall mount would be stationary, an owner whose work demands that he/she moves around the business would require a portable alert system to keep track of traffic through the business. When turned on, the PAS runs a peripheral check to ensure that the LEDs onboard and in-the-door sensors are functioning appropriately. The status of every LED is recorded and saved for later use. If a door is opened, the RF signal received from the door sensor is detected by



Fig. 8.15. Door sensor system showing magnetic switch on door and sensor with RF antenna.

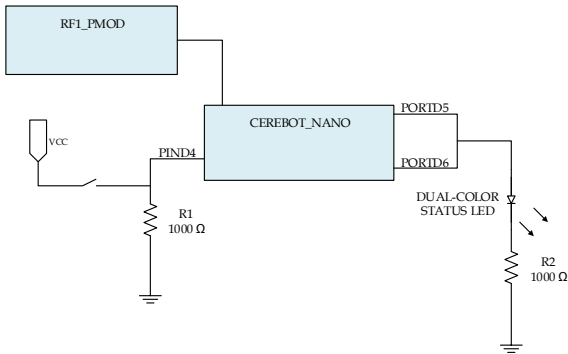


Fig. 8.16. Circuit diagram for door sensor system.



Fig. 8.17. Back – side view of the PAS showing indicator LEDs and battery pack.

the onboard Pmod1 transceiver and processed by the Cerebot Nano microcontroller. The microcontroller differentiates between the three door sensors in the system and enables the corresponding LED to signal an opened door. The microcontroller also activates two onboard vibrating motors to alert the user. In the event of a closed door, the microcontroller checks

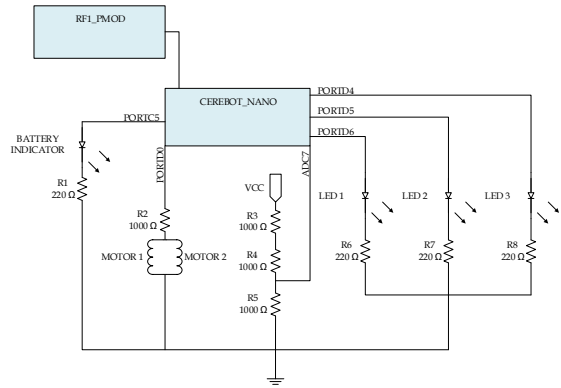


Fig. 8.18. Complete circuit diagram of the PAS Unit.



Fig. 8.19. Wall mounted unit showing LED matrices with corresponding door numbers

whether any other doors are open. If not, the motors are disabled as with the LEDs. The PAS is powered by an attached 3.3V battery pack using two standard AA batteries. An onboard battery power indicator LED turns red when the battery power runs below a voltage that significantly affects the performance of the PAS (about 2V). Figure 8.18 shows the entire wire diagram for the PAS including the component, LED door status circuit and the motor circuit.

The final major component of this visual alert system is the wall mounted display shown in Figure 8.19. This system design is similar to that of the PAS but without motors and LED matrices as the signal outputs for each corresponding door. When powered up the system runs peripheral checks to ensure the integrity of each respective LED matrix. RF signals are received from the onboard PmodFR1 transceiver

and the Cerebot Nano microcontroller determines whether a door has been opened or closed.

The signal is then transmitted to the LED matrix for the corresponding door. When a door is opened, the corresponding LED matrix is enabled. There are three 8x8 LED matrices; one for each corresponding door

sensor system. A 5V power supply is used to power the wall mounted display. The circuit for the unit, shown in Figure 8.20, uses three 5V relays and transistors to regulate the power going to the LED matrices when an “enable” signal is transmitted from the Cerebot Nano microcontroller.

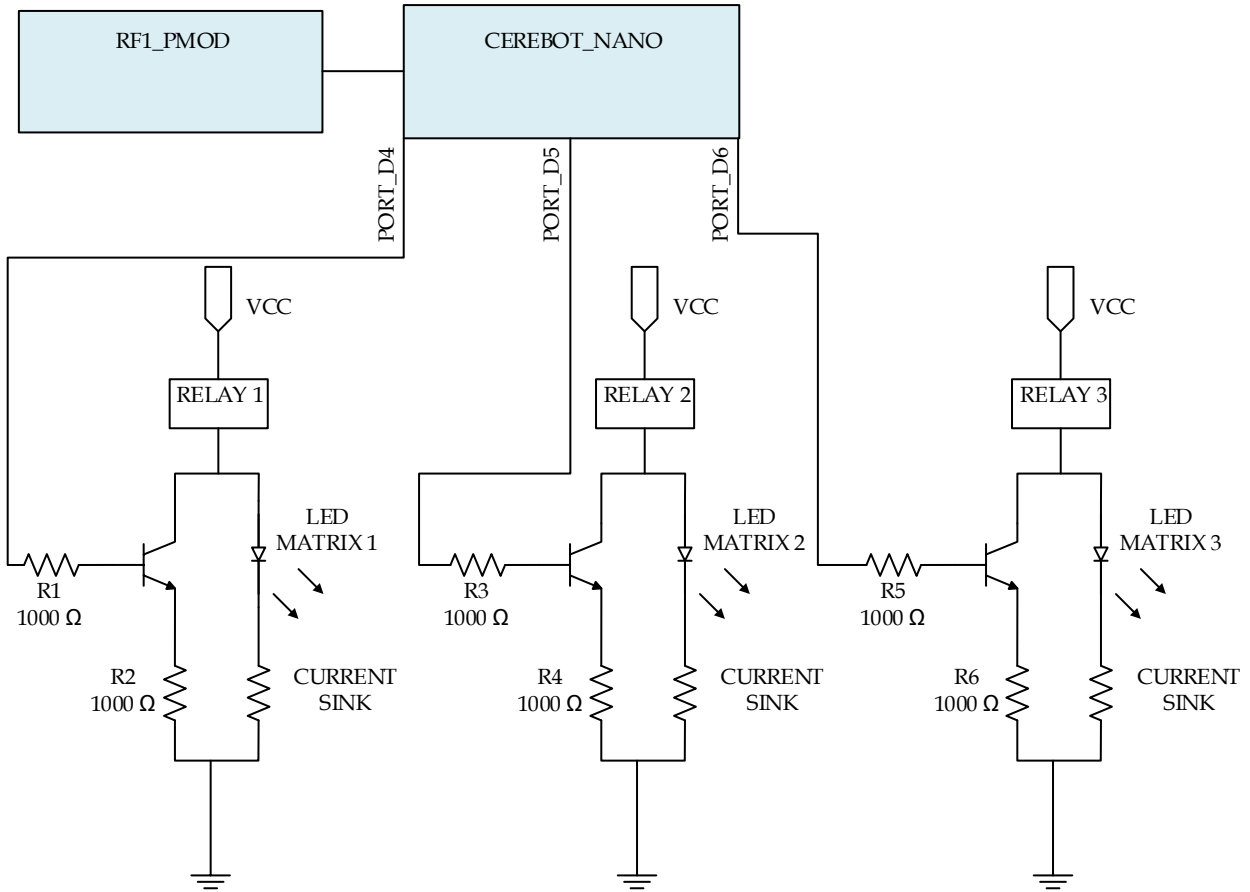


Fig. 8.20. Circuit diagram of complete wall mounted display system.

# CHAPTER 9

## NORTH DAKOTA STATE UNIVERSITY

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# WIRELESS MONITORING SYSTEM

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## INTRODUCTION

The wireless monitoring system alerts caregivers when clients enter a bathroom. The system is designed to be discrete, portable, and durable. Two proximity sensors detect general entries and a magnetic coil detects individual-specific entries. The detectors are hardwired to a transmitter that wirelessly transmits alert messages to a receiver. The receiver is carried by the caregiver so that they are notified when someone enters the bathroom. The caregiver may choose from a combination of three alerts: a flashing LED, an audible buzzer, and a vibrator.

Several monitoring systems are commercially available such as cameras and RFID-based systems like those found in clothing stores. However these systems are generally expensive and are not well suited as bathroom monitors. RFID systems can cost thousands of dollars, and cameras violate privacy laws when placed in a bathroom. Unlike commercially available systems, the wireless monitoring system balances the detection, privacy, and cost needs of the Developmental Work Activity Center (DWAC).

## SUMMARY OF IMPACT

The wireless monitoring system is developed for a client who has a history of flushing inappropriate items down the toilet. The monitoring system therefore helps the caregiver prevent damage to the plumbing system. The two detectors are easily hidden from sight. As seen in Figure 9.1, the coil detector may be placed under a door mat, and the small proximity sensors may be inconspicuously placed on the wall. At 3" x 2.5" x 2.5", the receiver is portable and easy to carry. The system uses durable parts and packaging to ensure reliable operation for years to come.

The completed system, shown in Figure 9.2, is currently in use at the center. The caregivers are

pleased with the device, and it is currently helping them to prevent damage to the plumbing system.

## TECHNICAL DESCRIPTION

The system block diagram, shown in Figure 9.1, is comprised of three main parts: 1) detectors, 2) transmitter, and 3) receiver.

The wireless monitoring system uses two detection methods: general and individual-specific. The general detection method uses two proximity sensors placed in series to determine whether someone enters or leaves the bathroom. The sensors are linked to a PIC18F4620 microcontroller. If the outer sensor is activated first, then a person has entered the bathroom and the microcontroller increments a counter. If the inner sensor is activated first, then a person has left the bathroom and the microcontroller decrements a counter. Any count greater than zero indicates that the bathroom is occupied, in which case the microcontroller sends an alert message to the transmitter.

Individual-specific detection requires the caregiver to implant magnets into each shoe of the client. When the client walks over the doorway coil, a voltage is induced and amplified by a high-gain DC op-amp. A signal is then sent to the PIC microcontroller, which again communicates an alert message to the transmitter.

The second part of the monitoring system is the transmitter. Once the PIC microcontroller receives a signal from one of the detectors, the PIC then outputs a constant signal to an MS series Linx Technologies encoder. For this design, only four of the eight available outputs are used: one for each of the four ways to alert the caregiver. The encoder sends a digitally-coded message to the transmitter which then mixes the message with a 418 MHz carrier.

The third part of the system is the receiver. The receiver demodulates the received signal. The

recovered coded message is then sent to the decoder, which drives the appropriate alert outputs. A yellow LED illuminates when the proximity sensors detect that someone enters the bathroom. When the coil sensor detects that a specific client enters the bathroom, the red LED, vibrator, and buzzer are all activated. A silent mode is available to disable the buzzer.

The detectors and transmission system are powered using a wall outlet while the receiver is powered by two AAA batteries. The receiver is equipped with a switch to turn off the system and save battery life. To power down the transmission system, the caretaker unplugs the unit from the wall.

The cost of the complete system is approximately \$105.

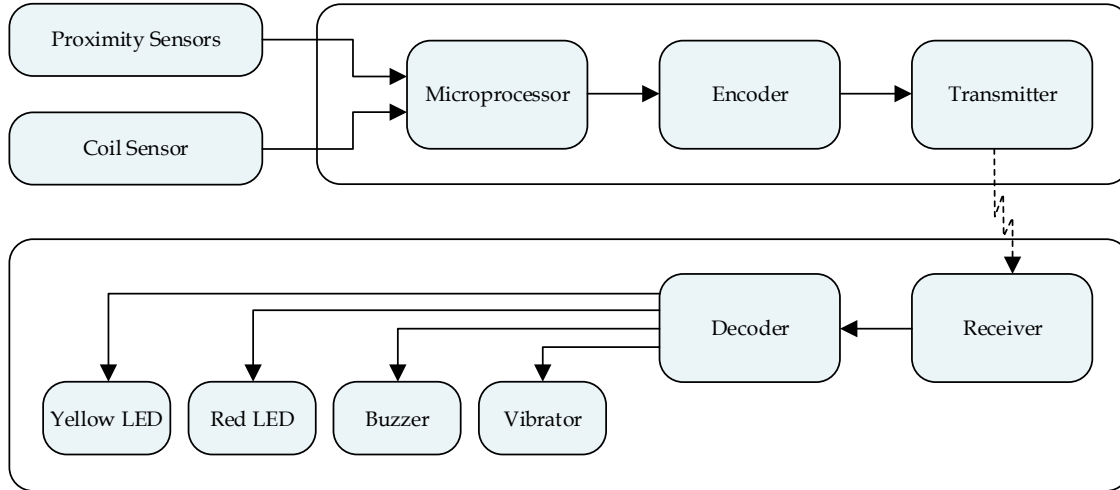


Fig. 9.1. System Block Diagram.

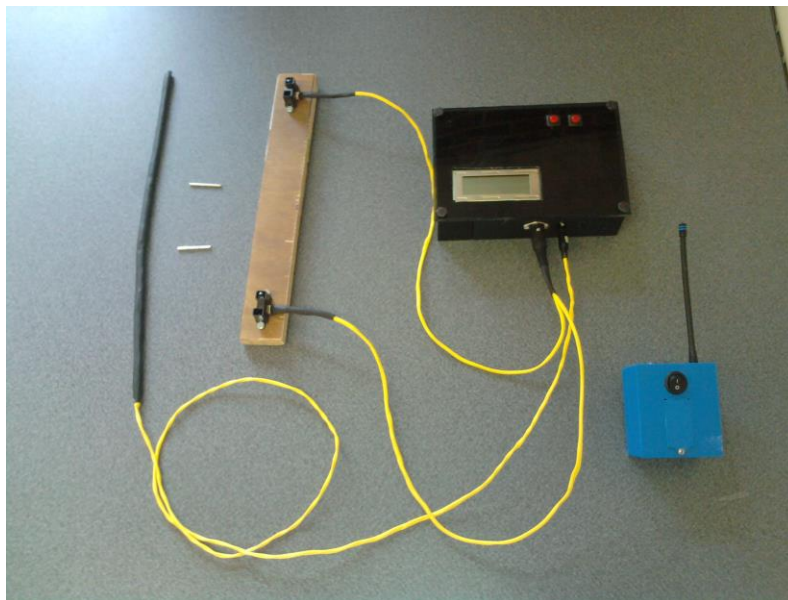


Fig. 9.2. Wireless Monitoring System.

# SOUND-ACTIVATED LIGHT BOX

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## INTRODUCTION

The sound-activated light box is an interactive sensory device for the Anne Carlsen Center for Children. The box is designed to be engaging, simple to use, and durable. The sound-activated light box is comprised of inputs, control circuitry, and a large display of high-quality RGB LED Neon-Flex Rope Lights arranged in a pattern of eight concentric circles. Vibrant and colorful light patterns are produced automatically or in response to sound or touch. Figure 9.4 shows the completed device.

Although there are sound-activated lights available on the market, most are geared toward disc jockey equipment and many produce strobe effects. These lights do not appeal to the client due to the potential of strobe-induced seizures. The sound-activated light box avoids these dangers and instead creates soothing rippling patterns, much like those produced by a stone being tossed into a pool of water.

## SUMMARY OF IMPACT

The Anne Carlsen Center provides educational, residential, and therapeutic services to young individuals with disabilities. The center has a sensory room which is filled with various sensory devices such as a motion activated piano and passive bubble tubes. The sound-activated light box provides the center an additional tool to engage and entertain the children. Upon delivery, the Anne Carlsen Center staff said that the box went “above and beyond” their expectations. The center is eager to install and utilize the box in their sensory room.

## TECHNICAL DESCRIPTION

The sound-activated light box consists of five main components: 1) inputs, 2) embedded microcontrollers, 3) rope lights, 4) power supply, and 5) enclosure. Figure 9.3 provides a block diagram of the system. A three way toggle switch selects one of three modes of operation: automatic, audio, and button. In all operation modes, color changes

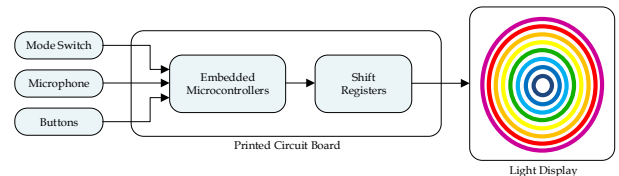


Fig. 9.3. Block Diagram.

progress from the inner ring outward, thereby producing soothing ripples of color.

In automatic mode, the embedded controllers continuously change the color of the rope lights without any input from the user. In this mode, the lights cycle through 180 colors in 23 seconds before starting over. Automatic mode allows a passive way to enjoy the light display of the box; this is particularly useful to accommodate individuals with severe physical limitations.

In audio mode, a microphone converts sound into a low-level electrical signal. An operational amplifier circuit conditions the signal to the zero-to-five volt range required by the microcontrollers. The microcontrollers then sample the signal using on-board 10-bit analog-to-digital converters. The sampled signal serves as the basis for output color: soft sounds produce “cool” colors (blues), loud sounds produce “hot” colors (reds), and intermediate sounds produce the gradation of colors in between. To reinforce a cause-and-effect relation between sound level and color, the system responds rapidly to changes in sound level. Still, color changes take approximately one second to propagate from the innermost to outermost rings. Thus, the system output is responsive yet soothing. The cause-and-effect relation between sound and color is intuitive for individuals of all skill levels.

Button mode allows users to change the color of the lights by pressing and holding one of the two five-inch buttons. One button causes colors to cyclically transition from “cool” to “warm”; the second button

causes colors to cyclically transition in the opposite direction. In this mode, it takes approximately 11 seconds to cycle through the entire color range. The somewhat long cycle time ensures users of broad ability range can successfully obtain the colors they desire.

Two PIC 18F4620 microcontrollers manage system operations. To determine mode of operation, the controllers continuously monitor a three-way toggle switch. If needed, the controllers then read the appropriate input (button or microphone) to determine the current output color. In the case of the microphone input, samples are processed at a 20 kHz sampling rate using a maximum-based filter that reduces flicker and ensures proper output color range. To set a particular output color, the intensity of the red, green, and blue components must be set. Since there are eight rings, the total number of required outputs is 24. Pulse-width modulation (PWM) is used for each output; the intensity for each RGB output is directly proportional to the duty cycle of the PWM wave. Shift registers are used to extend the limited number of PIC outputs to the needed 24 outputs. The outputs of these shift registers are clocked by the PIC controllers every 7 microseconds. This rapid switching is far faster than the human eye can detect and gives the output the illusion of a fixed intensity that is proportional to the duty-cycle of the PWM wave. The controllers also sequence colors from the innermost ring to the outermost ring to establish an output pattern that resembles rippling waves.

The RGB LED Neon-Flex Rope Light is made with high power LEDs that are spaced evenly every three quarters of an inch. The RGB LEDs are also known as multi-colored LEDs because they can create nearly unlimited color variations by blending various intensities of the primary colors of red, blue, and green. The LEDs, which are housed in a flexible plastic casing with a semi-transparent rounded plastic top, give the illusion of neon lighting. As seen in Figure 9.4, the rope light is sufficiently flexible to form the innermost circle, which measures 4.7" in diameter. The rope lights are powered by a 24 volt AC to DC power supply.

The power supply derives its 24 volt DC output from a 120 volt AC input. The sound-activated light box draws approximately three amps of current, the majority of which is used to operate the rope lighting.



Fig. 9.4. Sound-Activated Light Box.

This current draw is well below the 9.2 amp rating of the power supply and ensures the power supply remains cool. Voltage regulators are also used to provide the various voltage levels required by components of the box. A simple switch allows power to be turned on and off.

The device enclosure, which measures 4'×2.5'×6.5", is made of painted wood and particle board. The rope lights are protected by a 32" × 26" piece of Plexiglas that has an applied frosted film. Excess system heat, which primarily originates with the power supply and voltage regulators, escapes the box through two venting ports. Two 3.5mm mono jacks are used to connect buttons to the box.

The total cost of the sound-activated light box is approximately \$1200, including \$800 for the rope lights, \$100 for the power supply, \$90 for the buttons, and approximately \$200 for electronic components, printed circuit boards, paint, Plexiglas, and other components.



# ANDROID OS REMOTE CONTROL

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## INTRODUCTION

Built around the Android operating system (OS), the Android OS Remote Control, referred to as the AOS Remote, is designed to be inexpensive and easily operated. It can control multiple electronic devices such as televisions, DVD players, radios, or cable boxes. Any Android-compatible device can use the remote control application. The application communicates commands through Bluetooth to a custom hardware module. A microprocessor then converts the command to an appropriate infrared signal for the target entertainment device. The AOS Remote is designed to be compatible with multiple user inputs, thus accommodating various forms of disabilities. The application is controlled by any USB-based input device including trackballs, joysticks, and buttons.

There are similar remotes on the market, but these products are typically expensive, large, or do not properly accommodate persons with disabilities. The Relax and the Relax II are infrared transceivers that can control up to ten electronic devices. The Relax II costs approximately \$600 and is rather large. Remote control applications are available for Android devices, but the user can only control compatible devices. For example, DIRECTV provides an application allowing users to control their satellite using an Android device. However, if the user does not own compatible DIRECTV hardware, he or she cannot use the application. Unlike these other applications, the AOS Remote includes this necessary hardware. The AOS Remote allows each client to customize the application to operate any infrared-controlled electronic device.

## SUMMARY OF IMPACT

The client for this project is a twelve-year-old boy who has limited mobility. He is not able to independently control any entertainment devices. The AOS Remote allows the client to independently control multiple electronic targets without help from a caretaker. To accommodate the client's proficiency

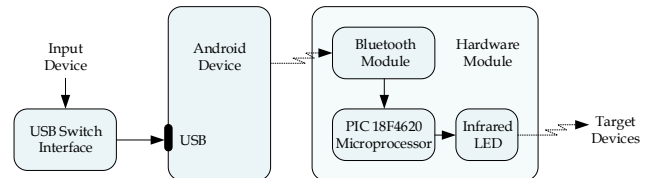


Fig. 9.5. System Block Diagram.



Fig. 9.6. Screenshot of the AOS Remote Application.



with a two button head-mount interface, the client's Android OS Remote is controlled by two buttons, as shown in Figure 9.7. The client uses these two buttons to toggle through the options of the Android application and then select his desired option. The application implements text-to-speech, which verbally confirms each selection. This increases the functionality of the AOS Remote, because the client relies heavily on auditory confirmation. The application also has the ability to have commonly used TV channels or radio stations pre-programmed to increase ease of use. Most assistive remote controls do not have this feature.

## TECHNICAL DESCRIPTION

As shown in Figure 9.5, the AOS Remote is composed of four main components: 1) an Android device, 2) a Bluetooth module, 3) a microprocessor, and 4) an infrared LED.

The Android device controls the operation of the remote. As shown in Figure 9.6, the main menu contains simple functions such as volume up or down and channel selection. There are also selections that take the user to submenus, such as favorite channels or numerical keypad. Input devices are connected to the Android device through a USB switch interface. The switch interface provides a mechanism to associate various input devices with different control actions such as toggle, select, and directional movement.

When the user selects a command, the Android confirms the selection with text-to-speech. All Android devices made after Android Version 2.1 have native text-to-speech. Once a selection is made, the application sends a signal through Bluetooth, which is also native on all Android devices.

The AOS Remote uses a BTM-182 Bluetooth module that receives a signal from the Android device once a selection is made. The BTM-182 has a built-in antenna that receives the command data. A PIC18F4620 decodes the BTM-182 output and creates a target-appropriate infrared control signal. This control signal is then output to an infrared LED. The electronic target accepts the input and performs the desired function.

The Bluetooth module, microprocessor, and the LED are housed together in the hardware module. A six-volt AC/DC converter provides power to these components through a five-volt regulator. The enclosure must be positioned so that the infrared LED is within transmission range of the target electronic devices.

The client's AOS Remote cost is \$600, which includes \$400 for a View Sonic G-Tablet and \$200 for the Hardware Module. The Android application can be distributed free of charge.



Fig. 9.7. Android Device with two button inputs.



# CHAPTER 10

## THE OHIO STATE UNIVERSITY

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# ASSISTIVE TRANSFER DEVICE FOR ADAPTIVE ADVENTURE SPORTS

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*Department Mechanical and Aerospace Engineering, Department of Biomedical Engineering, Allied Medical Professions  
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## INTRODUCTION

Adaptive adventure sports were developed for individuals with disabilities to enhance everyday life, challenge the participants, help build self-confidence, and enable learning through experience. One of the main challenges for the athletes to participate in adventure sports is transferring between two different elevations. Although numerous transfer devices are available today, many of these devices are extremely expensive, large, unsafe, or do not fulfill the needs of the participants. We designed a universal transfer device that addresses these issues as well as being portable, increasing safety during transfer, and ease of use for athletes or athletic organizations.

## SUMMARY OF IMPACT

The device is able to raise and lower anywhere between 6 inches and 24 inches off the ground, allowing the user to position the device seat so it is level with their wheelchair or sporting equipment. By doing so, they are only required to transfer laterally between two devices. Overall, the device improves upon existing transfer devices, increases the independence of the user, and increases participation in adventure sports while maintaining a safe and comfortable transfer process. The device meets all performance requirements through supporting a load of 300 lbs. and allowing a total height change of 18 in. During clinical testing, the device received an average overall rating of 4.19 out of 5 on the Likert Scale.

## TECHNICAL DESCRIPTION

The device consists of three main components: The base, the seat, and a manual hydraulic jack. The jack is mounted on the base frame, and the seat is mounted (through a drop-forward design) to the jack ram. The jack is actuated by a lever on the user's right side in which they pull up repeatedly to raise the seat



Fig. 10.1. Sled hockey (adaptive adventure sport).



Fig. 10.2. Current transfer device consists of a milk crate with foam padding which acts as intermediate step.

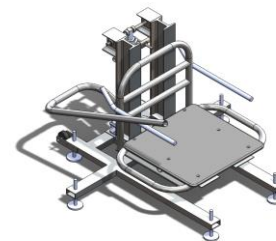


Fig. 10.3. Final device design.



to the height needed. The seat is then lowered, with the assistance of a volunteer, by a release valve connected to the back of the jack. The device is portable by separation of the seat component from the base and jack assembly (to be carried), or by tilting the device onto rear mounted casters (to be

dollied). The device also consists of 6 adjustable feet which allow for leveling of the device on uneven terrain. The total direct component cost of the device is \$625 and the total cost for the entire project is \$1,117.



Fig. 10.4. Wheelchair and transfer device setup.



# OFF-ROAD WHEELCHAIR FOR MANUAL WHEELCHAIR USERS

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*Community Interest: Flying Horse Farms*

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## INTRODUCTION

Manual wheelchair users experience one of the highest levels of limitation of their daily activities due to the limit of the environments they are successfully able to explore. Because both functional and physical restrictions are present when using wheelchairs, it is often more difficult to propel and maneuver on various outdoor terrains, such as dirt, gravel, snow, and sand. Self-propelling is difficult for some users on flat, level surfaces as well, and although wheelchairs provide mobility for users with disabilities to ensure a better quality of life, their performance is limited on various terrains.

On uneven and outdoor surfaces, stability is lost and a greater effort is required to propel the chair. Changes or additions to the wheelchair are needed to allow for easier and safer transportation on varied surfaces. To obtain a better understanding about how to modify wheelchairs to be used more in off-road environments, clinical information about the user's posture, propulsive patterns, and the limitations of existing wheelchair designs were taken into consideration.

We observed problems with similar devices and determined objectives and constraints for our new assistive device. In addition, we determined quantifiable metrics which will help us to determine how well the device meets the design objectives and whether the team was able to incorporate the objectives and constraints.

## SUMMARY OF IMPACT

Wheelchairs provide individuals with disabilities greater mobility, the ability to participate in activities, better health and improved quality of life. However, manual wheelchair users can experience difficulty propelling and maneuvering on various outdoor

terrains, such as dirt, gravel, snow, and sand. Due to increasing evidence that closeness to a natural environment and participating in outdoor activities



Fig. 10.5. Final design of device.



Fig. 10.6. Final device attached to wheelchair.

are healthy, manual wheelchair users should have the same opportunity to interact in the outdoor

environment as others. After brainstorming our ideas as a team, we narrowed our possible solutions and created a design matrix to evaluate which design would be best, as scored on the evaluation criteria established as most important for the design. We reached our final decision of a three pneumatic wheels design by weighing the costs, weight, and ease of attachment of the device to the wheel chair, along with the location of where the existing casters on the wheelchair would fit into a mounted device. The device our group developed will allow manual wheelchair users to access terrain not achievable in their current everyday chair. This will increase opportunities for them to explore nature, interact with peers at camps and provide a resource for exploring their environments.

### TECHNICAL DESCRIPTION

The entire off-road wheelchair attachment is comprised of steel. The attachment weighs approximately 12 pounds. All of the pieces of the device are welded together so no assembly is needed by the user.

The main advantage of our design is that it is truly a universal attachment for any manual wheelchair. In order to remain truly universal, the box of the frame must be wide enough to accommodate the widest

front caster placement on wheelchairs corresponding to our constraints. Correspondingly, we have designed our boxed frame to be 25 inches wide, as shown in Figure 10.7. The boxed frame is used to “trap” the caster between the rails. Again, with universality in mind, we have designed the boxed frame rails to 3 inches apart (center to center). This allows the attachment to accept wheelchair casters with diameters between 3 and 5 inches. Another consideration regarding critical dimensions is the clearance between the front wheel and any part of the wheelchair overhanging the front casters. Accordingly, the wheel is located 14.5 inches in front of the boxed frame front rail. In addition, the support rail is 8 inches in front of the boxed frame front rail. Based on our research, this dimension should provide enough clearance for many footrests on manual wheelchairs. The last dimension worth mentioning, is the ground clearance of the frame. The design allows a maximum ride height of just over 2 inches. The ride height is affected by many factors including tire pressure, load on the attachment, and also the location of the load on the attachment. We have tentatively determined that optimum ride height is between 1 and 2 inches. This is based on an optimal 15 degree angle.

The final cost of the attachment is \$332.03.

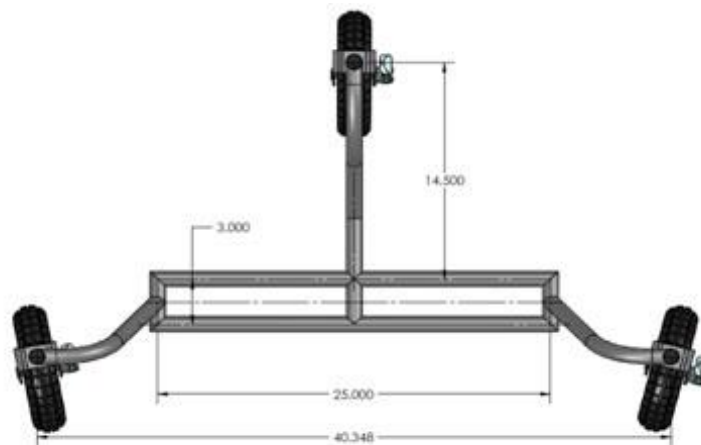


Fig. 10.7. CAD of Attachment with Dimensions.

# EVALUATION WHEELCHAIR

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*Community interest: Martha Morehouse Medical Pavilion*

*Supervising Professor: Dr. Robert A. Siston*

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## INTRODUCTION

A properly fitting wheelchair is essential for a comfortable and active lifestyle, as well as to prevent health complications that often arise from ill-fitting wheelchairs. Unfortunately, the current wheelchair seating and mobility assessment process has many opportunities for error, lacks consistency, and does not always provide the client with the best fit possible.

This current process uses tools that often require some estimation and doesn't allow the clinician to see the client in the device until the final order is already made. The purpose of our project is to create an evaluation manual wheelchair that can be used during clinical evaluations to quickly and efficiently provide a properly fitting wheelchair for manual wheelchair users to trial.

The final design of our evaluation wheelchair is an all-inclusive, highly adjustable chair that is easy to use and provides the patient with the ability to "test drive" their fitted chair in a simulated clinical environment. The design will allow adjustments to the following features: seat depth, seat width, axle location, caster position, back angle, back height, brake position, seat height, wheel camber, and footrest position.

The combination of these adjustments on a single wheelchair offers clinicians and clients a tool that allows a way to test a wheelchair and make adjustments before purchasing; improving the overall fit of the final wheelchair and thus the clients' quality of life.

## SUMMARY OF IMPACT

Individuals being evaluated and fitted for manual wheelchairs most often are not given the opportunity to "test drive" a manual wheelchair before the purchase of their everyday wheelchair. Our evaluation wheelchair provides benefit to patients,

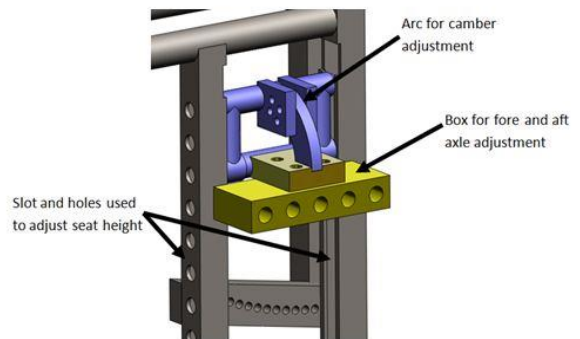


Fig. 10.8. Seat Height, Axle Location, and Camber Adjustments.

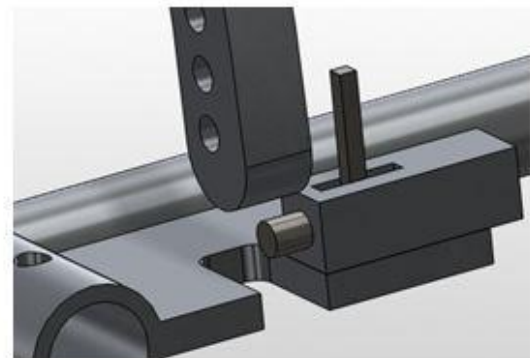


Fig. 10.9. Seat Angle Adjustment.

clinicians, hospitals and clinics, and wheelchair suppliers and manufacturers. Patients are ensured a better wheelchair fit, clinicians benefit in that they are able to more precisely place a wheelchair order for the patient, hospitals and clinics will save time and money with a more efficient wheelchair evaluation process, and wheelchair suppliers and manufactures will be able to better meet the needs of the clients with

the purchasing of more properly fitting manual wheelchairs.

## TECHNICAL DESCRIPTION

The seat back height for the wheelchair will be adjusted with two parallel telescoping tubes using spring-loaded pins and holes. The fore and aft axle adjustment is a solid aluminum box with five holes that go completely through, allowing the fore and aft position of the wheel to be adjusted with a quick release wheel axle. The seat height adjustment is achieved by removing two shoulder bolts and sliding the axle location box within a guide rail. The camber is adjusted through the use of an arc that passes between two plates, and is locked with a quick release pin as shown in Figure 10.8.

The width of the wheelchair is adjusted using five separate telescoping tubes which are held in place with two quick release pins. The seat depth is adjusted using two parallel telescoping tubes with removable quick release pins.

The seat back angle is adjusted with spring loaded pins on each side of the wheelchair. Two steel bars have thirteen holes spaced two degrees apart. The angle can be adjusted by pulling on a steel cable to unlock the pins from the holes on each side of the wheelchair. The angle for the seat is adjusted using spring loaded pins and steel arcs with holes as shown in Figure 10.9. The angle can be adjusted by pulling on a steel cable connected between the pins on both sides of the wheelchair and then moving the seat to the correct angle.

Our design is the first wheelchair with the ability to adjust every feature to the proper fit for the majority of the population using manual wheelchairs. Furthermore, it does so in a way that is simple and intuitive and saves all parties of the wheelchair evaluation and fitting process time and money. We believe this design is the solution to consistently providing a properly fitting manual wheelchair to individuals with functional mobility limitations.

The approximate cost of all materials was \$1600.



Fig. 10.10. Evaluation Wheelchair.



# MOBILE ARM SUPPORT

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## INTRODUCTION

Every day functions such as eating, drinking, dressing, grooming, and brushing teeth require muscle strength in the upper extremities. Individuals with diagnoses that result in proximal weakness to the trunk and shoulders may experience difficulty in tasks which involve lifting of the arm. Mobile arm supports exist to assist with these tasks, but a survey of existing mobile arm supports reveals that problems exist with the portability, versatility, and affordability of today's options.

A need exists for a mobile arm support that provides high functionality of motion and adjustability while staying at a relatively low cost, because it is difficult to obtain insurance coverage for mobile arm supports. We have developed a new mobile arm support by breaking the problem down into four sub-functions: 1) wheelchair attachment, 2) arm interface, 3) vertical motion, and 4) horizontal motion.

We created the sub-functions based on what we deemed to be critical design components and functions. We brainstormed, rated, and refined design concepts in each of the four sub-functions to come up with a complete final design. Throughout the design process, we kept simplicity in mind to ensure affordability of the final device.

## SUMMARY OF IMPACT

Diagnoses that result in proximal weakness to the trunk and shoulders include cervical spinal cord injury, muscular dystrophy, ALS, and multiple sclerosis. In general, activities of daily living, mobility, and access to communication devices may be impaired due to these limitations. Mobile arm supports are used to assist those with upper extremity weakness in completing these daily functions and to restore independence for these individuals. To test our device with two clients, we developed a test plan to test three key functional tasks: 1) reaching forward, 2) reaching upward, and



Fig. 10.11. Arm Positioning in Mobile Arm Support.

3) feeding. To test reaching upward, we asked clients to press a power button to open a door. To test reaching forward, we asked clients to type their name on a computer keyboard. To test feeding, we asked clients to raise a spoon to their mouth and return it to a bowl. Both clients showed improvement in feeding and reaching forward, and one client showed improvement in reaching upward. Both clients also showed a significant decrease in fatigue during the completion of these tasks. Based on these results, the device successfully assisted in each of the designated tasks and has the potential to increase the independence of patients with proximal weakness to the upper extremities.

## TECHNICAL DESCRIPTION

The device is attached to the wheelchair by sliding a mount into a channel that previously exists on the wheelchair and is common for many types of wheelchairs. A horizontal beam is welded to the mount and a vertical rod is welded to the horizontal beam. The rod from the wheelchair attachment is bolted to the mounted vertical rod and runs up the wheelchair nearly vertically. A ball joint rod end



bearing is located on the shaft near the shoulder, and a universal joint is connected to the bearing to allow for both horizontal and vertical motion of the device. Clamp-on shaft collars keep the ball joint rod end in place on the shaft and can be moved to adjust the height of the device.

The frame of the device consists of two circular aluminum rods that run from the shoulder joint to slightly past the elbow and are contoured to match the shape of the arm. The arm interface consists of three components: 1) an elastic elbow support, 2) a plastic elbow positioning piece, and 3) a circular forearm cuff. The elastic elbow support is positioned horizontally between the rods to allow the elbow to rest upon it. The elbow positioning piece sits behind the elbow and ensures that it does not slide back and out of position. The forearm cuff consists of plastic shell with foam padding on the inside, and it opens in half and locks around the user's forearm for use.

Figure 10.11 shows the appropriate arm positioning within the device.

Elastic bands generate the force to support the weight of the user's arm. The bands are positioned between the shoulder joint and frame and between the frame and forearm cuff. A tensioning device, consisting of an aluminum shell, spring, and pin, is placed on the frame and allows for adjustment of the force provided by the bands. The pin contains locking ball bearings and a snap ring. The spring allows the ball bearings on the pin to be pulled in and out. The aluminum shell contains internal holes to allow the pin to be pulled out of position, rotated to the desired position, and locked into place. In this way, the elastic bands are clamped onto the tensioning device and tensioned by rotating the pins to the desired positions.

The cost of the parts and materials for the final device was approximately \$326.09.



Fig. 10.12. Final Prototype of Mobile Arm Support.

# MIDLINE GAIT SYSTEM FOR INDIVIDUALS WITH ATAXIC SCISSORING GAIT

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## INTRODUCTION

Scissor gait is a deviation in which the lower extremities cross midline while walking and is a symptom of a variety of neurologic conditions. With ataxic scissoring, patients lose control of refined movements and have difficulty controlling their limbs in space. As a result, the legs may cross midline due to the individual's impaired neuromuscular control and, if not addressed, may lead to falls or patient injury.

Current physical therapy treatments for ataxic scissor gait include the use of freestanding assistive devices, which are prohibitively expensive, and manual techniques, such as holding a ski pole between the patient's legs, which can be inefficient and prevent the physical therapist from performing more skilled patient cueing. The goal of our project was to design a tool for use in physical therapy sessions that improves upon present treatment methods.

Our design is a system of components that must safely and securely attach to standard two-wheeled rolling walkers, greatly reducing the cost and improving clinical integration of the system. The design prevents an individual from crossing midline during gait training while maintaining the safety of the user and therapist. The components are adjustable and removable from the walker, allowing the system to be tailored to a user's specific needs.

## SUMMARY OF IMPACT

The purpose of our design is to provide physical therapists with a safe, effective, and affordable treatment tool for use with ataxic scissoring patients. The design will prevent an individual from crossing midline during gait training while maintaining the safety of the user and therapist. The components are adjustable to the user's specific needs in order to accommodate as many users as possible. Additional



Fig. 10.13. Current treatment methods for patients with ataxic scissor gait



Fig. 10.14. Solid model of Midline Gait System attached to a walker.

research was conducted in order to ensure our attachment subsystems would be compatible with as many user body sizes as possible. We reviewed the human anatomy and biomechanics of the involved body systems, and performed calculations to determine appropriate dimensions for each designed piece. The system can be used as a whole or as separate components, to cater to the individual needs and severity of the user's disability. After clinical testing at both Dodd Hall and the Martha Morehouse Medical Center, therapists responded positively as to the usefulness of the system as a way to treat patients with scissor gait, as well as other pathologies.

## TECHNICAL DESCRIPTION

The system design is composed of four attachments to a standard two-wheeled walker, each achieving a specific function. The attachments include a midline blocking bar, a forearm support system, weight receptacles, and a mirror attachment. The midline bar consists of connected components that fulfill depth and height requirements for different users and width adjustments to fit several walkers. In order to increase the attachment stability and safety for the user, the design includes a curve at the end of the solid bar down to the ground, capped with a spherical glider in order to provide adequate support on the ground. The midline bar adjusts in length and height via telescoping bars. The length of the cross bar will be adjusted by a dual spring-loaded system able to compress or expand to fit the walker width.

The forearm support and handle subsystem consists of several components. These components include a semi-circular cushioned armrest, a proprioceptive wedge, a central support pole that holds the armrest, clamps to attach the central support pole to the walker, lateral support bars, and four different types of handles. The four handle types are a straight vertical handle, a straight handle angled at 45°, a horizontal handle, and a tri-pin handle. The inner radius of the armrest is 2.25", meaning that it is able to accommodate a forearm that is a maximum of 14" in circumference. The length of the armrest is dependent on the length of the forearm of the average user, and more specifically the length of the ulna. The

purpose of the wedge is to cue the user if the elbows become overextended and the walker is pushed too far in front of the user. The central bar is adjustable in height by 3" and can rotate transversely 30° inward about its central axis. All four of the handle options for this system have a pin located on the anterior face that allows them to lock into the slot located at the front end of the base plate. The vertical handle, 45° handle, and horizontal handle are covered with ergonomic grips for comfort. The tri-pin handle is designed to support a user's hand if they do not have the physical capacity to grip the other handle options due to neurological or musculoskeletal conditions.

The weight receptacles have a lip which extends from the top of the medial wall to hang over the walker's side cross bar, making attachment possible in a single step. To prevent anterior-posterior and medial-lateral translation of the receptacles during use, there is a supportive bar across the bottom that is curved at the ends, which rests against the legs of the walker. This design allows various types of weights to fit within the receptacle, such as, ankle weights, dumbbells, and other quantifiable weights. The weight receptacles are made out of uniform Aluminum 6061 in 1/8" thick sheets, and are held together by right angle brackets.

The mirror component is comprised of three main parts: the mirror, the base and the arms. The mirror itself will sit in a frame in order to stabilize and protect it from damage if user were to collide with another object. The mirror is 15"x15"x0.25" to provide the user a full view from their feet. The angle of the mirror is adjustable via pin-holes on the sides of the base, in order to account for users of different heights. The top corners of the mirror will rest in a track and slide easily up and down as the bottom angle is adjusted. The mirror subsystem will have two arms that attach the component to the walker, one on each front leg of the walker, via clamps attached to each end of the arms. The arms are adjustable in width by two 6" long extension rods of 1" diameter located on either end of the front of the base. The total cost of parts and materials for this prototype was approximately \$1670.

# REDESIGN THE WALKER ASSISTIVE DEVICE

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## INTRODUCTION

Walkers are used to provide stability to people with decreased balance and lower extremity strength. The overall goal is to decrease a user's fall risk. Yet, if used improperly, walkers have been shown to increase fall risk in users. Poor posture, destabilizing biomechanical effects, increased attentional demands, interference during balance correction, and increased metabolic and physiological demands are all reasons why current walkers and their misuse can increase fall risk to the user.

Falls are extremely dangerous, especially for older users, who may have other ailments. Current designs do not promote correct posture while in use, which can lead to increased instability and fatigue, which leads to increased fall risk. This new walker was designed primarily to correct weaknesses in the current walker in order to reduce fall risk in walker use.

This redesign makes efforts to correct these issues by using biomechanical feedback to remind the user to use proper posture. Additionally, it uses a mechanical response system to adjust to how the user is using the walker. The goal was to create a walker that decreases fall risk in walker users, is intuitive to use correctly, and is able to be used by a wide range of walker users.

## SUMMARY OF IMPACT

9.1 million individuals in the United States currently use an assistive device for ambulation. 1.5 million people use walkers in the United States, and 78 percent are over 65 years of age. There are a number of reasons an elderly individual may require a walker, but they are most commonly used for balance

and support. Current walker designs can lead to increased fall risk through user misuse as well as several design flaws. Because current designs do not help correct the issues of poor posture, destabilizing biomechanical effects, increased attentional demands, interference during balance correction, and increased metabolic and physiological demands, these designs can actually be dangerous for users. A walker that helps to correct these issues, while not losing the stability that users need, would help to decrease fall risk thus making ambulating safer for users.

## TECHNICAL DESCRIPTION

The new walker design includes several additions and modifications to help to correct the issues listed above. The design is longer, which allows users to walk within the frame, to increase stability by keeping the walker close to them. Also to accommodate more users, the design can be adjusted for width as well as height. The walker has four wheels, but instead of only having brakes in the back, the new design incorporates four wheel brakes. Additionally, the brake activation lever has a shorter, more manageable activation, allowing users to easily engage the brakes.

One addition that was included are biomechanical posture cues; springs covered by soft housings that protrude out across the back opening of the walker. When a user leans forward, a sign of bad posture, the posture cues make contact with the user's legs, giving the user a reminder to stand up straight. Additionally, the design includes a weight-activated system to increase stability for users who use the device for more weight-bearing. As users press down on the frame, spring activated sleds are pressed to the

floor, changing the walker from a four-wheeled design to more stable two-wheel, two-sled design. This addition helps to make the walker more universal.

Approximate cost for all materials was \$2000.



Fig. 10.15. Prototype of Final Walker Design



# HIP CONTINUOUS PASSIVE MOTION DEVICE

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## INTRODUCTION

Between 22% and 55% of people who experience hip pain have acetabular labral tears. Surgery is required to repair a torn labrum. Following surgery, a strict rehabilitation program is prescribed for optimal recovery. This assistive device accurately replicates the continuous passive hip circumduction (circular) motion prescribed as a physical therapy intervention. Continuous movement is defined as constant motion of the involved area of the body by an outside source. Passive intervention means that the involved person does not actively contract any muscles.

Currently, physical therapists must perform this intervention without assistance from a device, because no device assists to aid in the intervention. This device assists with performing this prescribed continuous passive motion (CPM). Patients lie supine with their surgical leg in a boot that is attached to an assembly that provides the circumduction movement.

The device was presented to clinicians at the Ohio State University Sports Clinic at Martha Morehouse, for clinical feedback. This assistive device addresses the functional requirements to mimic the therapy currently performed by physical therapists or patient caregivers with a unique and innovative design.

## SUMMARY OF IMPACT

During the hip CPM process, someone or something other than the patient moves the surgical hip without any muscle contractions. Currently, patient compliance with the prescribed intervention is difficult because physical therapy visits are expensive and inconvenient to schedule and home exercise programs are physically difficult to complete. Improved patient participation in CPM may decrease healing time and improve functional and clinical outcomes. With roughly 30,000 hip arthroscopic surgeries performed in 2010 in the United States, it is

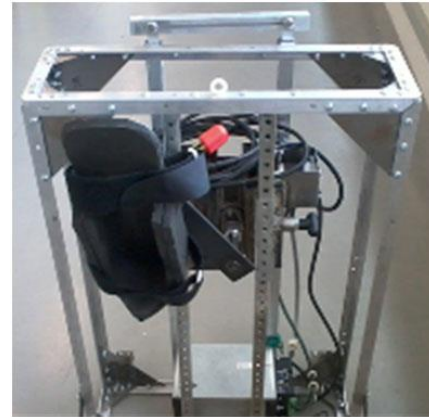


Fig. 10.16. Boot and Motor Attachment

important to improve clinical outcomes to accommodate the growing population of patients undergoing this surgery. This device provides passive circumduction of the hip joint and can be used independently. This device can enable patients to increase compliance and relieve physical stress for both the physical therapist and patient caregiver.

## TECHNICAL DESCRIPTION

Our design process consisted of generating ideas for device components that could then be easily assembled. These features remained throughout our design modifications.

The housing was at first a rectangular box with dimensions 24 inches wide by 36 inches high by 8 inches deep. For our design prototype, we deemed that it was simpler to make modifications and adjustments to an open box, rather than to an enclosed one. However, in a more finalized construction, we would enclose all the features housed in the box frame. The frame provides the housing for the motor that sits on an adjustable track,

the step-down gears and output shaft, and the speed controller.

After searching the products offered by many different manufacturers we chose a DC brushless gear motor from Anaheim Automation that comes with a gearbox already attached. This motor, controlled with a MDC150 speed controller, provides an output speed of 53 RPM with a maximum torque of 40 lb. ft. from the gearbox; adequate torque for our needs.

The boot is our patient-to-device interface and transfers the circumduction motion to the patient's leg. At first, we planned to use 3D printing capabilities to create a form-fitting boot out of plastic. The plastic boot would match the shape of a patient's foot for the utmost comfort. Despite the allure of the plastic boot, we decided to change our design to a simple "one size fits all" boot made from sheet metal padded with foam. After testing, we may find that a hybrid of sheet metal and a smaller design from the 3D printer will be suitable.

As the boot travels in the circular motion during the intervention, the leg distance from the device

changes. Originally, we wanted to compensate for this change by allowing increased freedom of movement for the motor shaft. However, after unsuccessfully manufacturing a smooth interface for the shaft to travel on, we needed to change our design more drastically. We replaced the moving motor shaft with a rolling cart. Instead of lying stationary on a mat, the patient now moves back and forth with the cart. This motion is now possible as the patient moves back and forth facilitated by the rolling cart. The result of the rolling cart is a much smoother motion than the sliding shaft design.

We added a retractable suitcase style handle and wheels in this design iteration. These additions allowed the patient to maneuver the hip CPM in the same manner as a large carry-on suitcase. Users are able to tow the hip CPM behind them. They can also transport and maneuver it easily within their home. Patients will likely be more comfortable with the hip CPM because it looks like a common item, a suitcase, rather than a piece of medical equipment.

The approximate cost of all materials was \$2010.

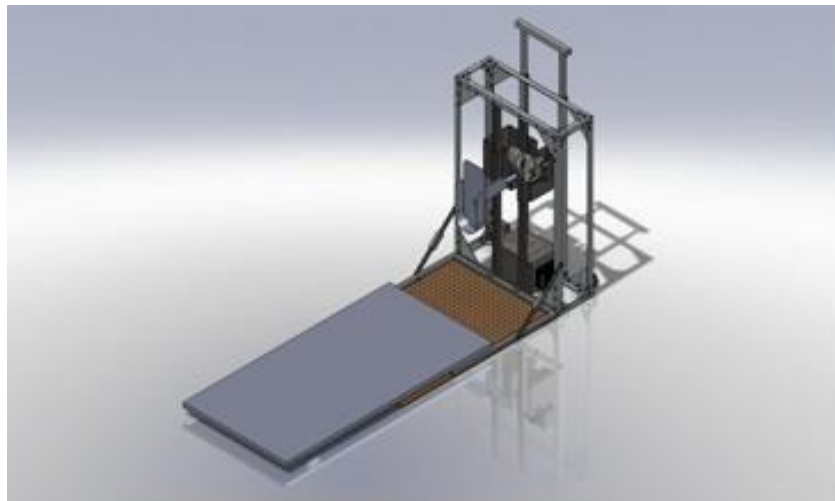


Fig. 10.17. Hip CPM device

# SUBOCCIPITAL RELEASE DEVICE

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## INTRODUCTION

Suboccipital release technique is commonly performed by physical therapists to relieve cervicogenic headaches, neck pain, and range of motion restrictions. Patients with these conditions routinely visit the clinic to receive this treatment. This can be a financial burden and inconvenience for the patients. Those who chronically suffer from these conditions may benefit from a device that can be used in the convenience of their home, and successfully deliver the suboccipital release treatment. Current devices on the market fail to replicate the effects of suboccipital release therapy. These devices on the market lack any dynamic component.

During suboccipital release therapy therapists adjust finger placement and provide traction or oscillatory motions with their fingers. Therefore, it is essential for dynamic movements when providing suboccipital release. Furthermore, devices on the market do not replicate the placement of the therapist's fingers accurately. The therapist's fingers are arranged in a V-shape orientation with four fingers comprising either end of the V. Finally, devices on the market greatly lack in adjustability to the user. Devices fail to allow the user to change the amount of pressure, location of pressure, and placement of head support.

Our team designed and developed a device to include dynamic movement, V-shape orientation of pressure applicators, and enhanced adjustability. We clinically tested our device with physical therapists and patients. The clinical tests were successful. Patient and physical therapist feedback both showed our device successfully replicated the effects of the manual technique of suboccipital release therapy.

## SUMMARY OF IMPACT

Patients with chronic headaches, cervicogenic headaches, neck pain, and range of motion restrictions will greatly benefit from a device that provides suboccipital release in the convenience of their home. This device will help reduce the financial

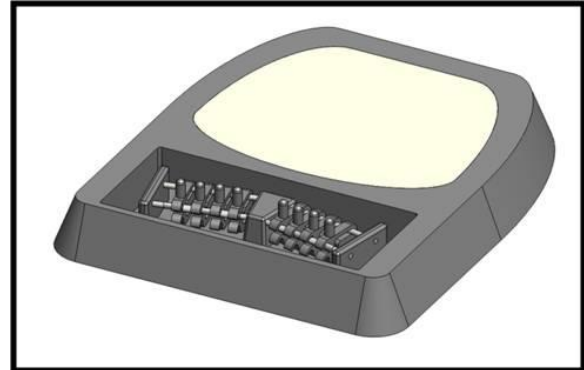


Fig. 10.18. Solid works model of device

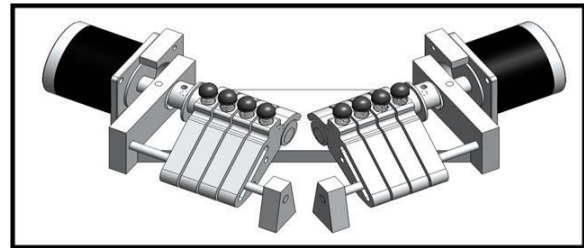


Fig. 10.19. Assembly of device.

burden of constantly visiting the clinic for the technique. Furthermore, the device will readily provide patients treatment when the patient is feeling pain or discomfort. The physical therapists will also greatly benefit from our device. The technique can be strenuous for the physical therapist and may lead to injuries to the therapist. This device will reduce the frequency physical therapists conduct this technique for patients reducing the risk of injury and fatigue of their fingers. During the clinical trials both therapist and patients viewed the device as a means for the user to more readily receive the technique. Therefore, the patient will not have to regularly visit the clinic and can use the device when needed.

## TECHNICAL DESCRIPTION

Our device contains five essential components for producing suboccipital release therapy. These include: eight modified pressure applicators, a

dynamic component, a head support, a base with attachments, and a fabric cover.

The 8 pressure applicators are arranged in a V-shaped alignment with 4 pressure applicators on either side. Each set of 4 aluminum applicators are positioned by a camshaft and an aluminum shaft which are both horizontally arranged and attached to supports. These supports also create part of the base. The camshaft supports the front region of the pressure applicator and the aluminum shaft supports the body of the pressure applicator. The modified pressure applicators are shaped with a hook on the frontal portion of the applicator allowing it to attach to the cams on the camshaft. The remainder of the applicator is supported by an aluminum shaft. The diagonal slot of the body of the pressure applicator contacts the aluminum shaft. This space allows the applicator to easily be detached or attached to the cam without removing any components from the device. The applicators move laterally on both the camshaft and aluminum shaft. Washers are inserted between cams on the cam shaft to secure both the pressure applicators and the cams. The pressure applicators are shaped with a protrusion between the hook attachment and body. This protrusion was drilled to hold a small threaded aluminum shaft that can screw or unscrew to adjust the height of the

pressure applicator. The head of this threaded shaft contains a ball and socket tip, which interfaces the user. A rubber head is attached to the ball and socket to provide greater comfort when using. Both cam shafts are connected to a stepper motor, which is programmed with Arduino microcontroller and circuit boards to rotate the cam shaft slowly at 10 RPM. The pressure applicators resting on the small cams will be raised and lowered at various heights as the camshaft rotates. This movement provides minor massage to the user similar to that of therapist. Two motors are used for each cam shaft to rotate both sides of the device contain the four pressure applicators. The motors will be housed in the base. The base is also used as attachments for the horizontal shafts and housing for the head support. The base also provides aluminum supports below the washers on the cam shaft to better support the weight of the user. The head support consists of memory foam which will be attached to the base of the device. Button snaps will attach the memory foam to the base at various locations. This will allow the user to adjust the memory foam where needed. A fabric cloth will fasten with snaps to cover the device for cleanliness and comfort to the user. This cloth can be removed, washed, and exchanged.

Final cost of suboccipital release device was \$313.21



Fig. 10.20. Suboccipital Release Device







# CHAPTER 11

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# BIONIC GLOVE FOR PERSONS WITH QUADAPLEGIA

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## INTRODUCTION

Our team created a Bionic Glove that will allow our sponsor, Keith Parsons, to work out with weights more easily and independently. Keith Parsons sustained a spinal cord injury resulting in an inability to perform gripping actions with his hands. Since he still has muscle control in the upper portions of his arms (biceps, triceps, shoulders, etc.) he is still able to enjoy the act of weightlifting; however, his limited gripping ability makes this activity difficult to perform independently.

Keith currently uses Action Life gloves, which use Velcro straps to fasten various pieces of weight-lifting equipment to his hands. The gloves are difficult for him to take on and off without assistance.

In our design, we added thumb loops to the Velcro straps to secure the glove to the user. Linear actuators were used to provide the mechanical action for opening and closing the glove (see Figure 11.1). Voice recognition hardware was installed allowing for operation of the glove via voice commands. The power supply and microcontroller were located on the forearm sleeve to evenly distribute weight.

## SUMMARY OF IMPACT

By making the modifications and adjustments to our Bionic Glove, the sponsor will be able to work out more easily and independently. He will be able to grasp a conventional dumbbell for strengthening exercises for his arm muscles. He will also have a reduced set up time for each upper body exercise he wishes to perform.

Dr. Everett Hills said the Bionic Glove design incorporates features of previous prototypes to create a unit that fits the user's hand, spreads the weight across the forearm to provide better balance, and uses voice recognition to control the duration of grasping

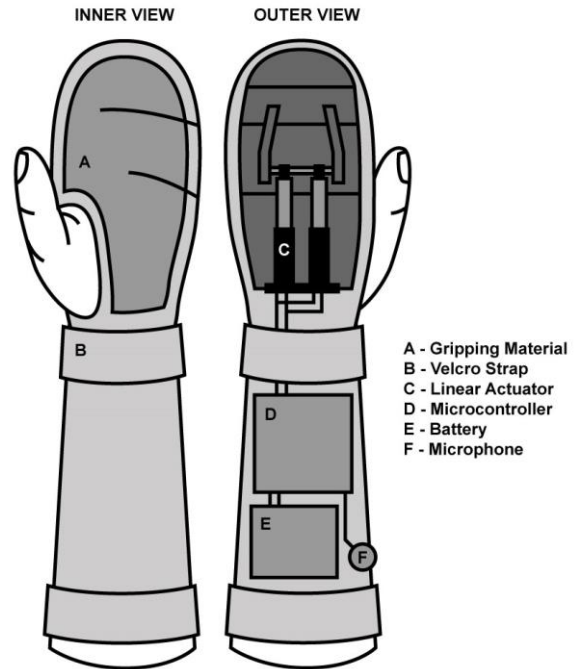


Fig. 11.1. Glove Diagram.

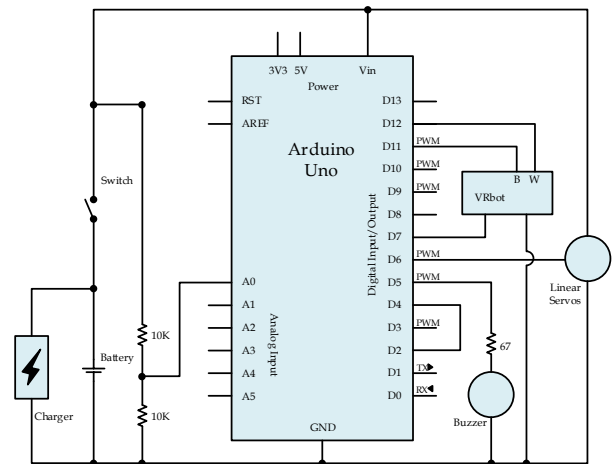


Fig. 11.2. Circuit Diagram.

an object. With this Bionic Glove, the user doesn't need to purchase special equipment for weightlifting; he can use traditional equipment in a gym.

## TECHNICAL DESCRIPTION

The bionic glove is constructed from a modified Action Life glove. The glove was altered to extend the glove to the forearm. This reduces the weight on the users hand by evenly distributing the components onto the sleeve. The main components are a battery pack, microphone, buzzer, microcontroller, linear servos, and gripping mechanism. The Arduino Uno microcontroller board controls the operation of the glove. A VRbot voice recognition module is connected to the board and receives voice commands through an external microphone. A 2.048k Hz Piezo buzzer is used to inform the user when a command is accepted or starting. Everything is powered by a rechargeable 7.4V lithium-ion battery pack that provides around 3 hours of operating use.

A gripping mechanism constructed of durable, lightweight metal is attached to the backhand side of the glove. Similarly to a mechanical claw, a hinge that simulates the pivoting of knuckles allows the glove to open and close the user's hand. Mounted to the back plate, two Firgelli L12 -R linear servos power the gripping force. The high 210:1 gear ratio provides a gripping force of around 100N and a back drive force of 300N.

Once the power switch of the glove is turned on, the glove waits and listens for a command. The main voice commands are "Glove", "Open", "Close", "Stop", and "Battery." The trigger word "Glove" is used to activate the glove. If successful, one quick beep will sound and then the glove will wait for a command. When the open and close commands are



Fig. 11.3. Bionic Glove Prototype.

issued, the servos are powered to retract or extend respectively releasing or tightening the grip. The stop command cancels the previous issued command. The battery command reports the life of the battery through a series of beeps. Three beeps represent fully charged, two beeps means halfway, and five quick beeps is when the battery should be charged before continued use.

# BIONIC GLOVE

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*Departments of Mechanical and Nuclear Engineering and Bioengineering*  
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## INTRODUCTION

Our team has created a glove capable of manipulating the wrists and fingers of an individual with paraplegia to grip both free weights and handles on common weight-lifting machines. The sponsor, Keith Parsons, has limited motor skills within his hands and wrists. Due to this, he is not able to completely close his hands and therefore cannot grasp objects.

As a team, our primary objective was to demonstrate the principles of effective design by inventing a new 'bionic glove' that our sponsor can use to lift weights and increase his upper body strength. Our goal was to create a simple glove enabling our sponsor to lift approximately 50 pounds. We will measure the simplicity of our design by how easily the sponsor can put the glove on and how he can use it. The effectiveness will be measured by how tightly the glove closes around a given weight and how independent the glove enables the sponsor to become.

## SUMMARY OF IMPACT

The Bionic Glove team's final design is known as the Wrist Reel Glove (WRG). The WRG allows the user the freedom and independence to enjoy activities requiring grip strength such as lifting weights and shooting pool. The concept uses a motor to wind the strap tight, securing the weight in place. The motor is activated by voice automation removing Mr. Parson's dependence on outside assistance. The WRG is powered by three rechargeable 9-volt batteries making for a readily available and inexpensive power source.

The foundation for our design is the reference glove provided by our sponsor. The reference glove is a simple, leather design with a Velcro strap used to close it. The wrist-reel design works in a similar

manner, except it strives to eliminate the inconvenience associated with closing and opening the glove by automating processes that were previously difficult or awkward for the user.

To open and close the glove, the user inserts his hand into the glove and tightens the wrist strap. Then the user gives a voice command picked up by the microphone located in the lower wrist of the glove. At the command, the glove will close and the switch will trigger the motor to begin winding the reel. As the reel winds, the hand naturally begins to close around the weight lifting bar. Left unrestricted, the motor will continue winding the reel until it reaches its locked position.

Once the user is finished and wishes to disengage the glove, the user simply flips a directional toggle switch. Once the microphone picks up the word "open", the voice activated switch triggers the reel to begin to unwind. The reel will continue to unwind until the hand reaches its original open position, unless interrupted by "shut the emergency stop toggle switch off".

Dr. Hills watched as the sponsor demonstrated the device. Both agreed the glove offered independence for its user. The sponsor, Keith Parsons, liked the efficiency of the rechargeable batteries. It had an initial expense, but was cost effective in the long run.

## TECHNICAL DESCRIPTION

In analyzing the final design and speaking with the sponsor about the long-term performance of previous designs, the team identified several areas of the design where analysis was warranted: the points where the voice relay and motor housing connect to the glove body, the strap reversal point, and the reel shaft itself.

For the voice relay and motor housing, a contoured aluminum plate was sewn with high-tensile Kevlar fiber to the leather base glove. The strap reversal point is simply a leather loop that is a component of the base glove. Both the Kevlar fiber and the leather strap were constantly observed as weight was increased to detect signs of fraying or wear.

The third component is the reel shaft itself. The team knows, from the product specifications, that the nylon strap that will wind itself around the reel is capable of supporting approximately a thousand pounds of force. From the design specifications of the glove, the largest weight that the sponsor requires the glove to hold is a 50 lbf weight. With the design of the strap, reel, and strap reversal point, the glove can be approximated as a one-pulley system with the weight attached to the pulley. For motor selection initially, we did a rough estimate of a maximum 25lb-in (3 N-m) holding torque is required when the weight is pulling on the string. That estimated number was then multiply the factor of safety to become our specification holding torque. The specified holding

torque was 175 lb.-in; that number doubles equal to 350 lb-in. After the specified holding torque was determined, we searched for a motor that has higher holding torque than we specified. We found one with holding torque 64.5 N-m (570 lb-in). Since the distance of travel was short, we needed a motor that has low rpm and small size with the holding torque required. We looked at adding a gearing stage to reduce the speed of the motor as well. However, such motor configuration has a large size. Also, since the voice activation relay runs on 24Vdc, we picked the motor to run on 24 VDC as well. This enabled us to eliminate a potentiometer that reduces the 24Vdc to the desired voltage. With one less component, the glove is much lighter and smaller.

Instead of picking a large rechargeable battery pack as our power supply, we decided to use 3 9V rechargeable batteries to save space, and it would be a lighter battery pack wrapped on the arm. Also, backup batteries will be available for replacement. A 9 volt battery charger will be provided in the product package when mass production takes place.

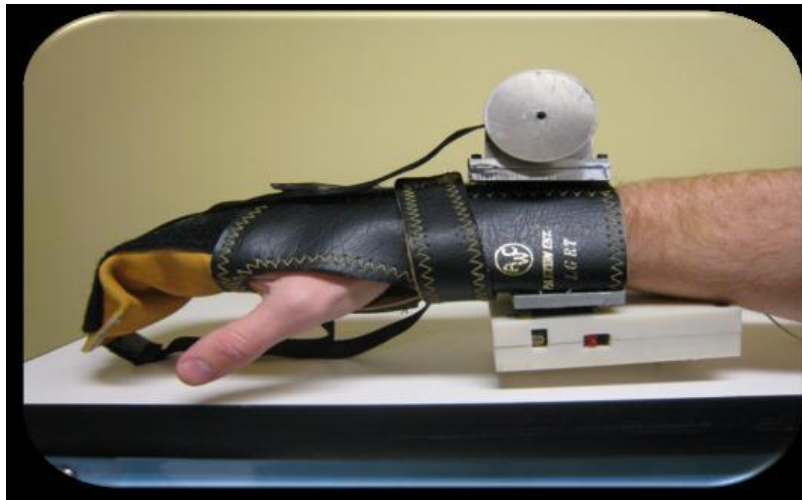


Fig. 11.4. Photo of final product.



# DESIGN OF A HANDCYCLE FOR CRAIG DIETZ

*Designers: Bello Galadanchi, Dave Friedman, Kristen McKee, Ashley Pachter, Murtaza Raza*

*Client Coordinator: Gretchen Kaag, IM ABLE Foundation*

*Supervising Professor:*

*Dr. Margaret Slattery*

*Department of Bioengineering  
The Pennsylvania State University  
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## INTRODUCTION

The IM ABLE team project is to design a safe, durable, operational cycle for a man with no hands and legs. Craig Deitz, a man from St Mary's, PA, was born with neither hands, nor legs but will stop at nothing to be physically fit. Craig would like to participate in the IM ABLE Got the Nerve 2011 triathlon race, however, without a cycle for a person with his disability, he can only participate in the swimming leg of the race.

For people with no upper or lower extremities, there are limited options to participate in sports. These people will either have to pay a large sum of money to have custom equipment made or just not exercise with a bike for their entire life. Our team will take the existing prototype and redesign it to accommodate the disabilities of Carl Deitz.

## SUMMARY OF IMPACT

This project has opened a new window of opportunity for Craig. As an active man, he strives to push all boundaries and engage in any type of strenuous activity of which he is capable. Developing a handcycle that Craig can operate, allows him to explore a new activity and to show others that disabled people do not have to constantly live with limitations.

Although the handcycle is specifically designed for Craig, there are many aspects of the project that could be implemented in cycles for others. For instance, the headrest brake design could be applied in handcycles meant for people living with many types of disabilities. Additionally, the propelling mechanism that is capable of converting vertical movement into rotational movement can be a universal design used in cycles for people with disabilities.

The team translated the customer requirements into a final design and was able to meet all of our project objectives. Our handcycle design uses Craig's most capable limbs for the two functions that require the

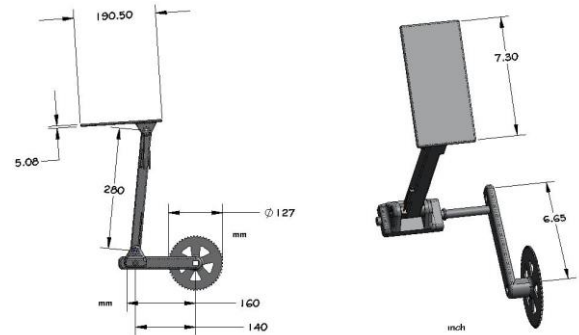


Fig. 11.5. Bionic Knee Design.

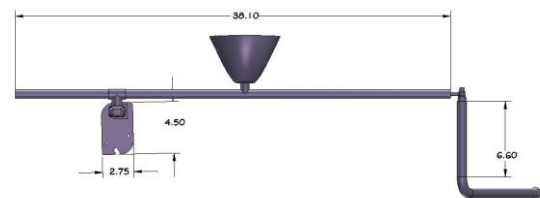


Fig. 11.6. Enhanced View of Steering.

most force, steering and propelling, and requires no limb usage for braking. The handcycle is durable with a dependable and accessible brake, controllable steering, and is both safe and comfortable.

## TECHNICAL DESCRIPTION

The recumbent seating included in our final design allows Craig's weight to be evenly distributed throughout the seat and Craig's center of gravity to be lower. This seating is much safer because it is lower to the ground than a traditional cycle.

Craig propels the bike with his strongest limb, his leg, by moving his leg in a linear motion and converting it to rotational motion using the bionic knee design (shown below in Figure 11.5). Because the cranks work in a circular motion, the springs need to push and pull the crank set over top dead center and bottom dead center of the circle. The forward push is

achieved from two torsional springs. (Torsional springs are small and strong, requiring only a small amount of deflection). The spring mechanism that pulls the pedal back during the transition from the downwards pedaling to upwards pedaling is a conventional, longer spring. The replicated knee is attached to a mold of Craig's leg.

The steering, (shown in Figure 11.6), is operated using his right arm limb. He inserts his limb into a prosthetic which is attached to a rod placed to the right of his seat. This rod is connected to the steering column.

Since both of Craig's most capable limbs are being used to propel and steer, it was best to use designs that do not require limb usage for both shifting and braking. For this reason, the team chose a headrest

braking mechanism where Craig leans his head back into the headrest in order to initiate braking.

It was initially thought that automatic shifting would be utilized in our final design. After working with the new trike, it was decided that automatic shifting was not suitable and an alternative design concept would have to be included in our final design. Therefore, the team chose to implement the other design concept generated for the shifting application. This design concept involves placing shifting levers on Craig's arm.

Also included for safety purposes, specifically to prevent tipping, support wheels were added. The total cost of parts and supplies is approximately \$825.00.



Fig. 11.7. Photo of Prototype.

# SELF PROPELLED WALKER

*Team Members: Prama Debnath, Kasha Kultys, Will Novak, Eric Soring*  
*Client Coordinators: Hershey Rehabilitation Center, Dr. Everett Hills, Dr. Sergio Chacin,*  
*Mrs. Nancy Ehrlich*  
*Supervising Professors: Dr. Mary Frecker and Dr. Maggie Slattery*  
*The Pennsylvania State University*  
*Departments of Mechanical and Nuclear Engineering and Bioengineering*  
*University Park, PA 16802*

## INTRODUCTION

The self-propelled walker was designed to aid patients with insufficient body strength. These patients would greatly benefit from a self-propelled walker to reduce the amount of energy required from the user. Many patients with neuromuscular conditions do not possess sufficient upper body strength to operate the current walkers available. The simultaneous action of grasping the walker and pushing it forward can prove to be burdensome.

## SUMMARY OF IMPACT

Dr. Hills and Dr. Chacin were extremely happy with the design and prototype of the self-propelling walker. Not only can the walker be a very useful device for someone with a neuromuscular condition, but it would also be very helpful for patients who are in a rehabilitation process and need a stepping stone between a wheel chair and a standard, non-powered walker. The device kept all features of a regular walker such as maneuverability, portability, and the ability to fold up and be placed in a small space. In addition, it proved to be strong enough that someone could transfer a significant amount of their body weight for balancing issues and still progress forward using the DC motor attached to the front shaft. The combination of these features will make life much easier for patients using the walker. The low amount of energy needed to use the device will allow a

patient to exert their energy in other ways throughout the day.

## TECHNICAL DESCRIPTION

The device consisted of modifications made from a walker already on the market, the Medline Rollator. All wheels, the breaking system and other attachments were removed from the Rollator, leaving a bare frame, from which the group used as their beginning design. A front shaft extended from the original two front legs housing the driving mechanism, an 18V DC motor. The motor was connected directly to an 8 inch "never flat" foam based wheel. Wires were run from the motor to the trigger device, which was mounted on the left handle of the device. Wires were then run from the trigger to the batteries, located underneath the folding seat. Omni directional wheels (not shown in Figure 11.8) for the two rear legs will be included in the final manufactured product. To prevent tipping when improperly used, two small caster wheels were added on the front of the walker. The beta prototype produced passed all tests to ensure safety and functionality and the group was able to stay within the \$1000 budget while meeting all of the customer needs. The total cost to produce the walker was around \$180.00, which will correspond to a market price of about \$750.00.



Fig. 11.8. CAD drawing and photo of final product.



# ASSISTIVE RIFLE TRIGGER PULL

Team Members: Leonard Weber, Eric Weidert, Ben Roscoe, Michael Thompson, Jim Vomero

Client Coordinator: Travis Oldhouser and Dr. Everett Hills

Penn State Hershey Physical Medicine & Rehabilitation

Supervising Professors: Dr. Mary Frecker and Dr. Margaret Slattery

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## INTRODUCTION

The Trigger Pull Assist Device (TPAD) was designed to provide trigger squeeze sensation to a rifleman with quadriplegia, in order to operate and discharge his firearms more independently. The device focuses on finger dexterity limitations associated with certain spinal cord injuries but which are essential in pulling the trigger of a rifle or pistol. Design criteria utilized for concept generation and selection were determined based on customer needs generated from the input of the project sponsor. The criteria include ease of use, traditional operation, steady operation, platform independence, device durability, weatherproofing and overall cost. The current products available require the user to blow or bite into a tubing placed in their mouth. Biting or blowing into the tube activates the device, setting the machine into motion causing a rapid trigger pull.

Our sponsor, who comes from a military background said, "That is not how you fire a gun." It was the intent of the design team to exceed the design criteria set by our sponsor and create a device that is novel allowing him to pull the trigger of his rifle. The loss of hand or finger dexterity complicates daily tasks, as well as, participation in many recreational activities. The TPAD (see Figure 11.11) was designed so the sponsor could participate in firing his guns and begin to participate in competitive shooting.

## SUMMARY OF IMPACT

Design criteria utilized for concept generation and selection were determined based on customer needs generated from the input of the project sponsor. The criteria include ease of use, traditional operation, steady operation, platform independence, device durability, weatherproofing and overall cost. The TPAD is an accurate and effective design permitting a traditional trigger pull sensation for a rifleman with quadriplegia. After testing the device, Dr. Everett Hills was impressed and thought the device would be

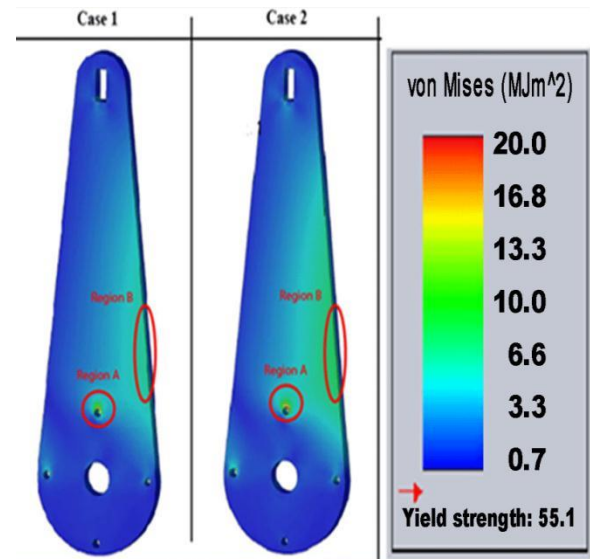


Fig. 11.9. Finite Element Analysis Model of the device arm.

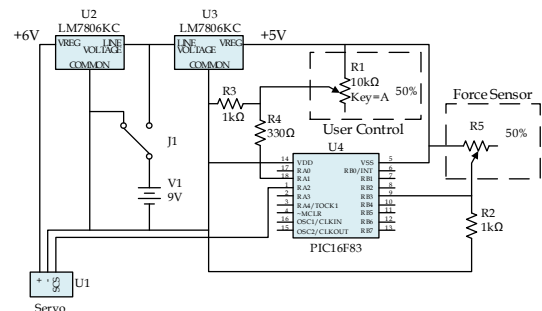


Fig. 11.10. Circuit Diagram of the microchip.

very useful. The TPAD met the objectives set by the sponsor and is in use by Travis Oldhouser.

## TECHNICAL DESCRIPTION

The most important elements of our final design include an RC Servo for torquing the lever arm, an aluminum lever arm to apply a backwards force to the finger strap, a Velcro finger strap to restrain the



operator's finger, and a Force Sensing Resistor (FSR) to actuate the device. Selecting these components required careful consideration of overall size, ability to inter-connect, and device compatibility. Figure 11.9 displays the groups Finite Element Analysis (FEA) of the device's arm. The analysis helped determine what material to use for the arm and how to design it. Figure 11.10 details the circuit diagram for a microchip - electronic board assembly the team constructed. The microchip - electronic board assembly was the heart of the device; it allowed the

device to have a pressure sensitive trigger pull. These components helped the device to successfully provide sufficient force to pull the trigger while minimizing overall size. Manufacturing the device was a five step process that required fabrication and assembly of the lever arm, leather strap, housing, housing mount, and electrical components and circuitry. The overall cost to create this device was \$809.81. We estimate the market value price to be \$100.00.



Fig. 11.11. Photo of final product.

# WII™ REMOTE FOR MAN WITH QUADRIPLEGIA

*Designers: Alice Cheng, John Dzikiy, Marisa Hicks, Madubuike Okafor James Peters*

*Client Coordinator- Dr. Everett Hills*

*Penn State Hershey Rehabilitation Center*

*Supervising Professor- Dr. Margaret Slattery*

*Department of Bioengineering*

*The Pennsylvania State University*

*University Park, PA 16801*

## INTRODUCTION

This project was to combine rehabilitation with enjoyment of the Wii™ system. The Wii™ is a system that uses an accelerometer to detect motion, which then transfers the motion data to the game. This project potentially promises to bridge the gap between self-rehabilitation and enjoyment. There are many articles on the prospect of “Wii-habilitation.” “Wii-habilitation” has been proven to show an increase in range of motion of the wrist, and possibly increase connectivity of neurons through repetitive motion. Applying the notion of “Wii-habilitation” to the broader scheme shows that it can be useful for many types of rehabilitation.

Mr. Bob Yorty is man with a C-6 injury resulting in quadriplegia who would like to use a Wii™ controller to play Wii™ video games for rehabilitation purposes. Mr. Yorty has wrist extension and elbow flexion, but does not have finger movement, elbow extension or wrist flexion. Therefore, he does not have enough control of his hands to grip or control the Wii remote. Mr. Yorty would like to use the Wii™ controller to play Wii™ Sports for rehabilitation and leisure purposes.

Adaptive Wii™ Remotes exist on the market but are expensive and less thrilling. A common device used by disabled patients, entails an intricate wiring system which includes a head set used to utilize their head movement abilities. The team believed this deprived Mr. Yorty of the excitement of the game, so we strived to create a more traditional remote that would include only the arm movements.

## SUMMARY OF IMPACT

We wished to optimize and customize the device making it patient specific while keeping both function and comfort within acceptable tolerances. During the development process, we analyzed and pushed the limits to Mr. Yorty’s range of motions to

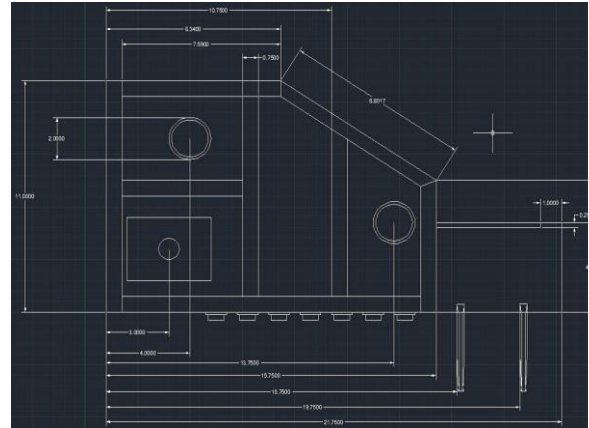


Fig. 11.12. CAD Drawing.

make the device as customized as possible. The device is a unique way to allow Mr. Yorty to integrate rehabilitation into home entertainment. According to Mr. Yorty, “when you see the potential benefit of what a Wii™ device has to offer, but only marketed to the “abled” not the “disabled” it’s a huge disappointment - both in physical activity, and, generally speaking, being left out.” Dr. Hills was questioned about “Wii-habilitation” and he replied, “Sometimes these rote physical tasks in traditional rehab can become so boring and take a long time for benefits to appear that the patient loses interest or enthusiasm for the rehabilitation program. This adaptive Wii device will allow the patient to perform therapeutic exercises that feel fun to pursue repetitively while enhancing the patient's physical skills and giving them an immediate sense of accomplishment.” Our project is a great way to overcome both of these obstacles. Mr. Yorty said he is looking forward to playing against his girlfriend’s daughter in boxing.

## TECHNICAL DESCRIPTION

Our team capitalized on the original Wii™ remotes virtual grounds. We mounted passively open buttons on a manufactured acrylic deck. All the ground wires

in the micro switches were soldered to the main ground in the Wii™ remote. Each passively open button on the deck was soldered to the positive terminal of the respective button on the Wii™ remotes circuit board. Our finally deck included all the buttons on an original remote. The geometry of the board was designed according to Mr. Yorty's anatomy and his wheelchair's specifications. The final design includes two C-clamp vise grips and a carrying strap that will enable Mr. Yorty to easily mount the board onto his wheelchair himself (These items are not shown in Figure 11.13). The device cost approximately \$425 to manufacture, but with mass production we would expect this device to drop below the current market products which range around \$350.

The team needed to determine how much force a human hand applies when dropped from a 45 degree angle relative to the elbow joint. The weight of an

average human hand is 1.25 pounds. The average length of a human forearm is nine inches. The height of the button is about one-third of an inch. The diameter of the A and B buttons is two inches. The height for the hand to drop onto button from a 45 degree elbow orientation was calculated to be approximately 6 inches. The pressure that would be applied to the button (weight of hand/area of button) was found to be approximately 0.4 psi. The actual pressure required to depress the buttons was the pressure applied by 400 grams of mass which is about equal to 0.27psi. From this analysis we have determined that an average person should be able to operate the buttons on the deck only using the weight of their hand.

The figure below shows the final versions of the "top view" of our device. Dimensions have been added to the CAD drawings to avoid any miscalculation in the manufacturing process.

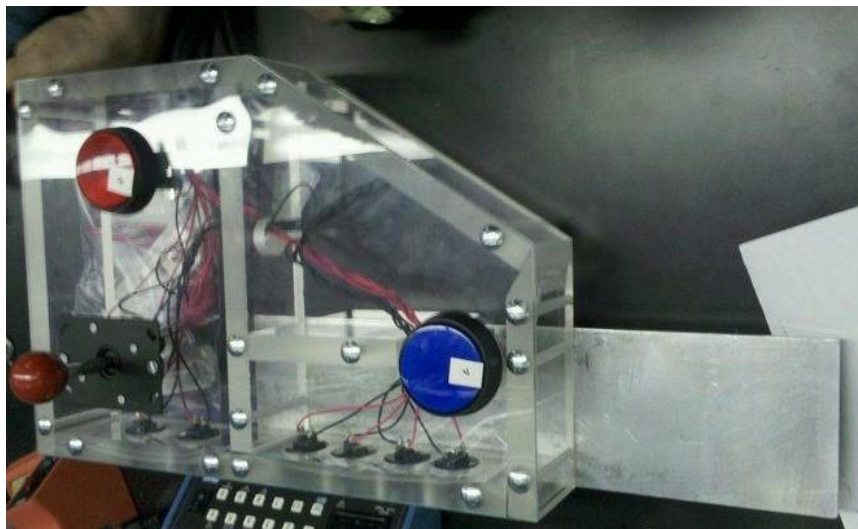


Fig. 11.13. Adaptive Wii™ Remote.



# CHAPTER 12

## ROCHESTER INSTITUTE OF TECHNOLOGY

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# NAVIGATION AID WITH TACTILE FEEDBACK

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*Mechanical Engineering Designers: Timothy Giguere (Project Manager, Tactile Interface Team), Robert Proietti, William Kelly*

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## INTRODUCTION

The Tactile Navigation Device will be a hands-free technology that can be used to navigate visually-impaired and blind people through high traffic areas where directions cannot be conveyed by voice commands, therefore, making tactile directions necessary to guide the user. Such a system will also be useful for people with Usher Syndrome, which results in both hearing and vision impairment. This device is being developed in stages; the first stage, now complete, involved the development of a tactile interface device (Figure 12.1) and a computer-based navigation system. The next step will be to integrate the two pieces into a single wearable system.

The system architecture for the tactile interface device is shown in Figure 12.2. It includes a keypad that enables a user to input a destination, a set of servo motors to indicate direction, a vibration motor to indicate proximity, and interfaces designed to work with the building navigation system and a bus locator system being developed as part of two separate projects (identified as P11016 and P11015, respectively). The device is capable of relaying instructions to go forward, back, left, and right. Those directions will be computed on the navigation side of the system and relayed through the microcontroller to the servo motor-driven pegs that provide the actual tactile feedback to the user.

The navigation side of the system is designed around a network of RFID (radio-frequency identification) tags and a tag reader carried by the user, along with a compass to identify the user's bearing. Based on identification of RFID tags visible to the tag reader, the user's current location can be identified and compared to his or her final destination, and directions can be computed. The second floor of the engineering building is being used as a test scenario,



Fig. 12.1. Tactile interface for navigation aid.

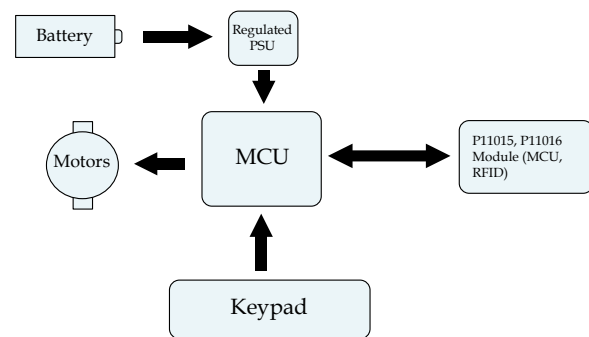


Fig. 12.2. Tactile interface device system architecture.

and the navigation team has defined this floor as a series of areas, each containing its own network of tags. The software uses Dijkstra's routing algorithm to determine the best sequence of areas to traverse to get from the user's current location to the final desired destination.

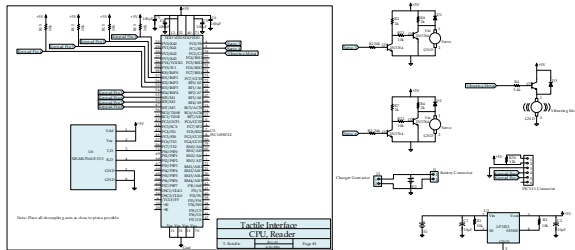


Fig. 12.3. Circuit schematic for microcontroller, keypad, and RFID tag reader; motor control; and power electronics.

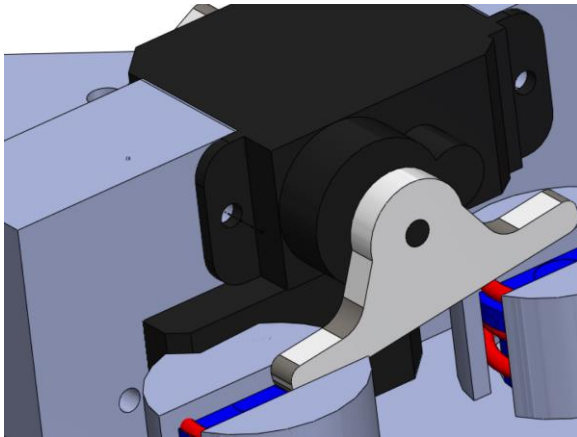


Fig. 12.4. Servo motor mechanism to provide tactile feedback. The motor arm (silver) rotates and engages one of two pegs (blue), depending on the direction of spin.

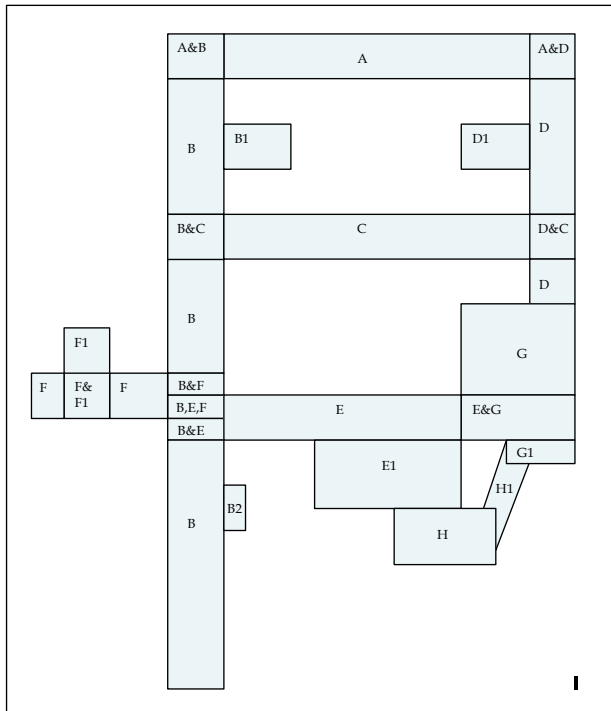


Fig. 12.5. Graph layout of the 2nd floor of the James E. Gleason Building.

## SUMMARY OF IMPACT

Since this system is in Phase 1, the full capability has not yet been demonstrated with the end users. The tactile interface device was tested with some volunteers, and they were able to correctly identify keys on the keypad to input information (98% success) and were able to correctly interpret directions from the device 94% of the time. The most significant impact of this project is that it has been selected to be used as a model multidisciplinary design project within the college and the next iteration will be run with multiple teams, each seeking the best solution.

## TECHNICAL DESCRIPTION

The tactile interface is driven by a PIC18F8722 microcontroller. It was chosen because it is capable of operating at the +5 Volts required for the navigation team's RFID tag reader, has enough pins to control the motors, can receive inputs from the keypad, is low cost, and can be programmed in C. The microcontroller software was developed using the PICDEM PIC18 explorer board, MPLAB IDE, and the C18 compiler. A 2"x2" PCB was designed to be housed within the tactile interface. The PCB contains the MCU, control circuitry, voltage regulator, and connection pins that interface with the keypad, motors, battery charger, battery, and PICKIT programmer. Circuit board schematics are shown in Figure 12.3. The device is powered by a 6V 2200mAh rechargeable NiMH battery pack, and the device is charged by plugging a wall charger into a charging port on the device. This eliminates the need to remove and replace batteries frequently.

In order to guide the user to his or her destination, two servos were used to push the pegs gently down onto the user's forearm in order to indicate direction. One of the servos pushes the pegs to indicate forward and backward, and the other pushes the pegs to indicate left and right (Figure 12.4). The servos respond to pulse-width modulation (PWM) signals, and move to different positions based on the duty cycle of the PWM received. There are six different PWM signals that could be sent to the servos: four correspond to forward, backward, left, and right, and the other two rotate the servos back into their neutral positions. The PWM signals correspond to the four different movements that are contained within the MCU memory space.

The servos are driven via a network of bipolar junction transistors (BJTs). These serve not only to amplify the relatively small current that the MCU is able to provide (around 10mA) to a level that is adequate to move the servo, but also to isolate the MCU from any back EMF that the servos produce. The high resistance seen from the base terminal of the BJT effectively buffers the sensitive pins of the MCU from any harmful electrical spikes that the servos emit. The BJTs themselves are protected from back EMF by a fly back diode connected from the collector to the upper supply. This sinks excess current in response to a voltage spike back into the power supply instead of the transistor. The PWM signals are sent out through an I/O pin on the MCU and into the base of a BJT through a 10k  $\Omega$  resistor resulting in an inverted PWM signal at the output of the first transistor. By chaining the output of the first transistor to the input of the second, the signal is inverted again, so that it is in phase with the original output coming from the MCU. Resistors were chosen so as to keep the BJTs in saturation. While in saturation mode, the transistor effectively acts as a switch. This reduces the power being dissipated through the transistor by lowering the voltage across the collector-emitter junction.

A vibrating motor is used to signal to the user that he or she has arrived at the destination. It is also used to give feedback to the user as certain buttons are pressed on the keypad. A single BJT is used to isolate the motor from the MCU which provides the control signal, and also to amplify the current to the proper levels. The base resistor was chosen so that the current flowing through the motor would cause it to vibrate at a level noticeable to the user without damaging the motor. Once again, a fly back diode was connected from the emitter terminal of the BJT (where the motor is connected) to the upper supply to prevent against damage caused by back EMF.

All of these components are housed in an enclosure manufactured in three parts. The base, shown in Figure 12.1, was rapid prototyped in RIT's Brinkman Lab, using ABS polymer. This was done to accommodate the complex geometry required to fit the user's forearm and support the various electrical and mechanical components. The housing walls were machined out of plastic and the cover of the case, holding the keypad, was machined from HDPE. The enclosure is designed to accommodate not only the input and tactile feedback mechanisms, but also

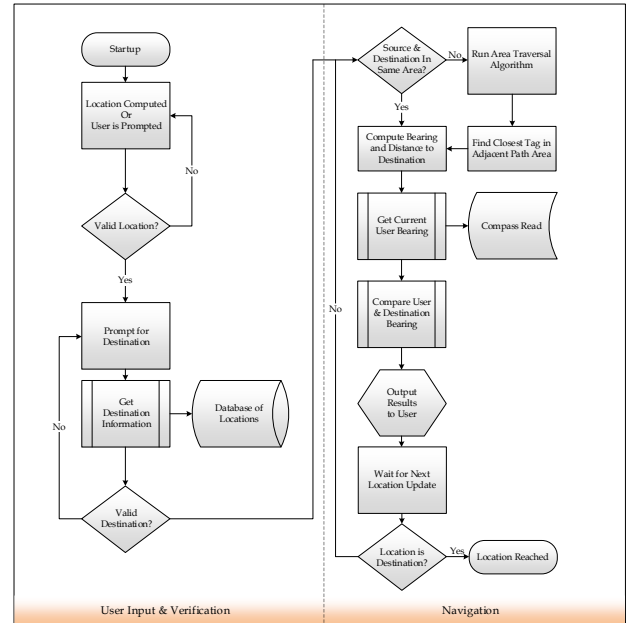


Fig. 12.6. Navigation software flowchart.

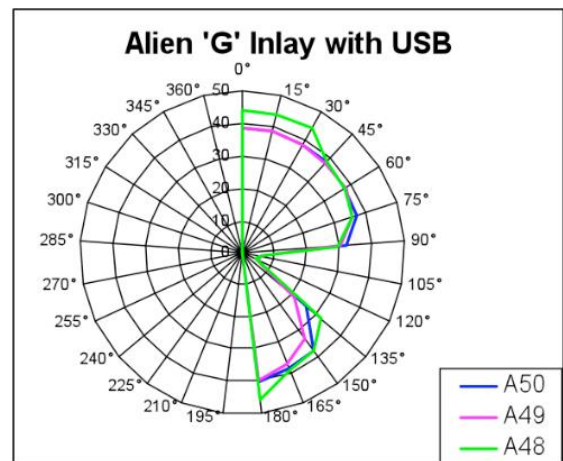


Fig. 12.7. Test results for the Alien "G" inlay tag. Measurements in inches.

the RFID tag reader that will be integrated in the next phase of the design.

The navigation software uses a two-level scheme. The top level is simulated by a graph, where each of the larger areas of a building are defined (Figure 12.5). These areas can be hallways, hallway intersections, stairwells, and large rooms such as conference areas. Within each of these large areas, locations are defined. Each tag ID corresponds to an x-position and y-position, the area containing the tag, and a brief description of the landmark the tag identifies. These two levels allow for a robust and expandable navigation algorithm. The algorithm itself uses

Dijkstra’s routing algorithm to define the path of areas that need to be traversed. Dijkstra’s is a greedy algorithm, which means the algorithm makes the optimal path choice at each stage. For instance if a point has 2 edges outwards with weights 4 and 10 the path with 4 will be traversed first. The path traversal using Dijkstra’s forms the logical operation that guides the user through the building’s highest level of organization. After the path of areas is computed, the algorithm will look for the closest location, which is a tag, in the adjacent area along the path. Computation of this bearing forms the method of traversal between the high level areas that Dijkstra’s search has returned. The program computes the bearing necessary between the 2 points. The program reads the current bearing that the user is showing from the compass, which with a comparison to the desired bearing, allows the direction of travel to be output in human terms. A flow chart for the navigation software is shown in Figure 12.6.

The navigation team chose to use passive RFID tags for location tagging, due to their lower cost and ease of maintenance. Active tags offer a wider read range, but they are considerably more expensive and would require periodic battery replacement. The tags selected, with 64-bit identifiers, were purchased from Alien Technologies. The team also selected the Skyetek Module M9 RFID reader and a low-profile antenna, which resulted in some sacrifice in antenna gain, but meant that device size could be kept smaller. Since the RFID tags were going to be placed in a variety of different environments, on a variety of different surfaces, extensive tag testing was done to determine the read range of the available tags. Based on the building landmarks being tagged, the team determined that they would need to test tags mounted on glass, metal, painted cinderblock, painted drywall, paper, wood, and plastic. Since the antenna will be placed on or around the user’s arm

Tag Type	Tag Label	Glass	brick	Metal	Plastic
ALN- 'G'	A6	39	36	2	28
	A7	41	81	2	31
	A8	36	95	3	49
	A9	52	90	2	39
	A10	46	90	2	46
ALN '2x2'	B1	x	6	x	42.5
	B2	x	7.5	x	39
	B3	x	7	x	36
	B4	x	4	x	34
	B5	x	4.5	x	42
ALN-Spot	C8	x	3	x	47
	C2	x	3	x	34
	C3	x	3	x	42
	C4	x	3	x	46
	C5	x	3	x	51

Fig. 12.8. Test results (in inches) for various tags with the reader held 1 foot above and below the plane of the tag.

when in use, the team determined that the tags should be placed at slightly higher than waist level on building landmarks for optimal readability. The team also determined that the speed at which the user walks by the tag has no effect on the read range. Representative test results are shown in Figure 12.8. There is an ongoing issue with tagging elevators, and the team was unable to determine whether the issue was the large amount of metal in and around the elevator or interference from electromagnetic brakes, but this is an issue that must be addressed in the next iteration of the project. Figure 12.9 shows the reader, antenna, and primary tags selected for use in this project based on the team’s testing.

The total cost of the project was approximately \$651.39 for the navigation unit, with an additional \$300 worth of RFID tags donated by the Alien Company, and \$428.31 for the tactile interface unit

More information is available at <http://edge.rit.edu/content/P11016/public/Home> and <http://edge.rit.edu/content/P11017/public/Home>



Fig. 12.9. Reader, antenna, and tags selected based on testing.



# CAMPUS BUS IDENTIFICATION

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*Computer Engineering Designers: Michael Delles, Irem Gultekin*

*Mechanical Engineering Designers: Mohamed Mandeel (Project Manager)*

*Client Coordinator: Franklin LeGree*

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## INTRODUCTION

The primary goal of this project was to design a portable device that assists visually impaired and blind people to select a desired bus and find the exact location of that bus at a bus stop, particularly when multiple buses are present at one time. These passengers typically have to get on the bus and ask the driver for the route number, and may need to exit the bus and board another, and repeat the process until the correct bus is boarded. This project will ultimately enable the end users to board their chosen buses with minimal outside assistance. Two bus stops are of particular interest in this project: Gleason Circle, a stop on the RIT campus where many buses often arrive at the same time, and a bus stop in the city of Rochester located at the Association for the Blind and Visually Impaired (ABVI)-Goodwill Industries, which employs a large number of people who are blind.

## SUMMARY OF IMPACT

Due to delays in setting up communication between RGRTA and campus, the system has not been fully implemented at this point, but the client coordinator is extremely interested in seeing the results of this project when it is continued next year. Further, a successful project will be useful to people without visual impairments, since it will enable anyone to receive a notification that their bus is about to arrive.

## TECHNICAL DESCRIPTION

The overall system architecture is outlined in Figure 12.11. The four key steps to that need to be completed are (1) identify user location, (2) identify bus location, (3) create navigation vector, and (4) user path correction. The user location is identified using an Radio Frequency Identification (RFID) tag placed at the bus stop. The user will be notified when he or she is within range of the tag, approximately 1-2 ft. This tag has a known GPS coordinate for each bus stop.

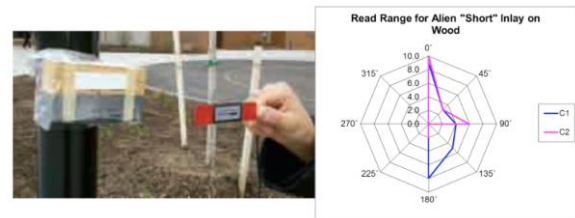


Fig. 12.10. RFID tag testing at Gleason Circle bus stop and sample test results.

The bus location is determined through access to the RGRTA GPS database, and the navigation vector is calculated based on the GPS coordinates of the bus and the user location.

To test the effect of attaching the RFID tags to metal bus stop poles, five different Alien RFID tag types ("G", "2x2", "Short", "Squiggle", and "Squiglette" inlay) were mounted to wood and plastic plaques, and these assemblies were then attached to the bus stop pole. Read range angles and distances were recorded. When mounted to a 1.5" thick piece of wood, the "G" and "Squiggle" tags were detected throughout the entire testing range of 0° to 180° at an average distance of one foot. Both of these tags were also consistently read at a 30° angle above and below the point parallel to the tag height. When mounted to a 1" thick piece of plastic, only the "G" tags were detected. Representative test results are shown in Figure 12.10. The final recommendation from the team was to mount the Alien G tag on wood at the bus stop.

The software to acquire information from RGRTA and calculate navigation vectors was written in C# and created in Microsoft Visual Studios 2010. The entire project consists of six classes: two threaded classes to gather data from RGRTA, named `timepointData.cs` and `Busdata.cs`; three object files to hold and organize this data, named `Bus.cs`,



TimePoint.cs, and GPSCoord.cs; and a main program to run the guidance algorithm, named vipbGuidance.cs. One of the complicating factors in this software is the fact that, on any given day, a single bus may be running a number of different routes. This means that the software needs to be able to link the mapping of different buses to their routes to the GPS information gathered by bus.

The first threaded file, timepointData.cs, gathers only the specific time point that each bus hits on the RIT route. The second, Busdata.cs, gathers the information of the regular GPS signal that each bus sends out at a rate of once per minute. This information is stored in two Dictionary objects, one that stores each Bus according to its route, which is determined by the time-points it hits, and another that stores the bus by its identification number with its most current GPS location. The Bus.cs object stores the ID number of the bus, the bus's last GPS location, the route it has been assigned to and the last time

point it hit. The TimePoint.cs object stores each time point as a String for its name and a GPSCoord of its location. The GPSCoord object is made up of two double precision numbers, for latitude and longitude. The vipbGuidance.cs class works by first prompting the user for a destination until a valid destination is entered. Then that route is searched for until the correct bus is identified. Once it has been identified it waits for the arrival of the bus to the user's timepoint. Once the bus arrives a new GPS signal is sent a minute after it arrives from which the Haversine Formula is used to compute a direction vector to guide the user. If the user deviates from the path a new vector is calculated. The program exits when the bus leaves the timepoint.

The total cost of the project was approximately \$408.91

More information is available at <http://edge.rit.edu/content/P11016/public/Home>

## Detailed Flowchart

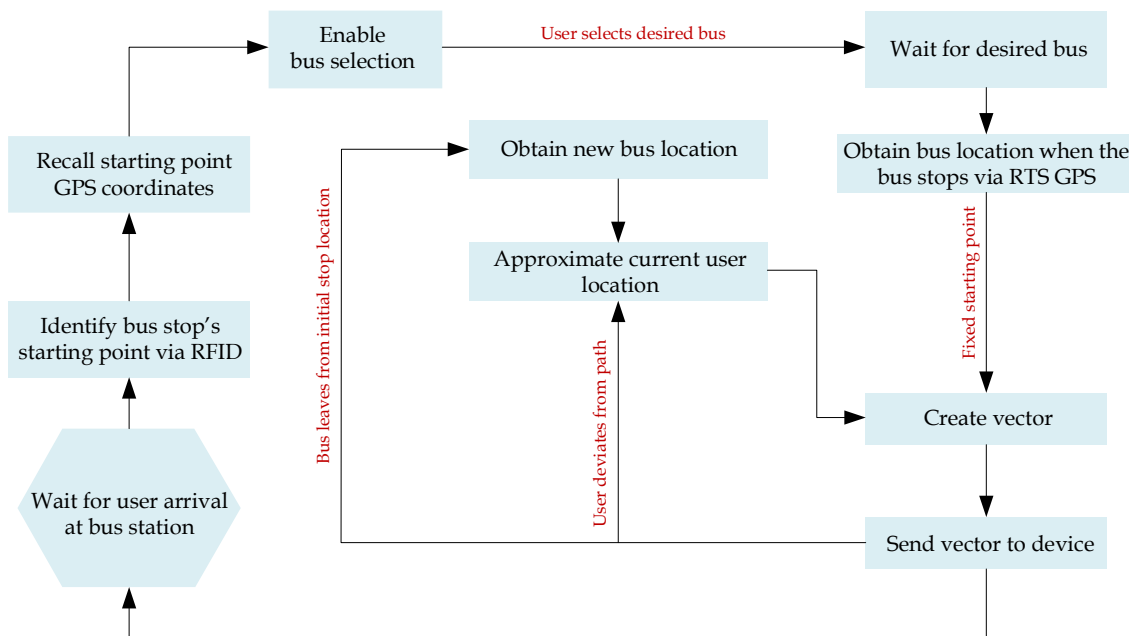


Fig. 12.11. Flow chart for bus identification system.

# BALANCE TRAINING BICYCLE

*Electrical Engineering Designer: Lawrence Grant*

*Industrial Engineering Designer: Wesley Seche*

*Mechanical Engineering Designers: Kyle Benesh (Project Manager), Marc Sciarrino*

*Client Coordinator: J.J. Mowder-Tinney, Ph.D., PT*

*Supervising Professor: Dr. Elizabeth DeBartolo*

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## INTRODUCTION

The Physical Therapy clinic at Nazareth College engages a variety of clients in need of balance training, and looking for a challenge. The balance training bicycle introduces some controlled instability similar to that experienced on a freestanding bicycle without the risks associated with actual bike riding. Clinic clients in need of balance training are those who have had strokes, or those who have other neurological conditions that cause an imbalance in strength between the left and right sides of their bodies. This device is a refinement of a prior senior design project, with specific goals of achieving a more realistic pedaling “feel”, better control over the bike’s tilt, and an improved user interface.

## SUMMARY OF IMPACT

The redesigned system is shown in Figure 12.12. The therapist noted that the pedal mechanism provides a much improved feel, and that the tilt resistance is much more consistent and easy to adjust. The team was able to accomplish this while retaining the positive features from the prior iteration, namely the seat, handlebars, frame, and ability to lock the bicycle in an upright position.

## TECHNICAL DESCRIPTION

The design was broken into three subsystems: 1) frame and pedal resistance, 2) tilt mechanism, and 3) display/feedback. The team was tasked with improving the pedal resistance and tilt mechanism without significantly redesigning the frame, seat, handlebars, and upright-and-locked position mechanism, and they chose to incorporate commercial off-the-shelf components for the pedals and the tilt mechanism.

The new pedal mechanism relies on magnetic braking to provide pedal resistance, which gives a much smoother and more realistic feel than the prior



Fig. 12.12. Balance Training Bicycle.

friction-resistance pedal system. The pedal mechanism is a magnetic eddy-current-brake pedal exerciser, similar to those in commercial exercise bicycles, which works by taking the rider’s rotational force input and using it to spin a large ferromagnetic disk between two opposite polarity magnets. This creates swirling currents of electricity in the disk around the areas crossing the magnetic flux, in the direction opposite of the pedaling motion. This creates a velocity dependent resistance against the rider’s input and avoids the stick-skip issues previously experienced with the prior friction braking mechanism. A portion of the frame was removed to make room for the pedal mechanism, and stress and fatigue analysis done to the modified frame indicated that the new static factor of safety is approximately 6 and the new factor of safety on infinite fatigue life is 5.4.

The prior balance bike design relied on a collection of elastic Therabands to provide tilt resistance. While this concept was appealing to the clinicians because of its simplicity, the Therabands proved to be difficult to attach and remove. The new design relies on a commercially available bicycle shock absorber, which contains a spring and damper acting in parallel. The shock absorber has a nominal spring constant of 350 lb./in and a damping coefficient of approximately 500 N-sec/m. Figure 12.13 shows the prior and current tilt resistance designs. The tilt resistance mechanism functions by using a pair of the bicycle shock absorbers, along with a pair of fabricated "sliders" consisting of a male and female part that slide together concentrically. These two pairs of components are linearly connected to each side of the bike to affect tilt resistance in both directions. The sliders act as a release when the bike tilts in the opposite direction of a given shock. This way, the shock is not placed in tension and the bike is allowed to tilt in either direction without interference. Analysis done on the tilt mechanism showed that, with a 300lb client on the bike at full tilt of 10°, a therapist guarding the client would need to apply a force of 38lb to bring the rider back up to a vertical position, ensuring safety for both the client and the therapist. Tests with a 200 lb. user showed that a rider allowed to tilt to one side would not fall quickly, but would take slightly more than 1 sec to fall up to 10°. Additionally, stress analysis on the brackets added to support the shock absorber indicates a static

factor of safety of 1.56 and a factor of safety on infinite fatigue life of 1.32.

The display mechanism is based on an Arduino Mega 2560 microcontroller. This microcontroller will be in charge of operating all of the relevant displays, using inputs from an inclinometer to sense tilt and multiple switches. The signal from the inclinometer will be run directly into the microcontroller for processing. An array of LEDs will be used to relate to the rider the current angle of tilt. The LED will be "selected" to be lit using a four bit control signal from the microcontroller which will run into a demultiplexer. A pair of seven segment displays serve to tell the rider how many times they have "fallen" (i.e., hit the maximum tilt angle set) to the left and to the right. Every time they reach the max angle for their riding settings the counter will increment. These can be reset to zero on powering off or by pressing the reset button. The buzzers will sound every time that the rider reaches maximum angle to add an audio feedback to their 'fall'. The volume for these buzzers will be controllable using the potentiometer. There is a power switch and a mode switch to allow the user to select the maximum angle setting (either 5 or 10 degrees).

The total cost of the project was approximately \$770.23

More information is available at <http://edge.rit.edu/content/P11001/public/Home>



Fig. 12.13. Left: old tilt resistance mechanism. Right: new tilt resistance mechanism.

# ALERT NOTIFICATION DEVICE

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*Electrical Engineering Designers: Stephen Berus, Athena Turner*  
*Client Coordinator: Prof. Gary Behm, National Technical Institute for the Deaf*  
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## INTRODUCTION

A missed alert for a deaf or hard of hearing person can have serious consequences. Even if the event is not life-threatening (such as a fire alarm), missing vital information can negatively affect the quality of life for deaf and hard of hearing people, as it restricts their independence. Most home and hotel alert systems are audible, thus neither convenient nor practical for these people. Products with non-audible functions exist on the market, but are cumbersome for travel or may require permanent installation. This project aims to create a portable device that combines visual and tactile cues that an alert is present, with a nominal usage scenario of an alarm clock to wake a sleeping person.

## SUMMARY OF IMPACT

The final device functions as an alarm clock that can be set from a computer and then operates independent of the computer to wake the user. It fits in the palm of the user's hand and uses high power LEDs on either side of the box as well as a bed shaker to provide both visual and tactile alerts. The finished device is shown in Figure 12.17 mounted on a tripod to elevate it.

## TECHNICAL DESCRIPTION

Work on this design project was broken into three parts: driver electronics, software, and housing. The driver electronics (Figure 12.14) consist of controls for the external bed shaker, controls for the LED array, and power regulation. The 12 LEDs were arranged as shown in Figure 12.14 with 6 parallel pairs of 2 LEDs in series, in order to reduce heat through power dissipation ( $384 \mu\text{W}$  v.  $768 \mu\text{W}$  for 12 LEDs in parallel). The bed shaker was protected by a diode and the Toothpick 2.1 Bluetooth Transceiver, used to communicate with a PC, was protected by a fuse. The final PCB layout is shown in Figure 12.15.

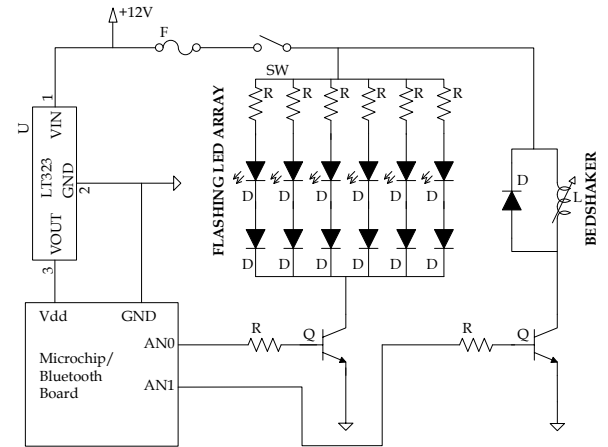


Fig.12.14. Circuit Diagram.

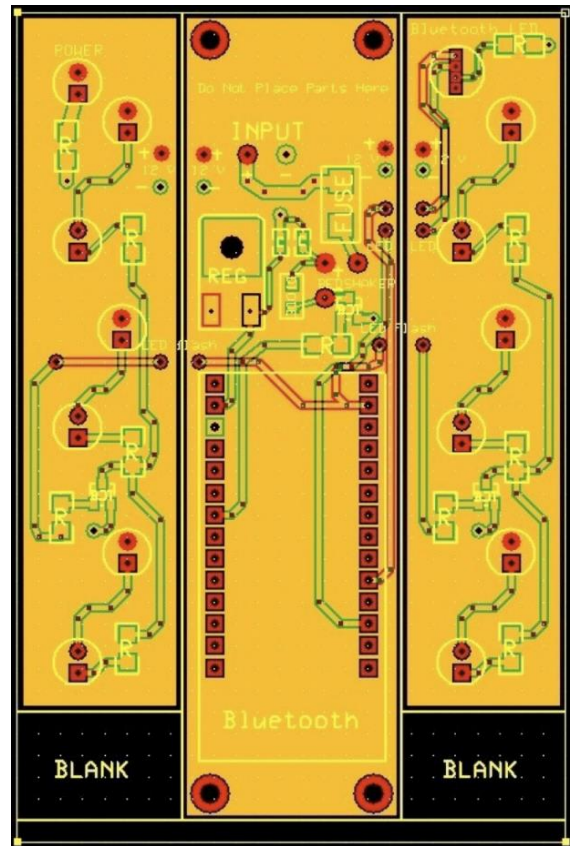


Fig. 12.15. PCB Layout



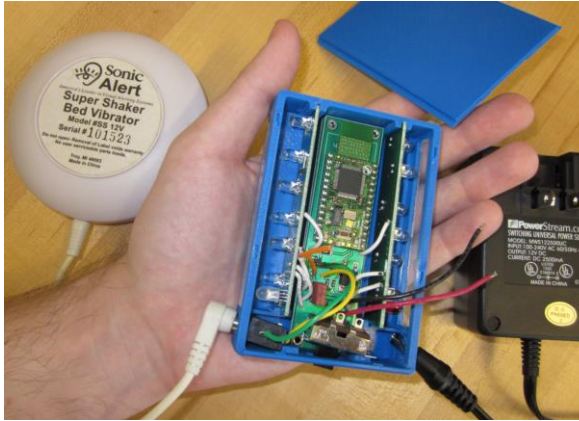


Fig. 12.16. View of inner workings of device, including bed shaker and power adapter ports.



Fig. 12.17. Alert notification device, mounted on tripod without power cord and bed shaker.

The software was designed using MPLAB IDE and FlexiPanel Designer, which came with the Bluetooth

development kit. FlexiPanel allowed for development of an application that runs on a PC and communicates with a Bluetooth device like the alert system created for this project. The final software allows the user to set the alarm time on a PC, and cancel or snooze an alarm sequence on the portable device.

The enclosure, shown disassembled in Figure 12.16, was created using a 3-D printing system, which allowed for a custom case design with viewing panels for the LEDs, built-in ports, and PCB supports for the three-part board. The enclosure passed compression testing (341 lb.), drop and shock testing (330 g with functioning electronics, although the enclosure cracked), and vibration testing (standard shipping truck vibration profile for 15 minutes). Additionally, the enclosure and the regulator and BJT on the PCB were all instrumented with thermocouples to monitor operating temperatures. The team found that the external surface of the enclosure never exceeded 88 °F during operation, which is safe for all users. Internally, the regulator reached a maximum of 145 °F and the BJT reached 118 °F during alarm activation, but both temperatures decreased rapidly in snooze or off mode.

The next step for this project will be to attempt to build a Bluetooth RF transceiver in-house and investigate rechargeable batteries and more scalable methods of producing the enclosure. These steps will lead to this device becoming available to the deaf and hard of hearing community at RIT.

Total cost was approximately \$690.69

More information is available at <https://edge.rit.edu/content/P11201/public/Home>



# STRAW CUTTING PROCESS IMPROVEMENT

*Industrial Engineering Designer: Matthew Estock (Project Manager)*  
*Mechanical Engineering Designers: Ian Balbresky, Tyler Banta, Mark Vaughn*  
*Client Coordinator: Wayne Geith*  
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## INTRODUCTION

The primary goal of the ArcWorks Straw Cutting Device project was to design, build, and deliver a functional straw cutting device to ArcWorks which will be able to cut multiple polypropylene copolymer (PPCO) straws to desired lengths with minimal deformation and burring. The device will have to follow ISO 9001 guidelines, along with complying with OSHA standards and being accessible to employees with a wide range of developmental disabilities. These straws are used within an assembly process at the ArcWorks facility which provides wash bottle assemblies for customers like Thermo Fisher and Nalgene. The current process at ArcWorks utilizes one automated machine along with a manual process to cut the raw material straws to the appropriate lengths. With the addition of our automated machine an increase in overall productivity at ArcWorks within their wash bottle assembly process will be seen; the increased productivity will benefit workers who are paid by the

piece, and will also allow ArcWorks to reduce inventory levels.

## SUMMARY OF IMPACT

The current device (shown in Figure 12.21) is able to safely cut 12 straws at a time, and is capable of cutting 1400 straws/hr., compared with the existing device's 700 straws/hr. capability, meaning that employees can increase their production and ArcWorks can reduce their safety stock. Unfortunately, the quality level of the cuts is not up to the standards set by ArcWorks.

## TECHNICAL DESCRIPTION

The new device is a pneumatically-driven machine that cuts 12 straws at a time, safely and with minimal physical exertion, and removes the debris from the cutting area. The straw cut is completed using a single blade with a double bevel that is angled at 45° to the direction of motion (as shown in Figure 12.18). The straw pattern was laid out to maximize blade

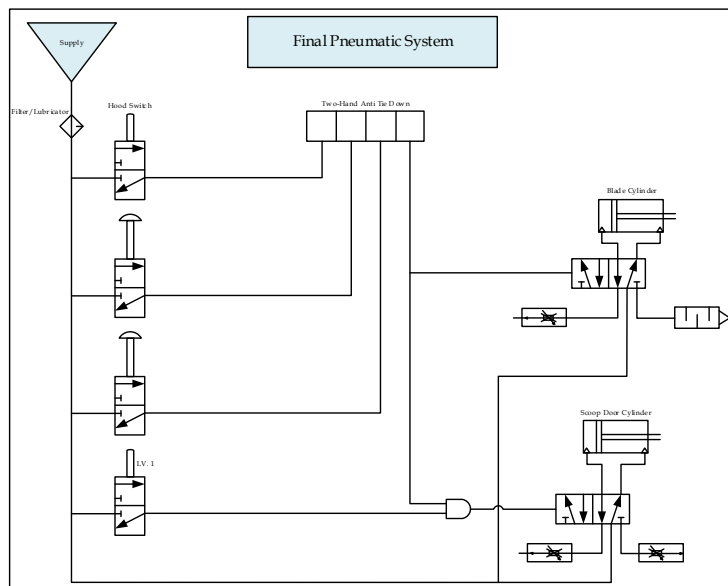


Fig. 12.18. Pneumatic system schematic.

utilization and to ensure that only one new cut is initiated at a time. The blade is mounted on a blade carriage system that is driven by a 300 lb cylinder with a 3 in stroke. The cylinder operates on a 100 psi compressed air supply, already available in the ArcWorks facility. The cylinder is triggered with a two hand anti-tie down switch, and a mechanical switch only allows actuation when the lid is closed. The pneumatic system design is shown in Figure 12.18. The cut quality does not currently meet ArcWorks's requirements, possibly due to the double bevel on the new cutting blade. The blade cuts through approximately half of the straw satisfactorily, but beyond that point, the straw bends and the remainder of the cut has the appearance of a tear, rather than a clean cut (Figure 12.19). The team has developed recommendations, including applying light pressure to hold the straw in place and prevent bending, and using a different blade; these will be investigated before delivering the machine to ArcWorks.

The device was required to be capable of cutting 9 different straw lengths, so an adjustable trap door mechanism was designed to support the straws during cutting. The height of the trap door can be changed to any of the 9 required length settings, and after a cut is complete, a 12 lb. pneumatic cylinder, with a 1 inch stroke, opens the door and allows the



Fig. 12.19. High-speed image of straw cut.



Fig. 12.20. Straw cutter support block.

cut straws to fall down for removal. The trap door does not currently function as designed, so a backup block (Figure 12.20) was created to support the straws until further work on the device can be completed. The block does not allow the 9-length adjustability, but does allow the machine to function.

The total cost of the project was \$1541.63

More information is available at <https://edge.rit.edu/content/P11008/public/Home>



Fig. 12.21. Straw cutter design. Clockwise from top right: blade carriage, trap door/height adjustment, vacuum attachment, and cutting plate.

# HANDS-FREE WIRELESS PRESENTATION REMOTE

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Electrical Engineering Designers: Steven Fleischmann, Evan McNamara  
Client Coordinator/Customer: Gary Behm, National Technical Institute for the Deaf  
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## INTRODUCTION

The goal of this project was to design and build a device that would allow presenters using American Sign Language (ASL) to have wireless presentation control without the need to carry around a remote device. Since ASL requires the use of both hands, the act of advancing or reversing slides interferes with the flow of the presentation and can become distracting if the remote is not easily accessible.

## SUMMARY OF IMPACT

The team was able to circulate their device for use by 15 ASL users over a 10-day period, each of whom submitted a survey sheet when they returned the device. Users were given the device itself, which has a form factor that approximates a very large wristwatch, the USB dongle for communication with the computer, and spare batteries (Figure 12.23). The highlights of the device based on user feedback were its Functionality (8.5/10), Fit (7.9/10), and Overall Satisfaction (7.2/10). In addition, users indicated that they would be willing to pay an average of \$25 for the device. Since the current device relies on a board that was not custom made for the system, but was modified from an existing wireless remote, the form factor of the device is fairly large and the evaluators gave lower scores for Aesthetics (5.6/10). However, the Client Coordinator noted that at the inauguration of the new President of the National Technical Institute for the Deaf at RIT, the incoming President misplaced his presentation remote and had to stop his talk to find it - if only he had had one of these devices, which would not have happened!

## TECHNICAL DESCRIPTION

After analyzing many different Power Point slide remotes, the team found that a pen-sized remote provided a significantly smaller board, simple

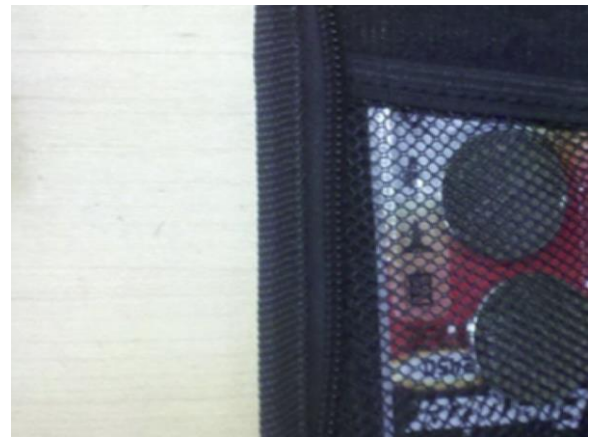


Fig. 12.22. Hands-free wireless presentation remote.



Fig. 12.23. Fully assembled device being worn.

functionality, and met general size and range requirements. The team decided to modify this board after some initial analysis of its functionality. The board used a single 1.5V AAA size battery, accompanied with an initial boosting circuit which

raised the voltage to 5V. This 5V supplied power to the on-board micro-controller which set idle and sleep times for the transmit chip. After a single button press, which constituted the 'active/transmit' mode, the chip would idle after 0.5 seconds and reduce its current draw from approximately 60 mA during active/transmit, to 4.5mA during its idle state. The idle state would continue searching for a signal for 20 seconds, at which point it entered a 'sleep' mode if no other button activation occurred. While in this sleep mode, the circuit drew only 200uA. This fact led us to believe that our battery life spec would be met due to having a non-constant draw from the most power-hungry portion of the device. In addition, the AAA battery was replaced with a 3V CR2450. This battery is readily available for purchase at common retailers, and the specifications of the CR2450 allow for a significantly longer battery life than the standard AAA.

Portions of the board were removed to reduce the footprint and allow for the smallest possible housing.

The battery contacts were removed and replaced with a CR2450 holder, and the surface-mount buttons on the board were removed and replaced with wires to allow new buttons to be attached in the desired locations. Figure 12.24 shows the board as it sits inside the device with the leads for the offset buttons. Since the enclosure severely attenuated the wireless signal, a new antenna was created and built into the system. The required antenna length was 2", so the antenna was coiled around the circumference of the case to maintain a small device size (Figure 12.24).

Finally, the team estimated the cost to make multiple devices and determined that a batch of 1000 devices, made with injection-molded cases from a rapid-prototyped mold, could be made for a cost of approximately \$15.24 per piece, without labor.

The total cost of the project was \$225.07

More information is available at <https://edge.rit.edu/content/P11032/public/Home>

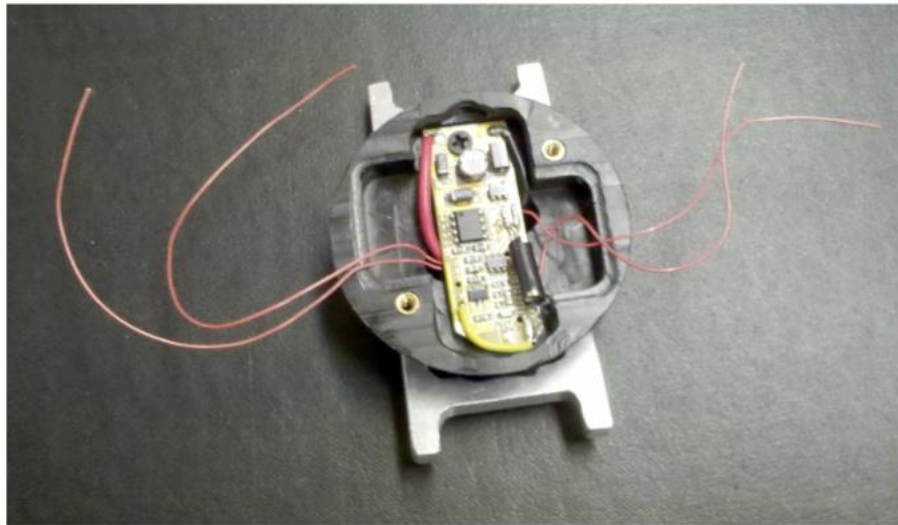


Fig. 12.24. Modified PCB placed in case, with leads for buttons shown.



# MOTION TRACKING SYSTEM FOR REHABILITATION

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*Industrial Engineering Designer: Maya Ramaswamy (Project Manager, Sensor Team)*

*Mechanical Engineering Designers: Evan Brent (Project Manager, Base Unit Team), Andrei Stihl*

*Client Coordinator: J.J. Mowder-Tinney, Ph.D., PT and Richard Barbano, MD, Ph.D.*

*Supervising Professors: Dr. Dan Phillips and Dr. Elizabeth DeBartolo*

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## INTRODUCTION

Two local clinics, one an outpatient physical therapy clinic and the other a neurology clinic, have a need for tracking human motion. Both clinics need a quantifiable way to measure the angle in space between two rigid links: either knee flexion during walking or head tilt relative to the torso. The physical therapy clinic works with many individuals who have had strokes and who would like to have a measure of their progress in returning to a normal gait pattern, and the neurology clinic treats people with cervical dystonia.

## SUMMARY OF IMPACT

Both customers were pleased with the device that was developed and were eager to use it in their clinics. The as-built system (Figure 12.25) can measure tilt (pitch and roll) to  $\pm 80^\circ$  and rotation (yaw) to  $\pm 180^\circ$ . Pitch, roll, and yaw can be measured to, respectively,  $5^\circ$ ,  $10^\circ$ , and  $8^\circ$  accuracy and  $2^\circ$ ,  $6^\circ$ , and  $2^\circ$  precision. The device can be put on quickly (less than 30 seconds), removed quickly (3 seconds), and sanitized between users, and is comfortable for users to wear. The sensors connect to a wearable base unit (Figure 12.26).

## TECHNICAL DESCRIPTION

This device was separated into two sub-projects: a sensor unit and a wearable base unit. The sensor unit is comprised of a pair of Razor 9 degree-of-freedom inertial motion sensor units (9DOF IMU), each packaged in its own protective enclosure and capable of being attached to either a leg strap for collecting knee flexion angles or a head strap for collecting head tilt angles. The 9 degrees of freedom that the sensor can measure are achieved with a 3-axis accelerometer, a 3-axis gyroscope, and a 3-axis



Fig. 12.25. As-built system being used to measure (left) knee flexion and (right) head tilt.



Fig. 12.26. Wearable, programmable base unit. Shown being used to capture knee flexion angles.

magnetometer. Each 9DOF IMU is coupled with a 3.3V FTDI breakout board for USB communication with the base unit, and one IMU is equipped with a



button to reset or zero out the sensors (Figures 12.29 and 12.30).

The sensors function differently depending on whether they are in head-tilt or knee-flexion mode. In knee-flexion mode, only one angle is required, assumed to be in the plane of motion of the direction of walking. The accelerometers on the 9DOF IMU are essentially used as a set of inclinometers, measuring angles of the upper and lower legs in space and finding the in-plane difference between the two. The lower leg schematic is shown in Figure 12.28 and the upper leg is similar. The angle  $\theta$  is calculated by the  $\arctan(-a_x/a_y)$ . For head-tilt, the 9DOF IMU is used as a pitch-roll-yaw sensor, and the magnetometers are employed in addition to the accelerometers. Since the magnetometers are very sensitive to the presence of ferrous metals, the system uses only brass fasteners.

The sensors interface with the base unit using a USB protocol, which enables vast communication, good signal integrity over the range of interest (approximately 3 ft.), minimal power consumption, and ease of implementation. A messaging protocol was developed to allow the sensors and base unit to communicate and identify themselves. The base unit is primarily comprised of a Beagle Board and Beagle Touch screen, along with a rechargeable NiMH battery pack inside an aluminum enclosure. The base unit is programmed in C. It performs a 10-number average of the sensor data and performs all necessary calculations. It also includes a graphical user interface that allows the user to select which mode (knee flexion or head tilt) to use and stores data in a comma-delimited format for export to Microsoft Excel (Figure 12.27).

The total cost of the project was \$675 for the base unit and \$735.76 for the sensor unit.

More information is available at <https://edge.rit.edu/content/P11011/public/Home>

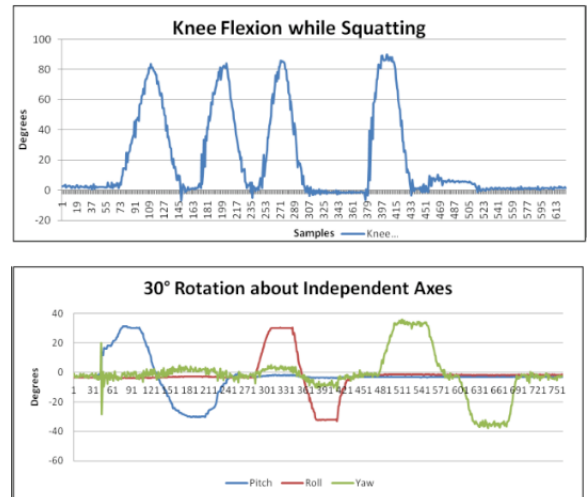


Fig. 12.27. Sample data collected using the human motion tracking system

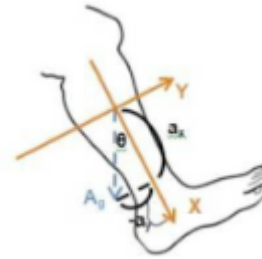


Fig. 12.28. Illustration showing the values used to calculate angle of the lower leg.



Fig. 12.29. Front and back of sensor unit with reset button, showing snaps to attach to knee or head straps.

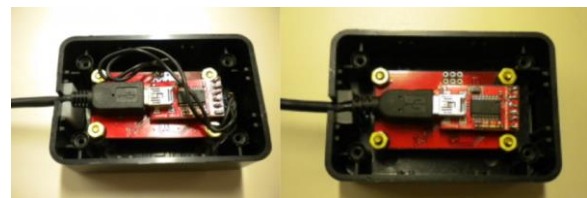


Fig. 12.30. Sensor units without reset button (left) and with reset button (right).



# CHAPTER 13

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# ASSISTIVE DRUMMING DEVICE FOR MUSIC THERAPY

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## INTRODUCTION

Currently, over 10,000 infants are diagnosed with cerebral palsy in the United States each year. This condition affects the motor control region of the brain which can impair a person's fine and gross motor abilities. Musical therapy has been shown to improve motor skills and even alleviate some of the pain associated with cerebral palsy. An assistive device was developed to help individuals with compromised motor abilities play the drums independently using a simple hand-driven interface which causes a motor-driven mallet to strike a drum (see Figure 13.1). This assistive drumming device will enable users to play the drums in a safe and independent manner without restricting them to certain skill-dependent instruments. Some existing commercial solutions use mechanical switches to trigger drums sticks to tap a percussion instrument. The problem with the commercial solutions is that they are not easy for users with limited strength since they require a high level of force to activate the switches.

## SUMMARY OF IMPACT

The Assistive Drumming Device allows students with physical disabilities to participate fully in music therapy sessions. Students who previously found it difficult to play the drums can now use the device to effectively play and accompany the therapist during music therapy. Previously, the students performed a vertical striking motion with their hands to play the drums which was uncomfortable and resulted in fatigue early in the therapy session. Implementation of the new technology allows the students to use horizontal hand motions, which are easier and less tiring. As a result, students receive the maximum therapeutic benefits from these sessions.

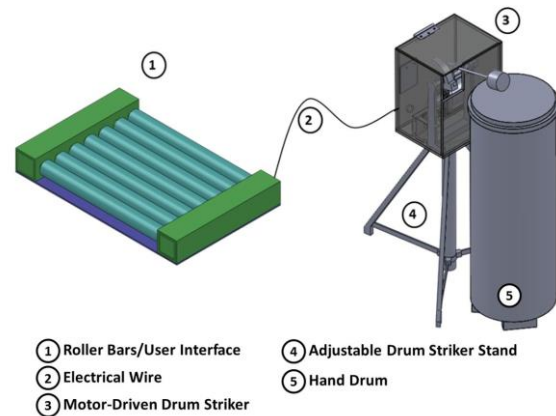


Fig. 13.1. Overview of Assistive Drumming Device: The user interfaces with the roller bars [1] using their hands which send a signal to the drum striker [3] to hit the drum [5] and create a sound.

## TECHNICAL DESCRIPTION

The design encompasses two primary systems that function together to meet the needs of the client. A trigger and a striker component interface with one another to meet the needs of the client as a final design solution. In essence, the trigger device will provide a means for the user to control the striking of the drum which is carried out by the striker device. In order for the trigger device to communicate with the striker device, instrumentation was implemented to electrically connect both devices. This naturally divides the final design into three components which will be referred to as subsystems: the trigger subsystem, the striker subsystem, and the electrical subsystem.

The trigger subsystem features plastic roller bars which can be easily rotated by a gentle waving motion of the users' hands or arms over the top of the bars. Rotary encoders from the electrical subsystem transduce this rotational motion into a digital signal.

This signal then travels to the striker subsystem which houses the electrical subsystem components. The digital signal is interpreted by a microcontroller which drives the motor to rotate the drum mallet of the striker subsystem. The striker subsystem contains an adjustable housing box which encases a rotatable drum mallet. This mallet is motor-driven and when

engaged, it swings down to strike a drum placed adjacent to the striker subsystem. Once a complete striking cycle occurs, the electrical subsystem restores the original position of the mallet in order to strike again (see Figure 13.2). The approximate cost of the assistive device is \$500.

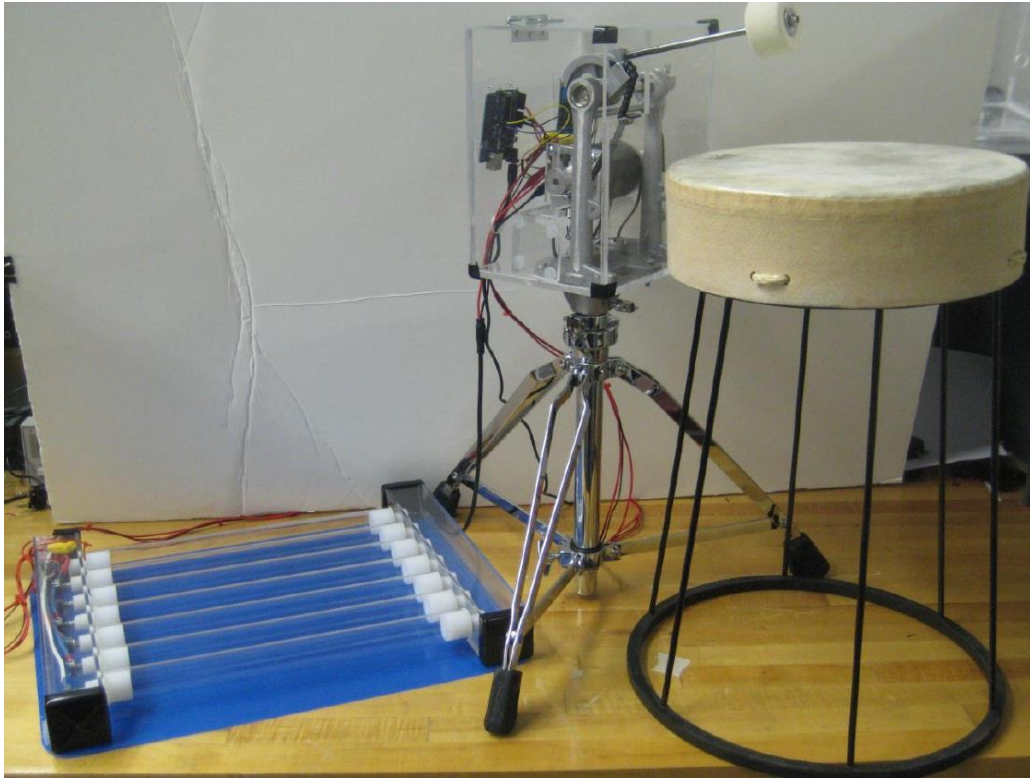


Fig. 13.2. Assistive drumming device as constructed.



# MULTI-SENSORY STIMULATION DEVICE

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## INTRODUCTION

The multi-sensory stimulation device (see Figure 13.3) was designed for a facility that provides a variety of services including vocational training, assessment, employment assistance, and individual therapy that allow their clients with physical and cognitive disabilities to become more independent in their daily lives. The goal of the device is to provide multi-sensory stimulation therapy to both over- and under- stimulated adults with cognitive disabilities. This device is able to provide stimulation to the user's sense of smell, sight, hearing, and touch. Aroma beads are used to produce different scents and to stimulate the user's sense of smell; touch rollers with different interesting textures are used to stimulate the user's sense of touch; picture rollers along with different colored LEDs that emit light in soothing patterns are used to stimulate the user's sense of sight; and a relaxing song accompanies these interactions in order to stimulate the user's sense of hearing. This device runs on the concept of themes; therefore, each type of stimulation has a portion that coincides with each theme. There are four themes contained within the device: a beach theme, a winter theme, a farm theme, and a meadow theme. Two textures also accompany each theme (one from each touch roller), as do one scent and two pictures. For LEDs, colors that are related to each theme are used in a pattern, such as blue and green LEDs for the beach theme. There is also an LCD display which communicates to the user which theme they are experiencing. The control panel, located on the back of the device, allows the user's therapist to personalize the user's experience by indicating whether the user is over- or under- stimulated, which theme they would like to experience, and the amount of time they would like to use the device (five minutes or fifteen minutes).

## SUMMARY OF IMPACT

The goal of the device is to provide multi-sensory therapy to the user. Caregivers have reported improvements as a result of multi-sensory therapy,

such as an improvement in concentration, a better relationship between caregiver and patient, behavioral improvements, improvements in self-awareness, and increased social and environmental interactions. Since the Hamilton Center has a variety of patients, each with a different level of ability, it was believed that, if the concepts of multi-sensory therapy could be harnessed and tailored to a more specific range of cognition, it would be noted by an improvement in patient well-being. This design could be easily modified to provide sensory stimulation therapy to adults or children of any cognition range. Improvements have been seen in patients with disabilities ranging from learning disabilities to dementia to chronic pain using these methods. This device is very portable, easy to maintain, and would be ideal in instances where more than one person would be using the device, such as a day-care center, a school, or a doctor's office.

## TECHNICAL DESCRIPTION

This project utilizes several subsystems: an auditory subsystem, a visual subsystem, a structure subsystem, an interactive subsystem, an electronics subsystem, a tactile subsystem, and an olfactory subsystem. All subsystems are controlled and powered by the electronics subsystem: upon start-up of the device, an LCD/keypad module relays user choices to a PIC18F4520 microcontroller. This microcontroller communicates with a second PIC18F4520 in order to evoke a particular response from the subsystems. With different scenes chosen by the user, different songs are played by a speaker in the auditory subsystem, using a playlist built into the program. For the duration of sound emission, two servos move the tactile subsystem rollers to a pre-determined location, while the PIC emits a constant signal to the second microcontroller. The second signal drives the visual roller. A second PIC controls the olfactory and interactive subsystems. As the PIC receives the signal from the first microcontroller, a constant signal is sent to the fan, driving it continuously. Another servo moves the

olfactory bowls to their appropriate positions, based on the port through which the signal is received. Twenty LEDs are controlled by the signal, which varies the colors that are observed. By the implementation of several loops in the program to ascertain the operating parameters requested by the client, the device can accept and execute several settings for different scenes and different stimulation

levels of the user. Two time increments are available for each setting, five minutes and fifteen minutes (instead of a timer, the program monitors the length of the songs that are playing, terminating a positive signal when a song ends). The entire unit is powered by eight AA rechargeable batteries, which reduces the operating costs. The final price for the unit was \$400.

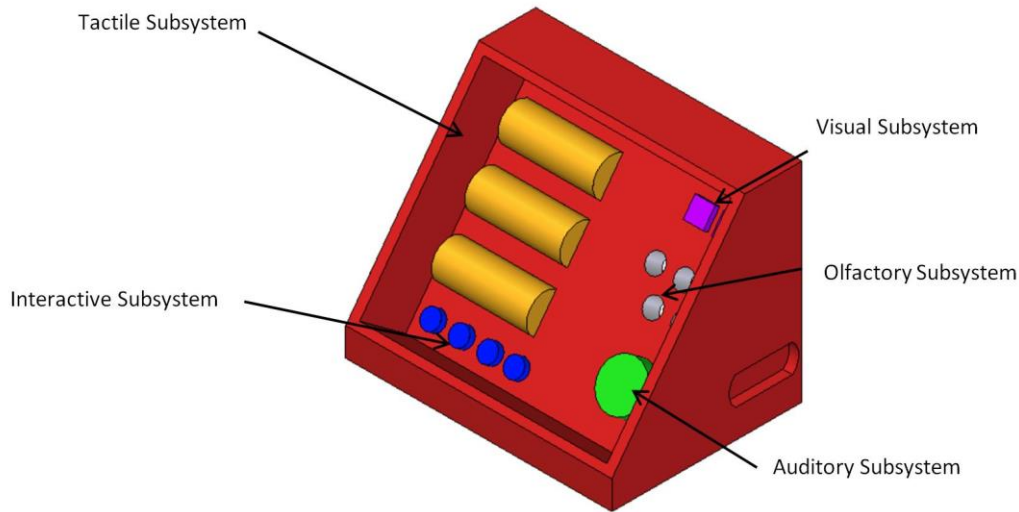


Fig. 13.3. Schematic drawing indicating the different tools used for sensory stimulation.

# ASSISTIVE DEVICE FOR OPENING POP CANS AND REMOVING THE TABS

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## INTRODUCTION

For persons with limited fine motor control, opening an aluminum pop can with the attached tab can be a difficult task. Additionally, it can be challenging to remove the pop tab from the aluminum can once it has been opened. No prior devices or processes were available in the market to assist persons facing this problem. The motivation behind the device was to provide consumers who have limited fine motor control with a durable and safe device for opening pop cans and removing the pop tabs, allowing them to perform the task independently while remaining active in the process.

In order to design this particular device (see Figure 13.4), specific criteria were identified which were of vital importance for the functionality of the device, as well as criteria that would enhance the device. In order to make this device feasible for use by consumers, the device had to accommodate the physical limitations of potential users by incorporating one of the following activation methods: one hand requiring no pincher-grasp motion, activation via foot pedal requiring less than 15 pounds of force, or activation with an applied elbow or hip force. Also, in order to make the device feasible, it had to be free of all sharp edges that could cause injury and the device had to dispense the removed tab to the user or to a collection bin. Desired attributes that would increase satisfaction with the device included increasing the number of users the device could assist, improving the robustness of the design over its lifetime, minimizing the potential for users to harm themselves while using the device, and decreasing the time it takes to open the pop can and remove the tab.

## SUMMARY OF IMPACT

The device improves the ability of a person with limited fine motor control to independently access the contents of a pop can. With the help of this



Fig. 13.4. The Can Opener device.

device, the clients will be able to operate the device on their own to open their beverage. Since the device also removes the pop tab, the users can collect the pop tabs and donate them to charities such as the Ronald McDonald Foundation.

The assistive device is durable. The materials used in the construction of the device were chosen to increase the lifetime of the device as well as to provide robustness to the design. Additionally, the design keeps the user separated from the internal mechanisms of the device during operation in order to prevent any harm to the user and produces an

opened pop can that does not pose any threat to the user from sharp edges on the can.

## TECHNICAL DESCRIPTION

The full design (see Figure 13.4) rests on a custom-made table set at 31 inches high. The device housing, which is composed of ABS plastic, has an effective internal compartment of 24 inches by 12 inches by 11 inches and contains the components which will act on the aluminum can. The right and top walls as well as the front door are clear plastic to provide the user with a direct view of the internal operation as it occurs. Each housing wall is fastened to the adjacent walls via aluminum trim and screws. The housing is recessed 0.5 inches into a 17 inch by 27 inch by 2 inch wood base.

Once the front door is opened, the user is able to pull the tracked cup holder out and insert an unopened aluminum pop can. The holder is pushed back into place which positions the can in the exact location for the can opener to appropriately contact the can top's rim. After the front door closed, the spring-stop is pulled on the right side of the housing and the can opener falls onto the can, with its tip piercing the can top just inside of the rim. By pulling the handle of the can opener downward from its vertical position to 90 degrees, the tip is pulled into the can opener body and associated turning gear. The user activates the can opener by rotating the handle clockwise, which turns the can inside the housing, cutting the lid as it rotates. Located on the can opener is a tab wedge which falls inside the rim and slides under the tab as the can rotates. Once the can opener has fully cut around the can rim, the handle is returned to the

vertical position and the aluminum can is released from the can opener while the tab and lid remain attached to the tab wedge. A handle on the right side of the housing is then raised up which drives a pulley system under the table to raise the can opener up until it is caught once again by the spring-stop.

As the can opener returns to its initial position, the tab wedge is turned clockwise until the lid strikes a point on the can opener and is forced off of the tab wedge and onto a ramp. The high density polyethylene (HDPE) ramp allows the lid to slide away from the can opener location and onto a platform, centered under an arbor press tip. The handle, which is still raised up by the user, can then be driven down to the table, activating the arbor press and punching through the rivet in the center of the lid. The tab and lid are effectively separated and the handle is raised up to retract the press tip. A resistance gate then allows the handle to come to rest such that the punch tip is inactive but can be overcome by the user during the punching action.

With the tab and lid separated, the user moves to the left side of the housing and pulls on the handle extending from the wall. This handle activates a spring-loaded slider, which previously situated the lid as it fell to the press platform, and pulls the lid and tab onto another HDPE ramp which facilitates their separation and exit from the housing into their respective collection bins. The user may then return to the front of the device and retrieve the opened pop can.

The approximate cost of this design is \$700.



# ASSISTIVE DEVICE FOR MUSIC THERAPY SESSIONS

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## INTRODUCTION

A design was required to aid the client, a music therapist, in administering music therapy to two of her patients with cerebral palsy. The design was required to be melodic while also taking all of the patients' physical constraints into account. This will provide the client the ability to provide a better therapy session for these two patients, both physically and cognitively.

The client is a music therapist who specializes in therapy with patients with neuromuscular disorders. She focused the scope of this project to help two of her patients, both with severe cases of cerebral palsy. Currently, the majority of their time in therapy sessions is spent playing the keyboard. Because the patients cannot control individual finger movements they have difficulty playing a single note at a time. Typically the patients fatigue quickly during their sessions, and are not able to hold their arms out in front of them.

## SUMMARY OF IMPACT

The prototyped design is a novel musical instrument (see Figure 13.5) which meets all of the needs of the client. The treadmill belt allows for alternative playing modes which the client can customize to the patient based on his or her motor skills. The user interfaces with the Tread-Tempo by lightly touching plastic note markers. In contrast to traditional keyboards, these note markers are much larger than keyboard keys. This allows the client's patients to play a single note with a fist or palm. As a result, the instrument is still melodic but much easier to play for patients with limited finger dexterity or muscle control.

## TECHNICAL DESCRIPTION

The user console is a 0.25" thick Plexiglas box to help ensure robustness during use. The console is mobile

and can be placed on a desktop or on a wheelchair. Internally, the console incorporates a miniature treadmill belt system (Tread belt), touch screens, stepper motor, microcontroller, and keyboard components. The Tread belt system is composed of nylon roller chains, sprockets, gears and bearings. Strips of polyethylene are woven onto the roller chains using a monofilament nylon thread to represent markers that correspond to a note. The sprockets are fixed to the side of the front and back walls of the device by inserting a drive shaft through them. The drive shafts are inserted, on either side of the wall, into a bearing that is fastened with screws to the Plexiglas panels. The gear on the drive shaft is linked to a gear on the stepper motor which relays information from the microcontroller. Under the belt, are stationary touch screens which lie on a Plexiglas platform, giving the sensitivity necessary for a microcontroller system to sense the physical input of the user/patient. The system recognizes which marker/note is being contacted and plays the corresponding note based on the position of the belt. The microcontroller also controls the client interface. The client interface has additional switches installed to let the client control the power to the motor, the speed of revolution, and the mode of play (stationary, manual, rotation).

Also located on the front panel of the console, is the original Casio SA76 44-key keyboard front panel, with all the switches and dials. This interface allows the user to control the power, volume, instrument tone, and background beats just as a standard keyboard. The Tread-Tempo has a foot remote. The remote is used for Mode 2 (manual) whereby the therapist can select notes for the patient to play on cue. The remote has buttons protruding from an angled face which allows the therapist to select a desired note. The last feature of the design is an ergonomic laptop stand to provide for optimal positioning for each individual user.



The cost of parts/materials was approximately \$650.

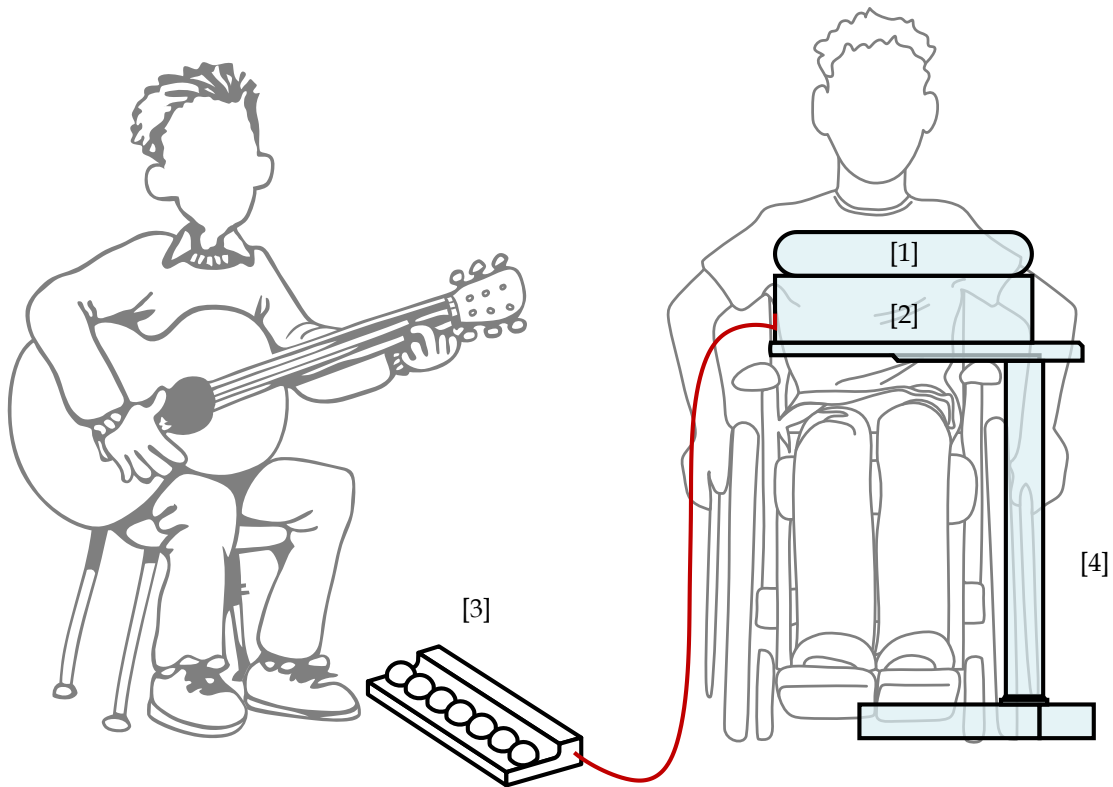


Fig. 13.5. Four subsystems in setup with client and patient—the tread belt [1], the console [2], the remote [3], and the stand [4].

# HANDS-FREE SECURITY SYSTEM

*Designers: Caroline Andersen, Cody Barron and Mychal Fitterer*  
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## INTRODUCTION

The client for this design project has Spinal Muscle Atrophy, a disease that impacts the nerves of the body and often results in reduced muscle function. She currently uses a wheelchair as her primary mode of transport, but has reported difficulty in gripping an object that is smaller in diameter than a standard colored marker. Her husband works outside of the home, leaving her alone in the home in a city with an above average crime rate for a large part of the day. As it is the desire of the client to feel secure in the home while maintaining her independence, it became the desire of the team to design a hands-free system that allows the client to independently lock and unlock her door from the interior of the home.

Prior to the project, there existed very limited solutions that were applicable to the client's situation, the best of which was a remote-controlled system. However the client's condition prevented implementation of any of the existing commercial solutions for a variety of factors unique to her situation and/or condition. The client specified that she preferred the ability to both lock and unlock the door from within the home to maintain her freedom and her sense of normalcy. The client also stated that she desired an inconspicuous system for the home.

## SUMMARY OF IMPACT

The system designed provides a level of freedom and independence to the client that was previously unavailable to her. Using the system, she can secure her home from the inside with limited physical effort; the only step in triggering the system is to move her wheelchair within the range-of-view of the modified motion sensor. Should she have a visitor to the home, it will now be much easier for her to open the door to welcome them in, and then to secure the home upon their departure. As the client previously depended on others to lock and unlock her door, she often felt trapped within the home and depended on her husband and friends to keep her safe. With this

device, she is able to implement her own safety precautions.

## TECHNICAL DESCRIPTION:

The design (see Figure 13.6) includes three separate subsystems with modifications incorporated for greater functionality and better manufacturing practices. The first of these subsystems is the user interface of the system. The main component of this subsystem is the motion sensor which is located within an exterior plastic housing. This housing was designed to be mounted on the wall next to the door in order to obtain the signal from the client whenever she or her husband wished to lock or unlock the door.

In order to reduce a potential misfiring of the system from unintentional movement close to the front door (i.e. retrieving an object from the closet located directly to the right of the door) the range of view of the motion sensor was limited. The range of the motion sensor has been focused using the exterior housing so that, rather than detecting a cone-shaped range, it sends an infrared beam that reaches 2 meters from the housing through a 0.3" diameter hole in the front face of the part. The housing was designed to encase not only the motion sensor, but also the printed circuit board, microcontroller, and h-bridge parts from the electrical components subsystem.

The electrical components subsystem was built by using a computer program to code a microcontroller chip to translate the input from the motion sensor into an output for the motor. A few changes to the initial schematic were made to ensure that the motor would have enough torque and that the battery would power the system without applying too much voltage to the chips. The electrical components subsystem was designed to be triggered by input from the motion sensor. When the sensor detects movement, the microcontroller sends an electrical signal to the h-bridge which then turns the motor clockwise or counterclockwise, depending on the current state of the lock.

The locking mechanism subsystem was constructed to maneuver the thumb turn from locked to unlocked position (and vice versa). This motion was determined and controlled by input from the stepper motor. In order to translate the rotation of the motor to the rotation of the thumb turn, a system of gears was designed and integrated into the internal workings of the deadbolt.

Following the manufacture of the gears, each gear was mounted upon the hub to which it turns. For the motor gear, the part was mounted upon the rotating

shaft and the lock gear was mounted onto the slotted shaft of the front plate of the deadbolt lock. The motor was mounted to a metal plate that was manufactured to fit within the plastic housing. The plate was attached to the housing using two small screws, and the plate also had holes to allow for the shaft of the lock and the motor gear to pass through. This mounting plate functioned in the alignment of the two gears to ensure that they interlocked in order for the system to work effectively.

The total cost for developing the prototype was \$350.

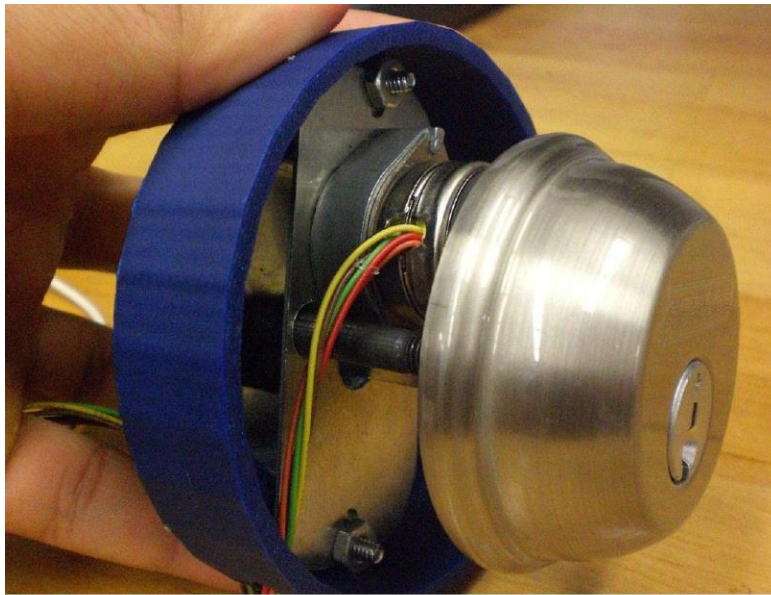


Fig. 13.6. View of the assembled deadbolt system. The motor receives a signal from the motion sensor via a microcontroller and operates a pair of gears to turn the deadbolt to the locked or unlocked position.

# LOCKER INDEPENDENCE

*Designers: Rebecca Bowermaster, Damien Harris and Nicholas Leedy*  
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## INTRODUCTION

A system was developed to assist a student with Spina Bifida with the task of opening her locker. The final design (see Figure 13.7) utilizes RFID technology and requires the user to push a button to unlock and open the locker door. This approach was useful for the student because she has difficulty remembering passwords, lifting the latch on the locker, and opening the door. There was no commercially available solution that addressed all of the needs of the client.

## SUMMARY OF IMPACT

The implemented design has the potential to improve the student's quality of life at school because it enables her to independently access her belongings with ease and in a timely manner. Previously, the client required extra time to put away or retrieve her belongings from a locker, which required her to leave early from class or arrive late. This design unlocks the locker door and opens it with the touch of a button. In addition, it keeps the student's locker secure from other students.

This design allows students with disabilities to focus on what is important to them – studies, friends, enjoying life – instead of being reminded of what they are not able to do. It will therefore boost the student's self-esteem and confidence. The user will be able to spend more time in class learning, too.

## TECHNICAL DESCRIPTION

The automated locker door opener uses a push-button activated radio frequency identification (RFID) system to signal a microchip-controlled pair of actuators to lift the latch and push open the door on a basic side-hinge locker. The automated locker door opener can be described using three subsystems: the security subsystem, the actuator subsystem, and the connections subsystem. The security subsystem

is the RFID reader, which limits access to the locker to the person in possession of the correct RFID tag card. The actuator subsystem contains the two actuators, which work in tandem to move the latch and door of the locker. The connections subsystem is centered around a programmable microchip which uses feedback from the RFID reader and two push-buttons to control the movements of the actuators. Each of the subsystems is powered by two nine-volt batteries.

Operation of the automated locker door opener begins with the user (and the RFID tag card) standing in front of the locker in which the device has been installed. The user pushes a green button and the RFID reader activates and scans for an RFID tag that has been granted security clearance. Upon recognition of an accepted RFID tag, the RFID reader sends a signal to the microchip. The microchip then activates the first of the actuators to lift the latch on the locker door, followed by the second actuator extending to open the door. The second actuator retracts upon full extension, so that the user is not impeded from closing the locker door at any time. When the user is finished accessing the locker, the door is closed and the red button on the exterior surface pushed. The first actuator then lowers the latch of the door, which secures the contents of the locker.

Security is ensured by two main mechanisms: read range and static actuator resistance. The read range of the HID ThinLine II Proximity Card Reader is approximately 6 inches. This ensures that the user is standing in front of the locker when the device activates rather than passing in the hall when the green button is accidentally depressed. The actuators also have a static resistance of 50 pounds of force which prevents possible thefts by physically denying access to the locker contents. The approximate cost to build and implement this device was \$550.

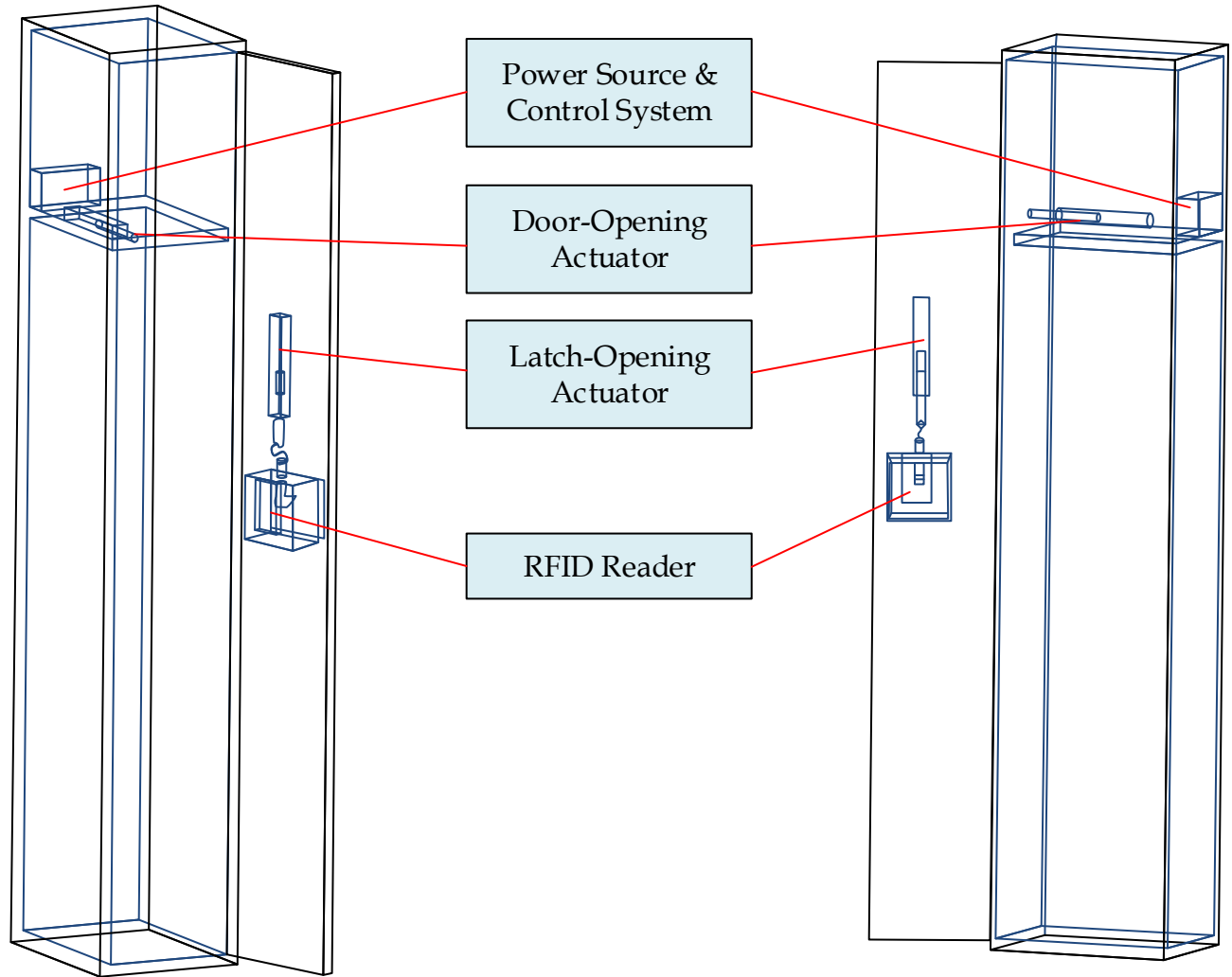


Fig. 13.7. Assembly drawing of the Locker Independence Design illustrating the various design components.



# ELECTRONIC FOREARM PROSTHESIS

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## INTRODUCTION

The client for this design project is a kindergarten student with bilateral ulnar and radial hypoplasia, a condition that has resulted in the absence of forearms and the presence of only two fingers on each hand. The condition limits his strength and range of motion, and causes him difficulty in everyday tasks such as writing, brushing his teeth, and using the restroom independently.

There are many existing prosthetic devices to assist individuals with missing limbs; however, these solutions are not viable for this client since he has functional fingers that extend from his humerus. Prosthetic devices on the market today do not allow the client to utilize his fingers which prevent him from building strength and developing a greater range of motion. A device was developed last year for this client that operated using pulleys. This device proved to be too difficult for the client to use since it required too much finger strength. The device was also far too large for a child and was uncomfortable for the client to wear and use.

Learning from the previous design, the approach for this project was to develop a device that would be easy to operate, small, and lightweight. While many design concepts were considered, a joystick (see Figure 13.8) was chosen as the mode of operation for the device. The motivation for this approach was to make the device easy to use, durable, reliable, and fun. With those motives, the client could enjoy using the device to help perform his daily tasks.

## SUMMARY OF IMPACT

The device provides a greater range of motion for the client (see Figure 13.9) by performing elbow flexion and extension, extending the user's reach, and allowing the user to grasp a variety of objects. These features allow the user to perform many tasks with more ease and even allow the user to perform tasks that he or she previously could not. Therefore the

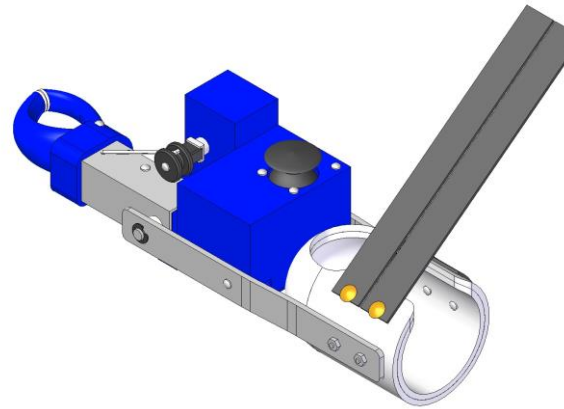


Fig. 13.8. Dynamic Transhumeral Prosthesis.

user's independence is increased by enabling the execution of tasks without assistance.

This device is useful to the client because it is easy to use, durable, reliable, and fun. The client understands how to operate the joystick to perform elbow flexion and extension or gripping. Also the device has proven durable enough to withstand typical day-to-day forces and is reliable because the device continues to function as expected. Since the joystick made the device similar to a game controller, the client enjoys using it.

## TECHNICAL DESCRIPTION

The design consists of four subsystems: socket, user input, elbow, and hand. All of these subsystems are securely attached so that they can function together.

The socket subsystem can be broken down into three major parts - custom fit socket, Velcro straps, and aluminum support bars. The socket is a custom fit to the client's arm to ensure comfort. The Velcro straps are used to secure the device onto his arm, while the aluminum support bars attach the socket to the user input housing.

The user input subsystem is based around a joystick. If the client moves the joystick up or down, it operates the elbow subsystem for flexion and extension. If the joystick is moved left or right, it operates the hand subsystem to grip objects. The joystick, servo motor, H-bridge, microcontroller, power board, and battery are all contained in a rapid prototyped user input housing.

The elbow subsystem consists of four major parts – a pulley, cable, dowel pin, and aluminum bar. The pulley is attached to the servo motor that is operated by the joystick. The dowel pin is attached to the aluminum support bar and user input housing and allows the aluminum bar to rotate about it. The cable

is attached to the aluminum bar and pulley, so that as the pulley rotates it moves the aluminum bar for flexion or extension.

The hand subsystem is comprised of four main parts: a stationary finger, moving finger, bar, and linear actuator. The linear actuator is controlled by the movements of the joystick and is positioned inside of the stationary finger. The bar is connected to the linear actuator and moving finger. Therefore when the linear actuator moves, it causes the moving finger of the hand to open and close and grip objects.

The cost of materials and supplies for this device was approximately \$425.

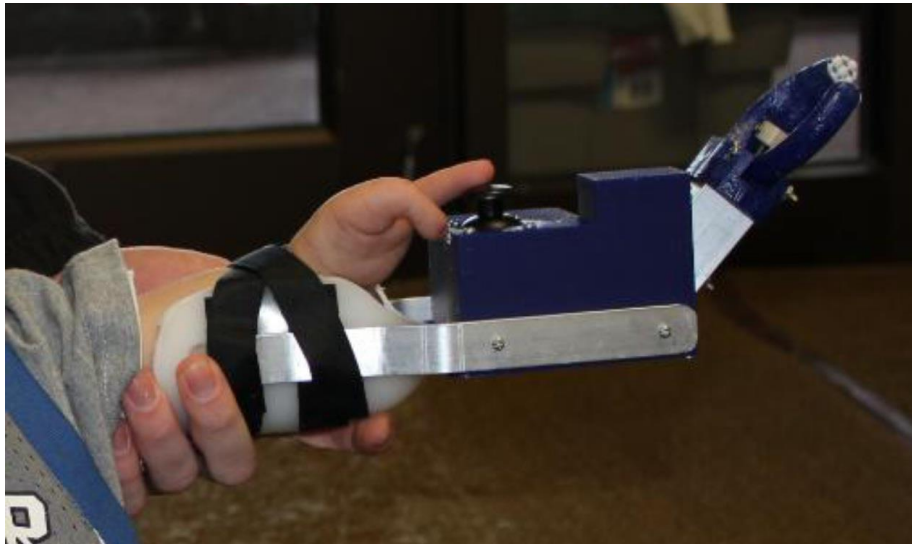


Fig. 13.9. Client operating the finished prototype with his left hand.

# GIVING HIGH SCHOOL STUDENTS LOCKER INDEPENDENCE: AUTOMATED LOCKER OPENING

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## INTRODUCTION

During high school, locker use is an integral part of a student's social routine during the school day. Many students cannot use a standard combination locker or keyed lock by themselves due to various disabilities. The client, Terre Haute South Vigo High School, has approximately 12 students who can benefit from a device that would allow them to secure and access a locker independently. Although this consists of only one percent of the student body, there are students at many other high schools across the country that could benefit from this device. If the same percentage held true for the 14 million students enrolled in high schools across the United States, there are about 140,000 students across the country that could benefit from an automated locker opening device.

Existing solutions are unable to address all disabilities simultaneously. For example, keyed lockers eliminate the use of a combination lock which accommodates users with visual impairments and memory limitations; however, wheelchair users and students with limited dexterity still find it challenging to manipulate the small key. Other solutions eliminate the use of a key through a keypad, a remote control, or a magnetic fob. Although these solutions provide easier mechanisms for unlocking the locker, none of them address latch lifting or locker door opening. The newly developed technology provides a solution that addresses these considerations as the user is able to press the button on the wireless key and the system will unlock the locker, lift the latch, and open the locker door (see Figure 13.10).

## SUMMARY OF IMPACT

Locker use is an important activity for high school students as it functions both as a means to access their

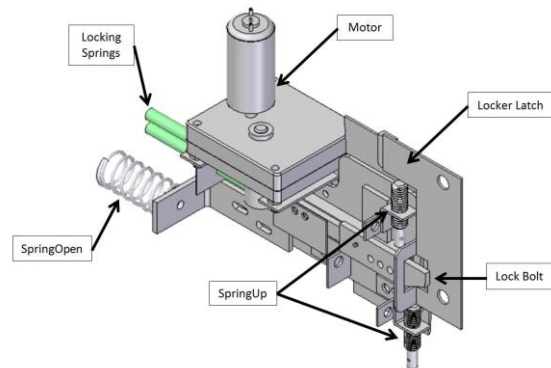


Fig. 13.10. A schematic drawing of the assistive device. The device fits on the inside of the locker door in place of a combination lock. The motor, lock bolt, and locking springs comprise the wireless entry system.

belongings and as a short social period between classes. Many students are not able to independently open their lockers and require the assistance of a faculty member. This makes the student stand out in a negative way by making them feel confined and restricted while additionally using the time of a faculty member that may be needed elsewhere.

The device assists students with muscle, memory, and visual impairments as well as wheelchair users. By removing the need to use the combination lock and by opening the locker door automatically, these students can use their lockers independently. Independent locker use enables students to open their locker and access their belonging in the same way as other students. This allows them to interact with other students during passing periods without a faculty member standing with them. This independence also allows faculty to use the time

between periods to prepare for their next class or other activities that may be necessary.

## TECHNICAL DESCRIPTION

The final design is composed of three systems as labeled in Figure 13.10. The systems are the Wireless Entry system which unlocks the locker, the SpringUp system which lifts the locker latch, and the SpringOpen system which opens the locker door. Wireless Entry is composed of a handheld wireless radio frequency (RF) transmitter carried by the student, a wireless RF receiver inside the locker, a DC gear motor, a lock bolt, and springs. The transmitter transmits a signal to the receiver causing the motor to spin, pulling back the bolt, and unlocking the locker. The SpringUp system then pushes up the locker latch using a spring plunger. The SpringOpen system consists of a spring on a lever arm to push the door of the locker open. After the locker is open, the motor

will continue its revolution and the locking springs secure the lock bolt in the locked position. After the lock bolt returns to the locked position, the locker can easily be pushed shut, securing the student's belongings. The interior components are protected by a metal case. The device also has a mechanical override in the case of failure in the device. The mechanical override can be accessed by the loosening of two tamper proof screws on the outside of the locker, moving back the override cover, and manually retracting the lock bolt. The assistive device successfully accomplishes the goal of providing a way for high school students who may have limited hand dexterity, limited trunk mobility, vision impairments, or those who use wheelchairs to independently secure and access their locker.

The final device (without the protective encasement) is shown in Figure 13.11 and the cost of materials and supplies was approximately \$350.

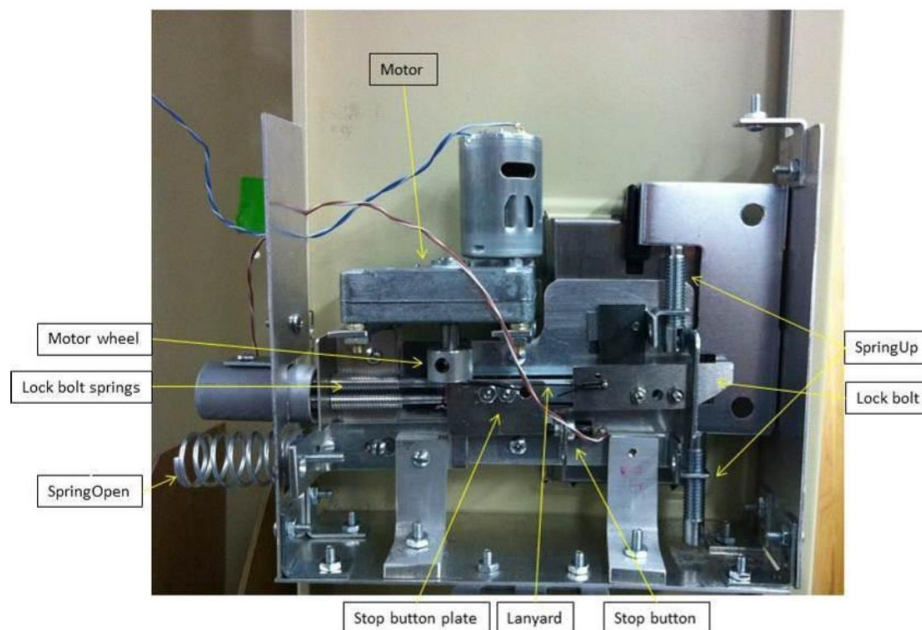


Fig. 13.11. The final mechanical components of the automated locker opening device.



# ASSISTIVE TECHNOLOGY TO IMPROVE GRIP STRENGTH

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## INTRODUCTION

Many senior citizens, stroke patients, and individuals with degenerative neurological and musculoskeletal diseases experience the gradual decline of muscle control and a significant reduction in hand grip strength coupled with an inability to coordinate fine motor movements. The client is a 59 year-old woman with Spinal Cerebellum Ataxia, a progressive, genetic neurological disorder that results in the gradual decline of muscle control. Due to the degenerative nature of her condition, the client has recently experienced a significant reduction in her hand grip-strength and in her ability to coordinate fine motor movements. While retaining full intellectual capabilities and upper arm strength, the client's independence has been limited considerably due to an uncontrolled tight clenching of her fingers and a substantial tremor of her hand. The client would benefit from a non-cumbersome device that improves her grip strength and aids her in daily tasks including grasping, eating, and using writing utensils. A therapeutic element to prevent the rapid deceleration of muscle strength, in the case of patients with degenerative neurological disorders, would also be a strong asset to any device.

## SUMMARY OF IMPACT

The assistive device (see Figure 13.12) operates by means of a novel ratchet mechanism that allows the client to control the movement and position of her hand while providing additional support to her fingers by locking them into the desired configuration. In addition to the practical function, the design provides a therapeutic activity that will aid the client in her physical therapy and assist in her efforts to decelerate the progression of her disease. The design accomplishes this by holding the client's fingers in a straight position when they are not in use, similar to the function of previously used therapeutic devices, to prevent curling of her fingers. The current design is superior to other methods of therapy

because it does not completely inhibit the use of her hand due to bulkiness and allows for an easy transition between the "default/therapeutic" mode and the "active" mode.

## TECHNICAL DESCRIPTION

The design consists of a right-handed fitted glove, secured to the user's hand via a Velcro® strap. Ratchets on the proximal interphalangeal (PIP) and the metacarpophalangeal (MCP) joints of each finger connect to distal, thin supports. Polypropylene was initially selected for the support material to accommodate for the dichotomy between the need for strength and the need for flexibility. The polypropylene was ultimately replaced by a metal as it became apparent that strength was critical for complete functionality. Each ratchet is sewn into the glove via the casings and the release mechanisms of each ratchet are connected to one another via the supports. The PIP ratchet release mechanisms are activated through the connection with the MCP aluminum supports. The MCP ratchet release mechanisms connect directly to the lever via supports.

The fabric glove spans from the client's fingers to the wrist. Nylon was selected as the material of construction for its durability and cleanability. The glove fingertips were removed so that the client can maintain a sense of touch. The thumb is likewise not encased to preserve full range of motion. The Velcro® strap around the wrist prevents the device from slipping.

Upon assembly of the design, the team encountered several challenges that required significant changes to the original design in order to ensure functionality of the device. Casings were added to encompass the MCP ratchets to guarantee that the ratchets did not snag on the fabric when in use.



The cost required to develop the device was approximately \$100, which includes all supplies and materials.

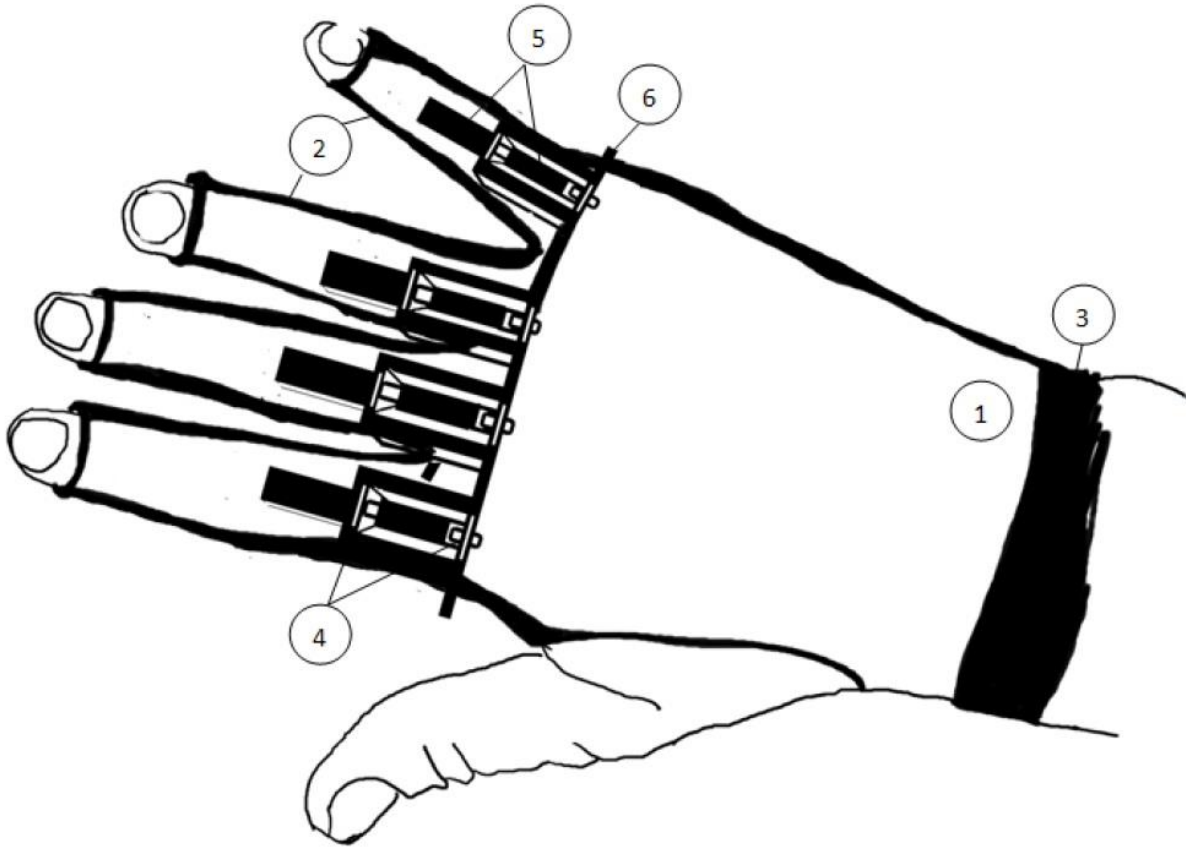


Fig. 13.12. The design consists of (1) a fitted nylon glove, (2) pieces of Under Armour® material for increased maneuverability, (3) a Velcro® strap at the wrist for securing the device, (4) ratchets at critical joints, (5) aluminum supports and (6) a protective casing.



# CHAPTER 14

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# T.R.E.A.T. (THERAPEUTIC AND RECREATIONAL ELECTRO-ASSISTED TRICYCLE)

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## INTRODUCTION

A rehabilitative tricycle was designed and constructed to promote rehabilitation and mobility for individuals with debilitated lower-body strength. Through a multi-mode system, the rider has the option to pedal the tricycle, drive it solely on electric power, or use assistive pedaling to reduce manual effort. This tricycle also incorporates an advanced therapy mode that further promotes physical improvement, by providing increasing pedaling resistance for lower-body muscle strengthening. While there are many electric tricycles on the market, none accommodates the rehabilitation of individuals with an impaired lower-body. Our tricycle helps these people recuperate and rebuild strength.

## SUMMARY OF IMPACT

Mobility and physical activity can be challenging for people with impaired lower-body strength. Currently, most apparatuses that facilitate mobility result in a further decrease of the user's strength and fitness. For instance, electronic wheelchairs provide a means of mobility, but they tend to reduce the user's physical activities. While wheelchairs may be the only solution for certain disabilities, they can be disadvantageous to those individuals that retain some portion of their lower-body strength. On the other hand, rehabilitative devices that increase the user's overall fitness tend to be constrained to a fixed location. Our design of the rehabilitative tricycle combines these two concepts and provides an accommodating solution for the aforementioned individuals. It can have a great impact on the lives of these individuals, by offering them both short-term and long-term solutions - mobility and rehabilitation.

## TECHNICAL DESCRIPTION

The overall system works partly like a standard tricycle. In this respect, the user may use leg power to rotate the pedals, which in turn, propels the tricycle. When the user's leg power is not sufficient to propel



Fig. 14.1. Prototype of T.R.E.A.T.



Fig. 14.2. Chain and Sprocket System.

the tricycle, a DC motor, connected to the back axle through a chain-sprocket system, turns on and aids the rider in reaching a desired speed. This motor is mounted in an enclosure, which is in the place of a standard tricycle's rear cargo basket. In this dual-function mode, the motor either solely powers the tricycle or complements the user input.

The other mode of this system is the advanced therapy mode. In this mode, the motor functions as a generator. The user can vary the inherent resistance of the generator by altering the position of a throttle. This produces a resistance that varies with respect to



the actual magnitude of regenerative braking. The power that the user inputs is captured and charges a battery which powers the motor and electrical components in various modes.

To accomplish the proposed functions, the mechanical system of the rehabilitative tricycle was designed and fabricated by customizing a Schwinn Meridian Tricycle. An Arduino Uno microcontroller was used as the central controller to receive input from components, including thumb throttle, brake levers and switches, run the control flow, and command the motor through the motor controller.

The cost of the parts and supplies for this project was \$1275.

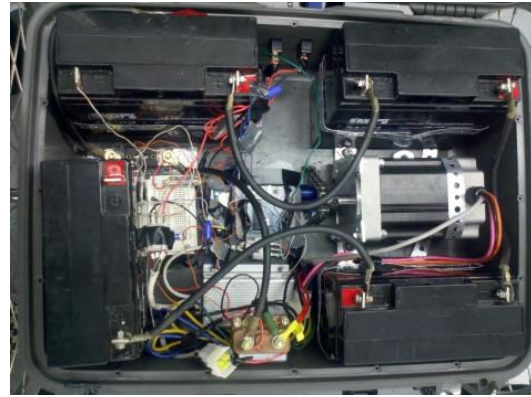


Fig. 14.3. Control System in Rear Enclosure.

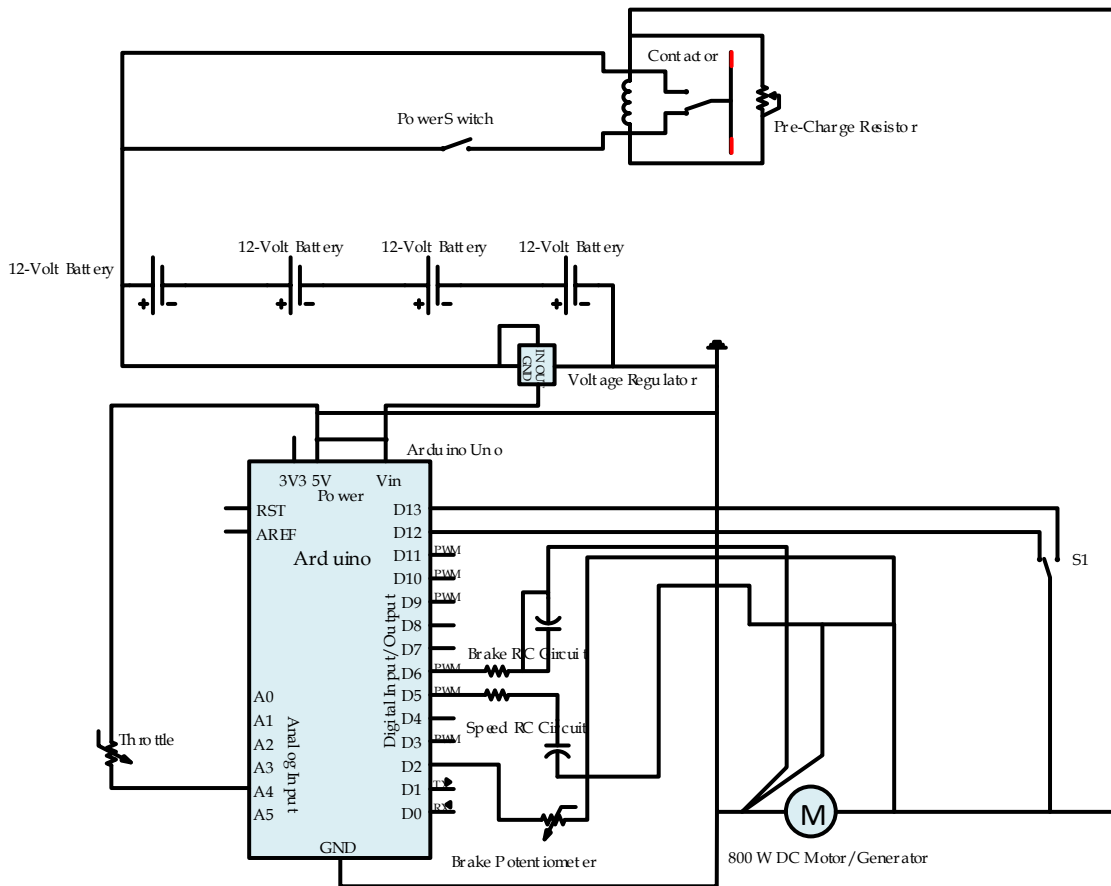


Fig. 14.4. Control Circuit.



# ANKLE EXOSKELETON

*Designers: Teng Lin, Ka Wing Ng and Ying Ying Cui*  
*Supervising Faculty Professor: Dr. Lei Zuo and Dr. Yu Zhou*  
*Department of mechanical Engineering*  
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## INTRODUCTION

An ankle exoskeleton was designed to help people who lose their walking ability, due to ankle weakness, to regain walking ability. Statistics show that 1.7 million people in U.S. (about 0.57% of the 3 billion total population) are suffering from weakness in their lower extremities and cannot lift their feet to walk. This motivated the design of the ankle exoskeleton. In operation, the designed ankle exoskeleton is attached to the leg and foot of the user, and generates force to support the foot and assist the walking action, according to the Electromyography (EMG) signal from the lower limb muscles.

## SUMMARY OF IMPACT

The prototyped ankle exoskeleton succeeded in generating motion and force outputs to assist walking according to the user's intention recognized from the EMG signal generated by the user's muscles. It provides a conceptual prototype for studying the EMG-based control for walking assistance. It will lead to an effective solution for people with ankle weakness to regain their walking ability.

## TECHNICAL DESCRIPTION

This project focused on the design of the mechanical system of the ankle exoskeleton, assuming that the control decisions have been made by EMG signal processing.

The ankle exoskeleton has a stepper motor as the actuator, a flexible shaft as the power transmission, a jointed foot mechanism to achieve the desired motion, and a light weight and long-lasting battery as the power source.

The mechanism is mainly made of 6061 Aluminum. The foot mount and base are made of aluminum plate. The materials were cut to custom fit the user's leg and foot. The mechanism is connected to a stepper motor through a flexible shaft which transmits the torque. Since the leg joints are not stationary when the user walks, a flexible mechanism must be selected to transfer the power. The flexible shaft, along with ball screw and bearings, provide an easy and economical solution. The ball screw is used to reduce weight while reach high energy efficiency, boosting the torque and eliminating the necessity of including a gear train. The bearings are used to make the mechanism move smoothly and reduce energy loss in friction. The stepper motor is controlled by the post-analyzed signals which are initially collected from the user's muscles and then processed by an EMG system to identify the user's intention.

The future work will include reducing the weight and adding more degrees of freedom to the mechanism.

The total cost of the parts and supplies for this project was \$900.



Fig. 14.5. Ankle Exoskeleton.

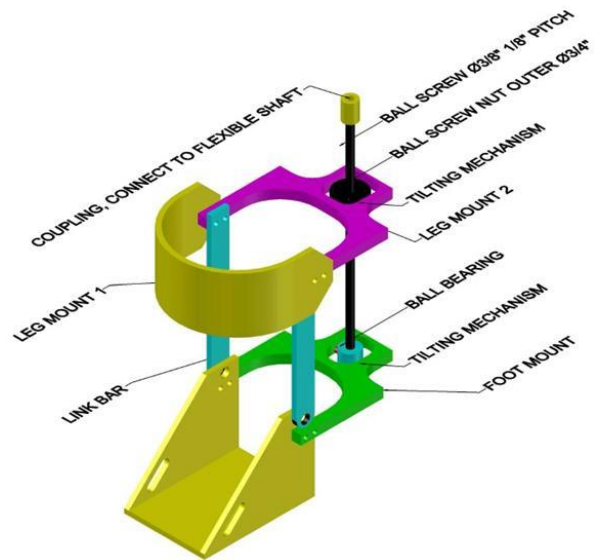


Fig. 14.6. Mechanism Design.

# ELEVATING WHEELCHAIR RELOCATOR

*Designers: Kevin Chen, Ross Garrett and Cora Walter  
Supervising Professor: Dr. Yu Zhou  
Department of Mechanical Engineering  
State University of New York at Stony Brook  
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## INTRODUCTION

An elevating wheelchair relocator was developed, designed and manufactured to lift a wheelchair user. Typically this is a process that involves either great upper body strength by the wheelchair user to elevate himself, manual lifting of the individual by assistive care professionals, or the use of sling lifts. We notice that, when the personal upper body strength is not available, assistive care professionals often sustain injuries from lifting wheelchair users, and the use of sling lifts requires excessive time and cumbersome equipment to relocate paraplegic individuals. To design an improved method, we propose to integrate a mechanism into a wheelchair for the user to lift and relocate himself onto a platform. The prototype consists of an offset rotating platform mounted atop a hydraulic lift. Once the platform is positioned atop the elevated surface, the user can manually slide himself on and off the surface with minimal effort. It eliminates the need of a separate machine or other assistance, and the user would have full control over the process.

## SUMMARY OF IMPACT

By mechanizing and motorizing the process that once would have required intensive physical labor, the elevating wheelchair relocator minimizes the effort of the wheelchair user and mitigates the risk of injury to assistive care professionals. Moreover, the use of a separate and expensive device, such as sling lift, becomes unnecessary, and the time to move onto a platform is largely reduced. Overall, the quality of life of the paraplegic user is improved as he would have more control over getting on and off a raised surface instead of depending upon assistance.

## TECHNICAL DESCRIPTION

A 660-pound capacity hydraulic scissor lift table was chosen as the base for the project as it provided a sturdy base capable of elevating and was compact enough to fit through standard door sizes. The capacity satisfied the 250-pound lifting weight expectation, with a safety factor included.



Fig.14. 7. Prototype of Elevating Wheelchair Relocator.



Fig.14. 8. Rotating Mechanism of Elevating Wheelchair Relocator.

Components were attached to the lift table to incorporate the other features of the proposed design. Atop the table, an aluminum plate was vertically mounted using bolts and brackets. Two pillow blocks were bolted onto the plate and a steel shaft was placed within these blocks such that they could guide the shaft's rotation. This shaft sat atop a thrust bearing embedded in a block of aluminum bolted onto the tabletop. Between the two pillow blocks and around the shaft, a large diameter sprocket was located. A chain was wrapped around this sprocket as well as another smaller sprocket mounted onto the output shaft of a DC Leeson right angle motor. This was done to both reduce the speed output and increase the torque output of the motor.

A flat steel plate was welded on top of the shaft, with the shaft positioned along one of the edges of the plate. This was done so that the plate rotation would be offset, allowing for lateral movement of the user

atop the plate while the shaft rotated. With a seat mounted on the plate for comfort, flip-up armrests were added for safety and ease of sliding onto an elevated platform. A seatbelt was also utilized to keep the user secure, and elevated leg rests were mounted onto the chair so that the legs would be kept parallel to the floor and away from obstacles during the rotating process.

Base extensions were mounted to the bottom of the lift table to increase the footprint of the device and prevent tipping during operation. A handheld control box was fitted with a DPDT switch with a momentary push button switch so that the user could alternate between the rotating directions. The chair would only rotate if the push button was physically pressed down, as a safety measure.

The cost of the parts and supplies for this project was \$1210.

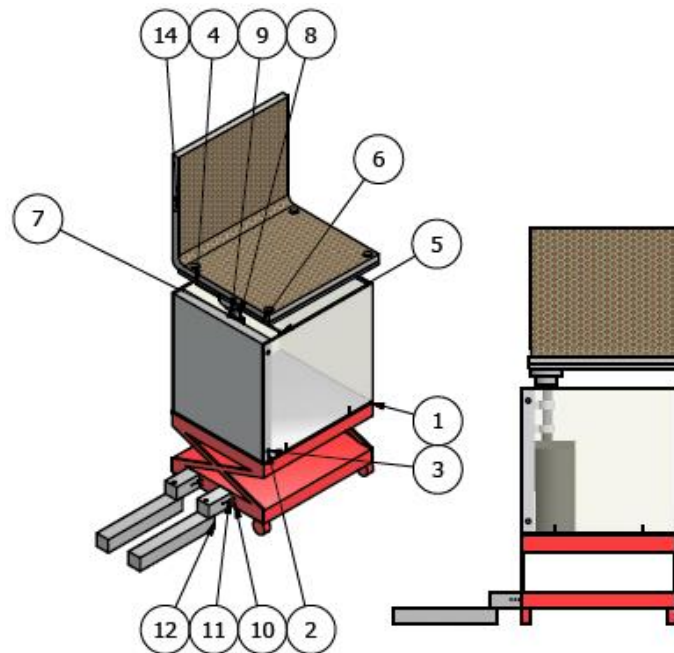


Fig.14.9. Design of Elevating Wheelchair Relocator.



# CR WHEELCHAIR

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Department of Mechanical Engineering  
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## INTRODUCTION

A special wheelchair was designed to reduce the operational effort of manual wheelchairs. Very few commercial wheelchairs are available for the same purpose, and the available products often aim at an increase in speed rather than a decrease in user's effort. To address this problem, a four-bar linkage and sprocket-chain system was used to provide the user with comfort and reduce the effort.

## SUMMARY OF IMPACT

The proposed design of wheelchair provides the user with an increased comfort by allowing the arms to function in a more natural position, and reduces the user effort greatly through the use of a sprocket-chain system and four-bar linkage. This design can easily be expanded to include multiple sprockets and other customizable features to accommodate more needs and provide a more flexible system that could more easily deal with various terrains and user needs.

## TECHNICAL DESCRIPTION

A standard hospital-style folding wheelchair was customized to accomplish the proposed functionality, with a consideration of the design and fabrication effort.

To accommodate the linkage and sprocket-chain system, the wheelchair frame was modified and fitted with threaded inserts for shoulder screws to carry the driving handles and sleeves added to the frame to house the shaft and bearing assembly for the crank of the linkage. Furthermore the rear wheels were modified to carry a plate that mounted a large sprocket that would be driven by the linkage.

The linkage was designed to create a natural comfortable arcing motion for the user to move the



Fig.14.10. Prototype of CR Wheelchair.

handles through and furthermore to transfer the motion easily to the sprocket-chain assembly. A Grashof crank-rocker four-bar linkage was selected and designed because of its simplicity and its ease of customization. The sprocket-chain system allows for the wheel and driver sprockets to be freely placed and connected through the chain, and furthermore provides significant mechanical advantage to the user through the transmission ratio of the two sprockets.

The system is simply driven by rhythmically pumping the two handles simultaneously, which turns the crank and drives the sprocket-chain system. Turning is achieved by pumping one handle while allowing the other to idle, in much the same manner that one would turn a standard manual wheelchair.

The cost of the parts and supplies for this project was \$600.



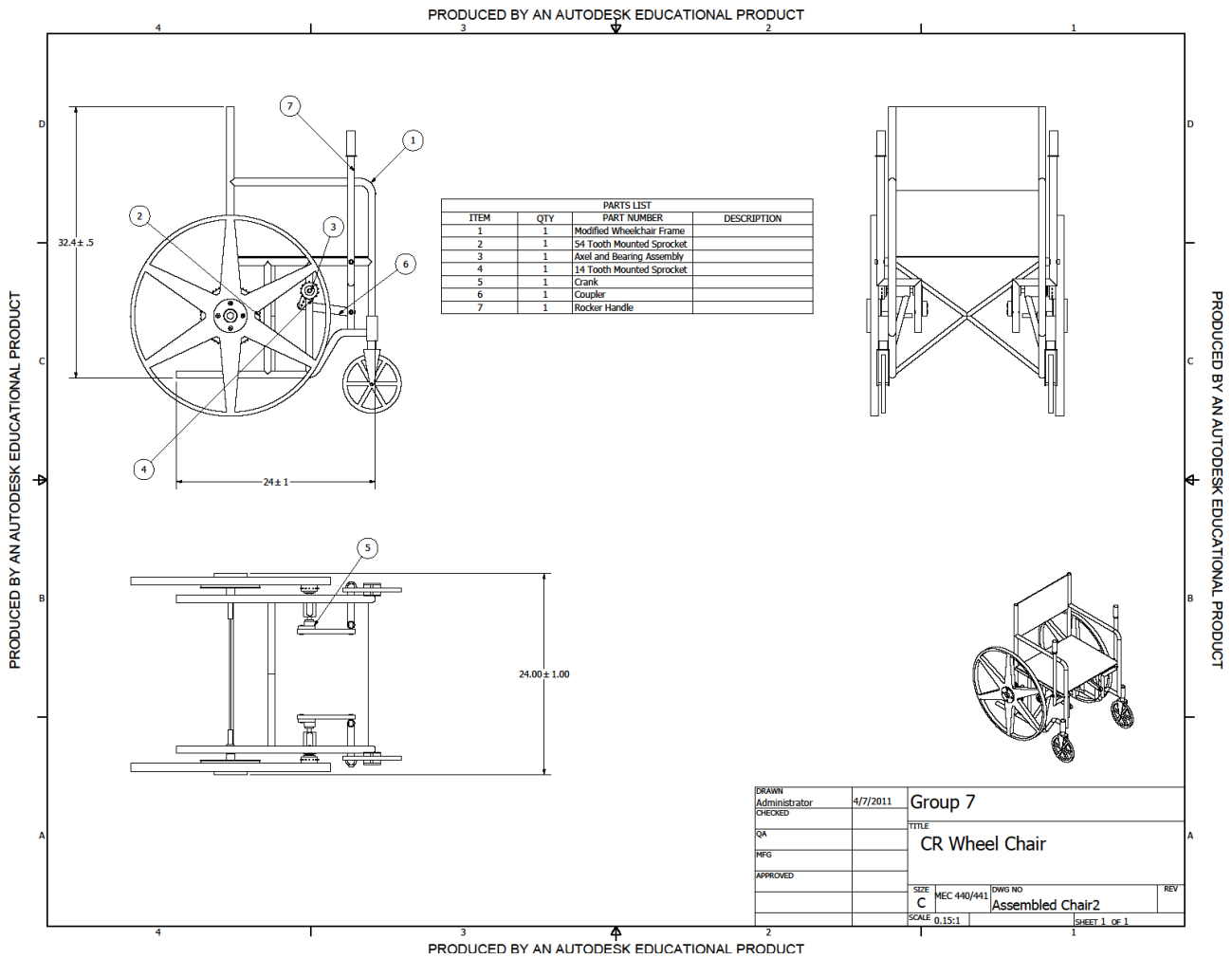


Fig. 14.11. Design of CR Wheelchair.

# CURB CLIMBING WHEELCHAIR

*Designers: Leo DeMino, Alex Felce and Gennaro A Manna  
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State University of New York at Stony Brook  
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## INTRODUCTION

The curb climbing wheelchair serves as a solution to a common problem that many wheelchair users face on a daily basis. The device allows a user to traverse a curb in the absence of a handicap accessible ramp. The mechanism is capable of both climbing and descending a curb in a safe and fluid manner. Since the climbing system is supplementary to the wheelchair's primary function, the weight of the additional system is kept to a minimum. Safety is clearly paramount to our design considerations. Due to this consideration, the design keeps the angle of the chair approximately parallel to the ground throughout the process. The main challenge is to control the center of gravity of the system, thus avoiding any tipping and ensuring that the forces are distributed correctly. Ultimately, the design provides an inexpensive and elegant solution to traverse a curb, and consequently gives wheelchair users greater freedom, safety and peace of mind.

## SUMMARY OF IMPACT

The curb climbing wheelchair can have a large impact on the targeted market. During the market research and user needs analysis, we found that wheelchair users, who did not possess the strength to ascend and descend a curb without assistance, felt intimidated by the possibility of encountering curbs without a ramp. The only device on the market is far too expensive for average wheelchair users. If the design could go into production, it would have a serious impact on society because its design is simple and affordable. Moreover, one of the key objectives of this project was to add a simple, light and safe retrofit device onto a wheelchair, thus giving the user peace of mind that they did not need to search for a ramp if one was not readily available. This goal has been achieved.

## TECHNICAL DESCRIPTION

The user will activate the device through a three way switch fixed on the wheelchair, and the lifting process will be run on a DC battery. The driving force of the system comes from a linear actuator. Its power is



Fig.14.12. Prototype of Curb Climbing Wheelchair.

transferred to lift and lower the wheelchair through the use of linkages, chains, sprockets and gears. The lifting process takes roughly 14 seconds and is able to lift the user in a safe and controlled manner while keeping the user horizontal. For the drive system, the user will be able to continue using the big wheels on the wheelchair even when they are off the ground to move forward or backward to get either over the curb or away from it. After the wheels get to their desired orientation with the curb, the user reverses the actuator and the wheelchair is lowered down and the wheelchair is able to continue on its way.

To make sure everything was safe for the user, the materials were carefully selected to ensure that they were both light and strong enough for the application. We used a combination of 4130 aircraft steel for shafts that dealt with high forces and 6061-T6 aluminum for the other components where the forces are less. We used an assortment of bushings and bearings to ensure that all the parts were moving smoothly and easily to prevent material breakdown.

The cost of the parts and supplies for this project was \$1200.

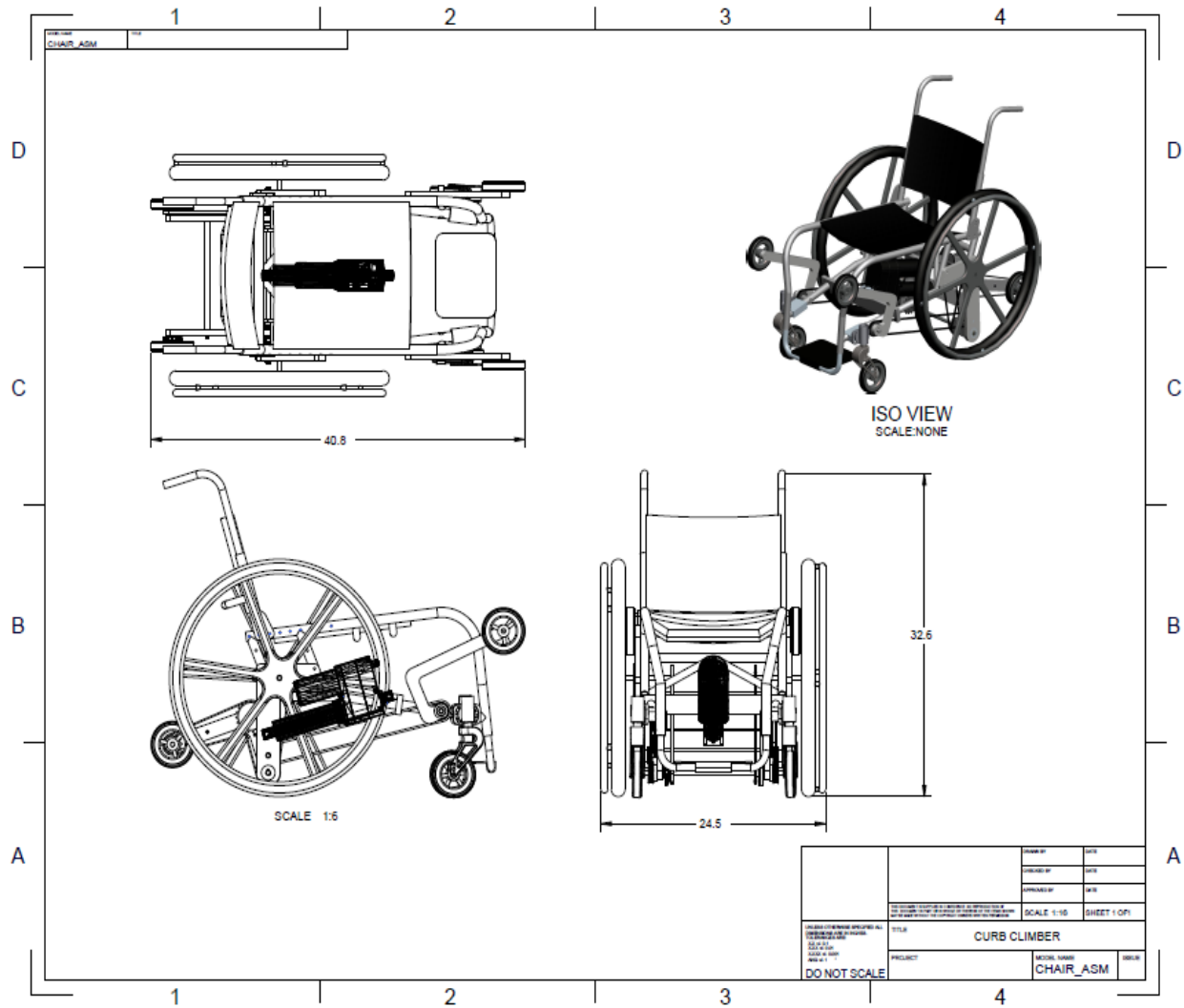


Fig.14.13. Design of Curb Climbing Wheelchair.

# ALL-TERRAIN TRAVELING BASE

Designers: Chuancai Zou, Rui Wang and Nan Qin  
 Supervising Professor: Dr. Yu Zhou  
 Department of Mechanical Engineering  
 State University of New York at Stony Brook  
 Stony Brook, NY 11794-2300

## INTRODUCTION

The All-Terrain Traveling Base was designed to provide a way for wheelchairs to travel on various terrains, including sand, hard surface, grass, incline surface, bumpy terrain and stairs. The motivation of the project was to design a capable base for wheelchairs, which can climb stairs and travel on different types of surfaces independently, because very few current products are applicable. A combination of a belt and wheel system was chosen as our solution. Under wireless control, the traveling base can move forward and backward, adjust the seating level, turn left and right, and overcome different terrains.

## SUMMARY OF IMPACT

The designed traveling base provides an effective and economic solution for electrical wheelchairs to climb stairs and overcome rough terrain. It will offer many wheelchair users more independence and freedom. For instance, in New York City, many subway or train stations do not have elevators. By replacing the regular wheelchair base with the All-Terrain Traveling Base, wheelchair users would never worry about the availability of elevators or travel a long distance for a handicap path. They can use the shortest path to arrive at the platform, just as other people. Moreover, we notice that the proposed technique can also be applied to a broader range of vehicles, e.g. all-terrain mobile robots.

## TECHNICAL DESCRIPTION

The designed traveling base consists of four major subsystems: driving, transmission and motion delivery, body connection and control system. The overall shape of the base resembles a spider with all the electrical components contained inside its body. The prototype base is controlled through a four-channel remote controller.

The base can transform into different poses by adjusting the active length of the linear actuators. In the driving position, linear actuators are fully



Fig. 14.14. Driving Position of Prototype.

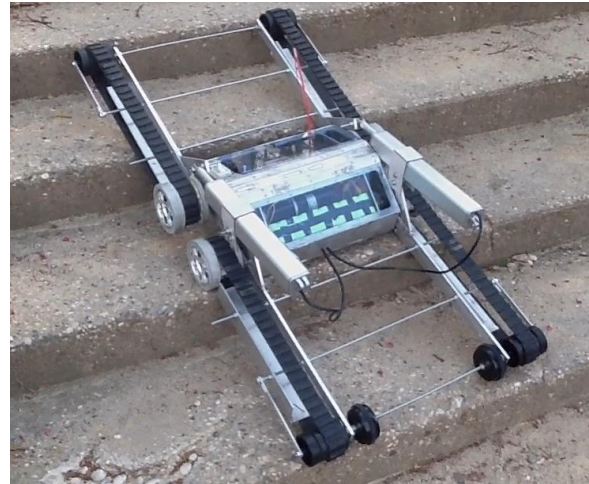


Fig. 14.15. Climbing Position of Prototype.

extended, and the base reaches its highest level. The gear motor delivers force through the sprockets and shafts to the body wheels. By rotating the belt, the force is delivered to the driving wheels which directly contact with ground, and the whole base is travelling. In the case of climbing stairs, the linear actuators shrink until the belt holder is parallel to the ground. In this way, the contact surface between the belt and the ground is large enough to drive the base upward or downward by the friction force.

Due to the constraints in manufacturing and cost, a scale-down prototype was fabricated. The body material used 6061-Aluminum, the actuator holder was made of 4130-Steel sheet, the wheels were made of plastic, and the belt was made of rubber. As a result, the allowed external load to the prototype is

about 60 pounds in the normal driving position. A full-scale base would be able to support a payload of 250 pounds.

The cost of the parts and supplies for this project was \$1250.

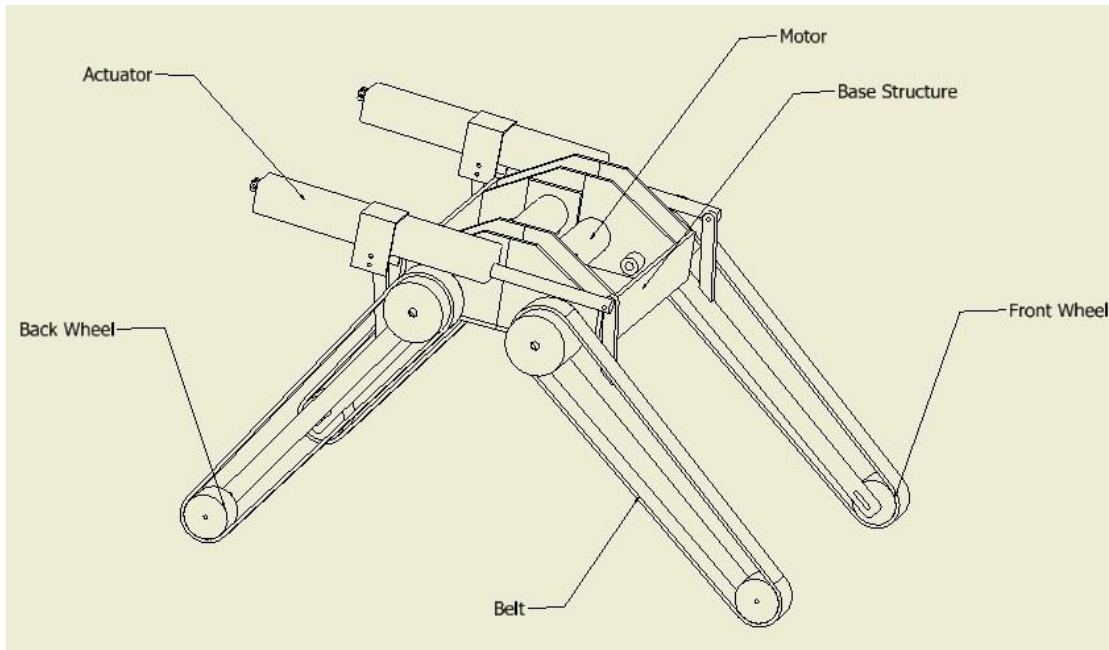


Fig. 14.16. Design of All-Terrain Traveling Base.



# VARIABLE-RESISTANCE ARTHRITIC ORTHOPEDIC

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## INTRODUCTION

The objective of this design project is to design a device that reduces the effect of mild arthritis and aids in leg injury rehabilitation. The device has two main features. Firstly, the device will act as a knee brace to support the joints. It takes the excessive pressure off the knee which would otherwise be experiencing the effects of vertical forces. It will result in less wearing of the cartilage in the knee, and the user will not feel as much pain. The second feature is the resistance mechanism which will add resistance against the motion of the knee joint to help strengthen the muscles and ligaments surrounding the knee. The resistance can be adjusted, depending on the effort needed for effective use.

## SUMMARY OF IMPACT

People who suffer from knee arthritis experience discomfort as a result of excessive vertical forces on the knee. In most knee arthritis cases, the muscles and ligaments of the leg are too weak to support the knee. This can cause knee joint to wear and a considerable amount of pain. By acting as a knee brace, the device provides support to the muscles and ligaments surrounding the knee. On the other hand, used as a resistance training device, it builds muscle and ligament strength. By increasing the strength of muscles and ligaments in the leg, the knee will be better supported.

## TECHNICAL DESCRIPTION

A resistance mechanism is attached to a knee brace in place of a standard hinge. The user can select the appropriate force range by turning a handle and then locking the mechanism with a thumbscrew. Thus, as the user walks, he will feel a resistance to the motion of the knee.

The key component to the resistance mechanism is a spiral torsion spring that has its center fixed to a hexagonal shaft. The outer edge of the spring is

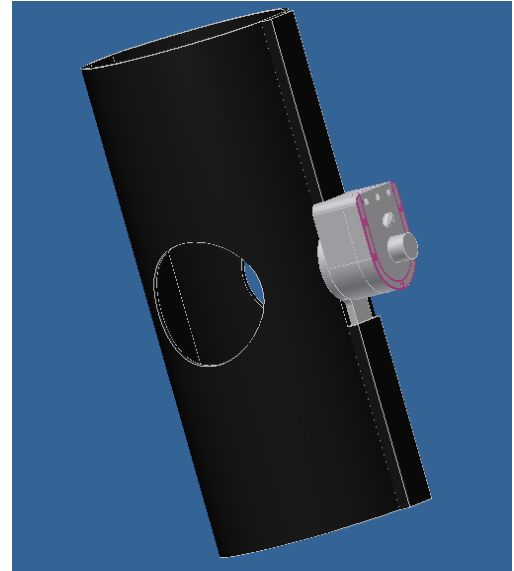


Fig. 14.17. Variable-Resistance Arthritic Orthopedic.

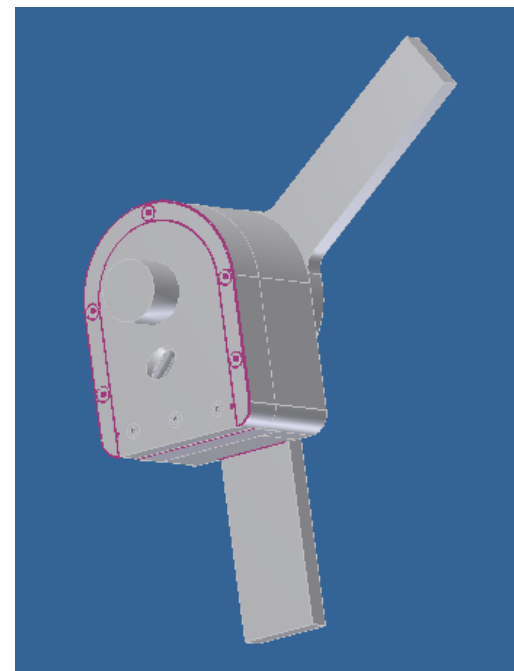


Fig. 14.18. Resistance Mechanism.

constrained to the lower leg, attached to the user's upper calf. As the knee is flexed, the end of the spring undergoes deflection and the resulting force acts in the opposite direction to the movement of the calf.

In order to control the preload on the spring, a ratchet mechanism is used which consists of a ratchet wheel, two pawls and a cam. The two pawls constrain the ratchet wheel from spinning in a certain direction. The cam engages with the pawls at four specific rotary positions, moving them in and out of contact with the ratchet wheel. Rotating a thumbscrew connected to the cam allows the user to choose between increasing the preload, locking the

mechanism, decreasing the preload, and a zero resistive force mode. All of these components were made of 303-Stainless Steel.

The outer casing contains the spring as well as the ratchet components, and is made of 6061-Aluminum. It is attached to the two hinge plates via a press fit bushing. These hinge plates fit into sleeves on the side of the knee brace. The compact design allows it to fit on the knee brace in place of the preexisting hinge.

The cost of the parts and supplies for this project was \$235.

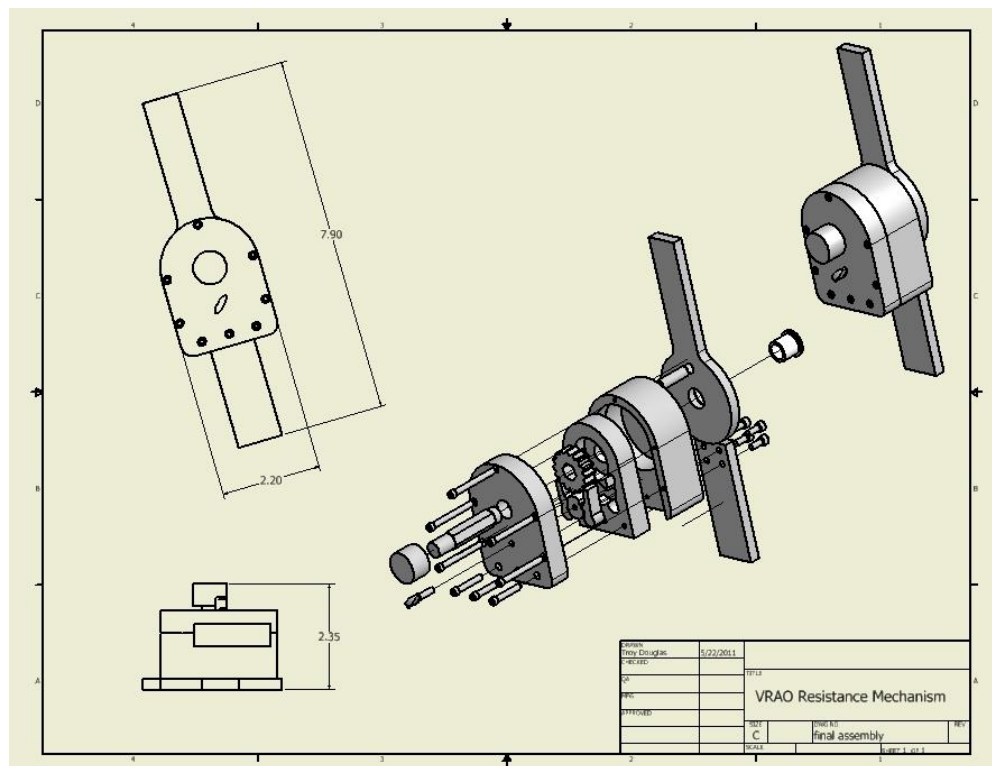


Fig. 14.19. Design of Resistance Mechanism

# HAND DRIVEN TRICYCLE

*Designers: Thomas Caldecutt and Lang Lang  
Supervising Professor: Dr. Yu Zhou  
Department of Mechanical Engineering  
State University of New York at Stony Brook  
Stony Brook, NY 11794-2300*

## INTRODUCTION

A hand driven tricycle was custom designed for a client to enforce the use of and thus exercise his weakened left hand and arm while providing mobility. An assistive device taking into account such types of imbalance is, in general, not available on the market. To provide a solution, a standard tricycle was modified with a new hand crank mechanism that enforces the engagement of the user's left hand and arm. The tricycle becomes drivable only when the left hand and arm applies sufficient force. In this way, the tricycle provides a rehabilitative function to the weak side of the user. While the tricycle is driven by hands, it is steered by feet.

## SUMMARY OF IMPACT

Designed for the specific client, the hand driven tricycle will help to improve muscle mass and increase the strength of the user's left hand and arm to help the client recover from his weakness. This design can also be easily adapted to fit with people with right side weakness. It provides an effective and economic rehabilitative solution for this specific category of potential clients.

## TECHNICAL DESCRIPTION

The entire system was designed and prototyped by modifying a Schwinn tricycle such that the client can use his arms and hands to pedal with a hand crank. The original pedals were removed. A hand crank and sprocket-chain set were added to the frame of the tricycle in front of the user, which work with the existing sprocket-chain set to transfer the power from the hand crank to the rear wheels. The hand crank has two handle grips for the user to hold. The input to the system will be the user rotating the hand grips. By turning the crank, the user will be producing the motion necessary to move the tricycle. This motion will be transferred, in sequence, from the hand crank to the rear wheels.

In order to enforce the use of the client's left hand, a left hand handle grip has been specially designed. For



Fig. 14.20. Prototype of Hand Driven Tricycle.

the left hand grip, the input will be the user pulling a slider to the left from its original position. This sliding motion will disengage the brake mechanism that acts against the driving system. The brake mechanism works by clamping onto the sprocket so that the friction safely slows the user down. Since this sliding motion alone does not exercise the users left arm, a spring is added to the slider, which constantly exerts a force to pull the slider back to its original position. In this way, the user will need to apply a constant force output which will help to build muscle strength. The spring constant is chosen so that the force required is substantial to the user but not so large that the user would become fatigued.

The hand driven tricycle has a separate input for turning which is provided by the footrest attached to the front fork. The input to turn will be applied by the user pushing or pulling the left or right foot. The cost of the parts and supplies for this project was \$400.

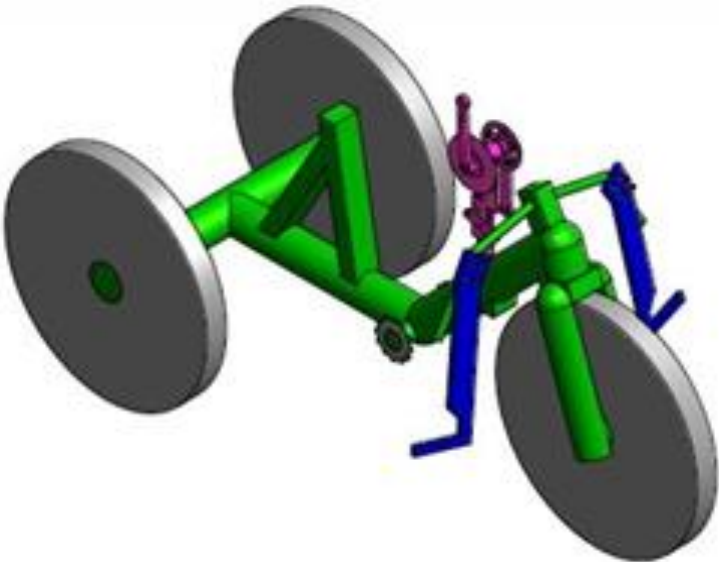


Fig. 14.21. Design of Hand Driven Tricycle.

# MEDICAL STANDUP WALKER FOR CHILDREN

*Designers: Sylvie Choucri, Peter Golaszewski and Huiheng Lin  
Supervising Professor: Dr. Anurag Purwar and Dr. Yu Zhou  
Department of Mechanical Engineering  
State University of New York at Stony Brook  
Stony Brook, NY 11794-2300*

## INTRODUCTION

Diseases such as polio, muscular dystrophy, multiple sclerosis and many more affect a child's ability to stand up and move around under one's own power, decreasing the ability to do many things other children take for granted. This project introduces a device that helps children with the above disabilities to stand up from a sitting position and walk around.

## SUMMARY OF IMPACT

The standup walker we designed provides a valuable assistive device to children with difficulty in standing up and walking around. This device will make those children less dependent on caregivers. With little effort, they can stand up and move around on their own. This will have immense impact on the children's development, in particular enabling them to interact more with their peers and participate in more activities.

## TECHNICAL DESCRIPTION

The principal mechanism of the device is two sets of four-bar linkage. The length of each bar (coupler, crank and rocker) is carefully calculated to imitate a natural standing up or sitting down motion path. The motion of each four-bar linkage is provided by a linear actuator attached to the frame and to the rocker. The user controls the lifting or lowering motion by a switch connected to a 12-volt battery, activating the linear actuators.

The frame is made out T6061 aluminum alloy for light weight, strength and machinability. It is adjustable by sliding bars and pins in the horizontal direction for different widths and lengths. The lengths of the bars of the four-bar linkages are also adjustable. The motion of the four-bar linkages may also be stopped at any height, providing for adjustability in the vertical direction.



Fig.14.22. Prototype of Standup Walker.

Four swivel wheels are attached at the bottom of the frame to provide mobility and are lockable for safety.

The support to the user is provided by a rock climbing harness, which is attached by S-hooks to the crank and fits kids ranging from 35 to 110 pounds.

The cost of the parts and supplies for this project was \$810.



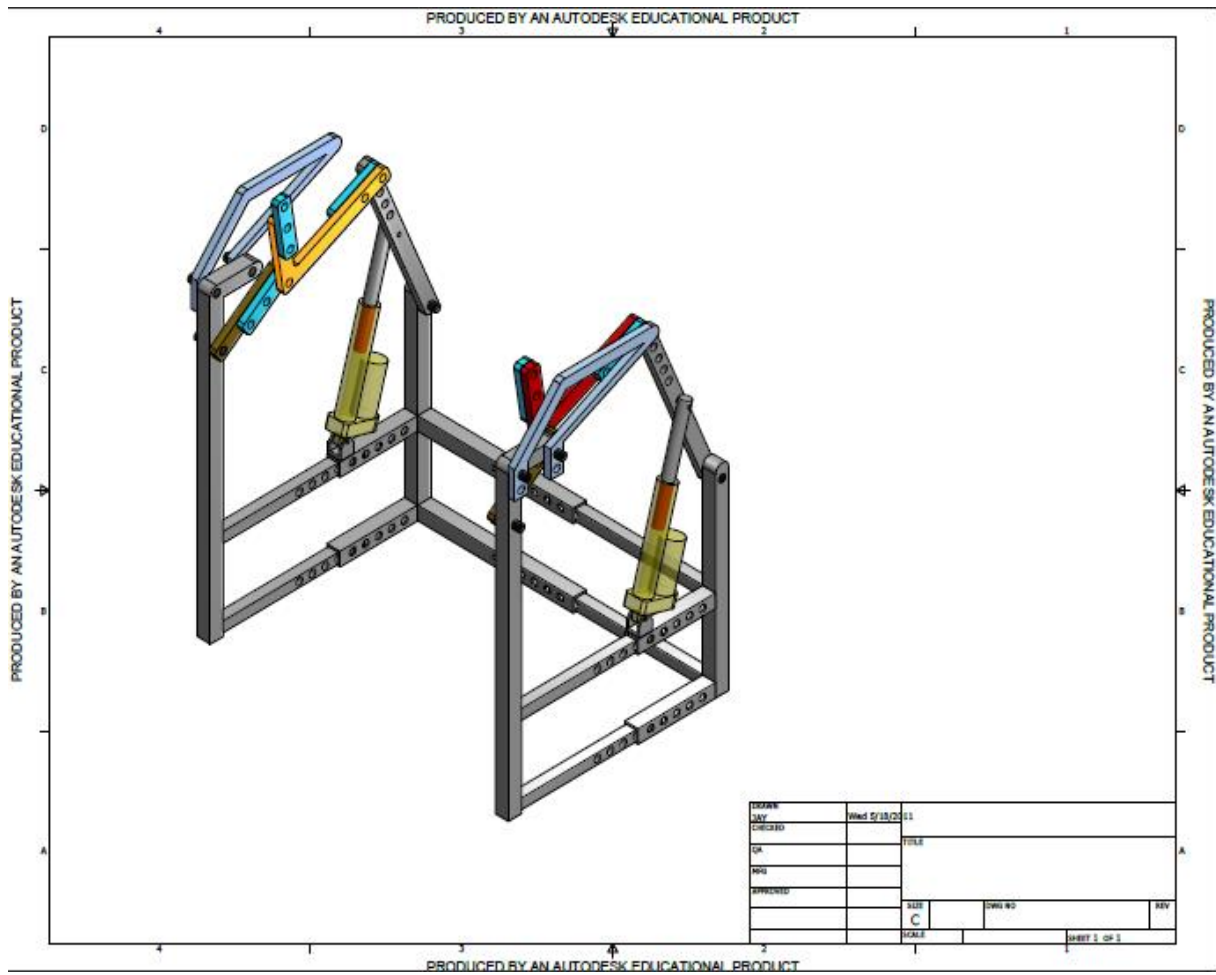


Fig.14.23. Design of Standup Walker.



# CHAPTER 15

## TULANE UNIVERSITY

School of Science and Engineering  
Department of Biomedical Engineering  
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### Principal Investigator:

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# THE ROCKAWAY: THE WHEELCHAIR GLIDING SYSTEM

*Student Designers: Mikolai Altenberg, James Barrios, Amaris Genemaras, Martin Sosa  
Client Coordinator: Manda Mountain; St. Margaret's, New Orleans  
Supervising Professors: Dr. David Rice, Dr. Annette Oertling  
School of Science and Engineering  
Department of Biomedical Engineering  
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New Orleans, LA 70118*

## INTRODUCTION

St. Margaret's Daughters Nursing Home plans to add to the intergenerational activities available to its residents. One traditional activity is a senior rocking a baby or small child in his or her lap. Since many of the residents use wheelchairs, this presents a problem. These residents are often unable to transfer between their wheelchair and a rocking chair independently, and since they are very reluctant to ask for assistance to do so, they would be left out of this activity.

Our design includes a wood frame that surrounds, on three sides, a wheelchair platform. The platform is supported at its corners by four steel bars. These bars terminate on simple bearings that allow the platform to move forward and backward while staying parallel to the ground. This provides the simple and comfortable motion of gliding chairs. A ramp permits the wheelchair user to mount the platform. A single lever raises the ramp upright so that the wheelchair is locked into position on the platform.

Motion is initiated when the wheelchair user pushes against the stationary footrest or by pulling on the handrails.

## SUMMARY OF IMPACT

"Boy, oh, boy, did they do a good job!" exclaimed the resident at the home who was the first to try out the new rocker. The first time she tried it, she was able, all by herself, to mount the platform, lock in her wheelchair, and begin rocking. She noted as well that it would be a nice place to read a book.

Some wheelchair rockers are commercially available, but these are difficult to access independently and present stability, comfort, or safety issues.



Fig. 15.1. The Rockaway with client. Photo by Guillermo Cabrera-Rojo.



Fig. 15.2. Shown is the ramp with continuous hinge, return spring, cable, and cable housing.

The Rockaway is attractive to the residents and staff because its surfaces are wood, a familiar material, and the sides is painted to resemble a New Orleans streetcar, an iconic mode of transport in New Orleans that has a distinctive rocking motion.

"There's nothing more beautiful than intergenerational interaction," said the St. Margaret's administrator.

## TECHNICAL DESCRIPTION

The wheelchair gliding system consists of three basic components: 1) a wraparound frame topped with handrails that supports a footrest and a rocking platform; 2) a suspended rocking platform; and 3) an approach ramp with latching lever and cable system to secure the wheelchair during rocking.

The frame is made primarily of wood. This material was requested by the Home because of its friendliness and non-institutional look, and because the staff knows how to maintain it. The footprint is 45.5" wide by 60" long. The sides are 30" high, the back is open, and the front is "dropped" to keep the user from feeling confined and to give the staff better visibility.

The platform is made of three-quarter inch birch plywood, 40" wide and 32" long. Side and front rails form guides and stops for the wheelchair and stiffen the structure. Four steel bars, 1/8" x 1" x 28" with simple end bearings, support the platform from the frame. Each side of the platform is a four-bar mechanism (the bars are the two suspension rods, the platform itself, and the frame from which the rods

swing) that keeps the platform parallel to the floor while it swings back and forth. The platform is suspended one-half inch off the ground and can swing five inches in either direction reaching a maximum height of 1.0 inches.

The ramp permits independent access to the platform. A 35" continuous hinge fastens the ramp to the rear of the platform (see Fig. 15.2). The ramp is tapered to minimize the bump on entry. Two spring mechanisms from snap rattaps hold the ramp to the floor. A strip of rubber mounted beneath minimizes skidding. A J-hook toggle clamp (DE-STA-CO model 371) operates the cable system. Aircraft cable routed through bicycle brake cable casing pulls the ramp to vertical. This action releases the friction and secures the wheelchair in the platform.

The action of the toggle clamp is straightforward, and its position is visible to the user and others. Rocking is initiated by pushing on the footrest or by pulling on the handrail. We considered motor driven rocking, but found that the system didn't need it.

Safety is paramount. Regular maintenance and inspection of wear points is specified. The platform is designed to work with a 400 lb. load, but overloading causes no harm to the user or the rocker. The platform will deflect to the floor, preventing any lateral motion, and the floor will support the excess weight. Overloading causes no damage to the system.

The cost to replicate the wheelchair rocker is approximately \$400.



# THE GYRO-RYDER: A HORSEBACK RIDING SIMULATOR

*Designers: Seth Figueroa, Tyler Humphrey, Lindsey Shepard, Christina Yee*

*Client Coordinators: Carrie Cassimere*

*The Chartwell Center, New Orleans, LA 70115*

*Supervising Professors: Dr. D. A. Rice, Dr. D. P. Gaver*

*Department of Biomedical Engineering*

*Tulane University*

*New Orleans, LA 70118*

## INTRODUCTION

A local school that serves autistic children ages 3-18 uses equestrian therapy. The educational goals, which are individualized for each student, include balance, following instructions, and learning cause and effect. To provide additional practice opportunities and better prepare students for horseback riding, the school requested a simulator that could be used for longer periods under the attention of fewer staff. Because the stimulator training was to prepare for horseback riding, the details of mounting the horse, sitting in the saddle, and holding and using the reins had to be similar.

The Gyro-Ryder is a horseback riding simulator with a regular saddle and interchangeable reins. It is mounted on a pivoting post and is guided by an internal gyroscope. Pulling on the reins tilts the gyroscope, and momentum transfer causes the body and the rider to turn in the direction of the pull. The reins provided are standard, color-coded, or padded.

## SUMMARY OF IMPACT

The school reports, "The Gyro-Ryder horse simulator ... has been such a wonderful asset to our students in so many ways. It has become a motivator for one of our students, who has refused to even attempt to get on the horse for the past 3 or more years, to actually get on the live horse at the stables because he has found stability and consistency with the horse simulator. It has allowed some of our other students to practice and generalize motor planning steps required for getting on and off the horse. Other students have been able to practice the motor planning skills to use the reins, guiding the horse to the left or right. Some of our younger students are learning and practicing following directions for 'pull,' 'red,' 'blue,' 'left,' and 'right,'"



Fig.15.3. Team member demonstrating the simulator.

## TECHNICAL SUMMARY

The Gyro-Ryder comprises three main parts: 1) The body assembly, 2) the base support and bearing system, and 3) the gyroscope assembly.

An 18" diameter HDPE drainage pipe forms the structure of the body assembly. It sits on vertical steel shafting 5.5" long that fits into the base support. The shafting is welded to a steel plate that is through-bolted to an internal steel plate. A brown blanket for a horse like appearance covers the body.

The plywood base support is 48" in diameter and is laminated to a thickness of 1.5". A 2.5" x 14" schedule 40 steel pipe is welded to a flange that fastens at the

center of the base. This pipe contains thrust and roller bearings that accept the vertical shafting of the body and allow easy rotation.

Making the body and the base separable greatly simplifies transporting the simulator.

To avoid tipping, the base radius extends beyond the length of the body to insure that the overall center of gravity is always within its limits. The calculated strength of the body and base support and bearing system exceeds 600 lbs. applied anywhere. This strength, which was confirmed by proof testing,

provides safety factor of three with respect to the maximum expected rider weight.

The gyroscope system uses the GYROWHEEL bike trainer (<http://www.thegyrobike.com>). It is a battery powered gyroscope that replaces a bicycle wheel. We mounted it to the front fork of a bicycle and welded the fork to the steel plate internal to the horse body. The GYROWHEEL contains it's own battery, charger, and control switches which we left intact. To reduce sound level, we lined the horse body with sound absorbing material.

The total cost of this device is approximately \$900.

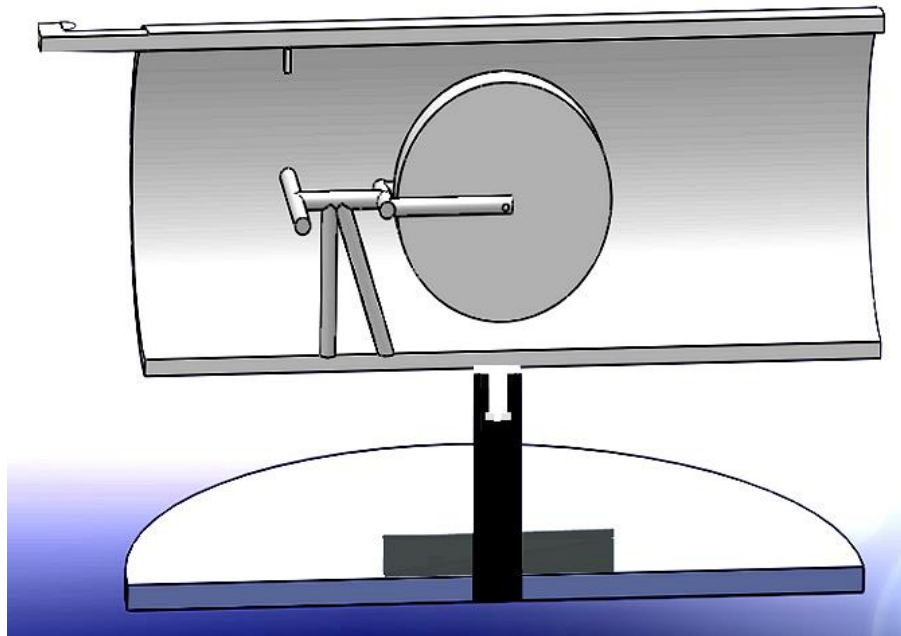


Fig.15.4. Cutaway view of Gyro-Ryder components.

# STIMULATORY DEVICE TO TREAT MANIC-ABUSIVE AUTISM

*Designers: Lydia Barrett, Theodore Brown, Renee Huval, and Nathan Pham*

*Supervising Professors: Dr. D. A. Rice, John Sullivan*

*Department of Biomedical Engineering*

*Tulane University*

*New Orleans, LA 70118*

## INTRODUCTION

Our client is a thirteen-year old autistic boy with self-abusive tendencies who slaps or pinches his neck, often breaking the skin. The goal of our project is to identify and test techniques that reduce injury to the neck. We took several approaches to minimize hand contact with the neck. The most successful of these is a neck vibrator. We modified a commercially available vibrating pillow by adding a remote push button switch that straps to our client's arm. When the button is pushed, a motor in the cushion vibrates. This design provides not only physical protection by surrounding the neck, but also a means for harmless self-stimulation.

## SUMMARY OF IMPACT

Self-abusive behavior is particularly difficult to handle in autistic individuals. They are often unable to communicate what is bothering them or causing the manic behavior. Our client appeared to slap because he needs to stimulate himself. Our design provides a separate channel for stimulation that he can control. The device does help deter client's self-abuse, but it was not always accepted by our client. The need for novelty, or lack of novelty, is common in people with autism disorders. Consequently we added a number of changeable covers with different colors and tactility, so that the teachers would have flexibility with using the device.

The lead teacher acknowledged that they had "a very difficult situation," and reported that "... I do see a decrease in the incidents of self-abuse in our student."

## TECHNICAL DESCRIPTION

We chose to modify a commercial product for the stimulator, the Homedics NMSQ-200 Neck & Shoulder Massager (amazon.com), because it (a) had all the necessary components, (b) it was battery operated, (c) was lightweight, (d) was cost-effective because of mass production, and (e) had a proven safety record.

We bypassed the vibrator intensity controls and removed the heating elements. Added wires connected the battery directly to the vibrator motor through the remote normally open-momentary contact push button switch (Jameco #26623).

The wires connecting the switch to the pillow went through a standard inline 1/8" audio jack and plug (Radio Shack 274-333 and 274-286). This allows easy button replacement and provides a safety "breakaway" feature should the wires become entangled.

The push button is encased by a Belkin Silicone Armband Case for 80/120 GB iPod classic 6G (amazon.com N14312). This case has adjustable straps, is easy to don and doff, and is comfortable to wear.

Approximate cost: \$39.48.



Fig.15.5. The stimulation device with button cable and connectors.



# A VIOLIN BOWING PROSTHESIS

*Designers: Hudson Chien, Joan Lien, and John Pitre, Jr.  
 Client coordinator: T. Fryer, Ochsner Hospital, New Orleans  
 Supervising Professors: Dr. David Rice, Dr. Cedric Walker  
 Department of Biomedical Engineering  
 Tulane University  
 New Orleans, LA 70118*

## INTRODUCTION

Our client is learning to play the violin. She has a congenital transradial amputation of her right arm and uses a myoelectric prosthesis to grip the bow. It does not work well because the gripping action can't hold the bow securely at the proper angle and the battery and motors make the prosthesis too heavy to hold in position for long. The best our client could manage with her existing prosthesis was fifteen minutes of light playing. We designed an alternative, the Violin Bowing Prosthesis (VBP), to minimize these problems.

## SUMMARY OF IMPACT

Our design maintains controlled bow position and minimizes total weight, so the user can comfortably practice for extended periods of time. On our client's first trial run with the VBP, she was able to don the device, strap the bow into the clamp, and practice for over an hour without fatiguing.

## TECHNICAL DESCRIPTION

Figure 15.7 shows the assembled prosthesis, and Figure 15.8 shows an exploded view of the VBP. This design comprises several component groups: The socket (A), the connecting rod (B), the clamp mount (D-H), and the bow clamp (I-K). Aluminum or thermoplastic form all parts except for the stainless steel screws.

The custom fitted socket with rod mount (A) is made of Duraplast, a standard thermoplastic for prosthetics. Shaping the socket was particularly challenging because below the elbow sockets typically have a lip that goes over the elbow to keep them from falling off. This lip reduces the range of elbow flexion, so a careful tradeoff between retention and range of motion needed to be made.

The rod (C) is an aluminum tube that is fixed to the socket by spring-pin (B). We used a pin, rather than a screw mount, because we needed to limit the

rotation of the rod. Interchangeable rods of different



Fig. 15.6. The violin bowing prosthesis in action.



Fig. 15.7. View of prosthesis without bow.

length permit large prosthesis extension adjustment.

The clamp mount (G) grips inside the tube by friction when drawbolt (H) pulls wedges (E) and (F) together. Pin (D) prevents wedge rotation during tightening. This arrangement is similar to a standard bicycle handlebar quill or stem assembly, and it allows fine angular and extension adjustments.

Rapid prototyping in ABS thermoplastic formed the bow clamp (I) and (K). The bow is placed between



the two custom pieces. A hook and loop fastener (not shown) holds the pieces together. The process can be done easily with one hand. The clamping is firm and, unlike some commercially available bow clamps, no

metal will touch the bow which minimizes risk to the bow finish.

The final cost of the VBP was \$ 73.20.

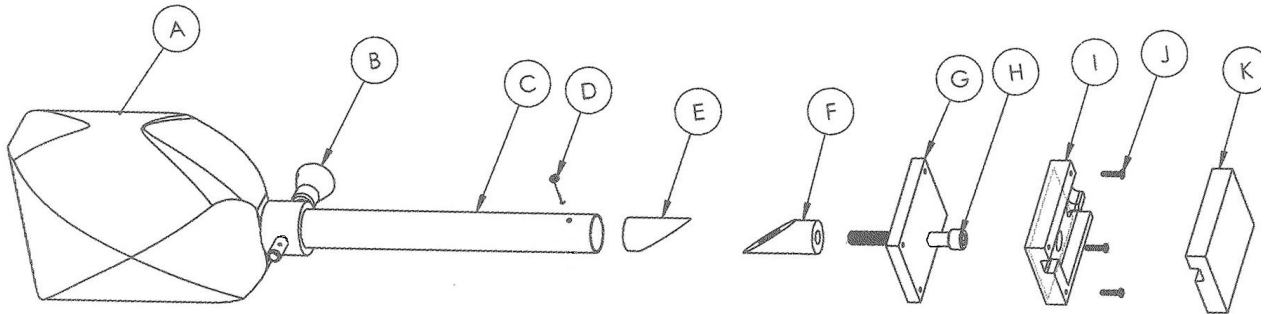


Fig.15.8. Exploded view of the VBP. See text for details.



**CHAPTER 16**  
**UNIVERSITY OF ALABAMA AT**  
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# WATERING ASSISTANT FOR KIDS WITH CEREBRAL PALSY

*Designers: Stacey Pest, Quinn Dunlap, Anastasia Wengrowski, Jessica Patterson*  
*Client Coordinator: Marliese Delgado, OTR/L; Hand in Hand, UCP of Greater Birmingham*  
*Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD*  
*Department of Biomedical Engineering*  
*University of Alabama at Birmingham*  
*Birmingham, Alabama 35294*

## INTRODUCTION

Hand In Hand (an affiliate of United Cerebral Palsy of Greater Birmingham) offers outreach programs for local families to facilitate the growth and development of impaired children by educating their parents to foster constant learning. Hand In Hand has a daycare facility where children can be assisted by skilled physical and occupational therapists, speech pathologists, and special instructors. Recently, a beautiful garden was donated to the facility for the children to enjoy. The faculty at Hand In Hand wanted the children, both wheelchair-bound and ambulatory, to be able to assist in the gardening process. However, the garden was inadequately designed for the children in wheelchairs to experience; the planter bed edges are too wide for the children to approach and assist with gardening.

Because people with motor disabilities have trouble getting enough exercise, horticulture therapy is a step toward activity, as it can help children develop leisure skills, participate in community activities, and gain a sense of responsibility. In order to facilitate such therapy, this design team developed watering constructs to assist wheelchair-bound children with cerebral palsy to garden at a local daycare. The major constraint in designing this apparatus was that it was adaptable for children with a range of disabilities/symptoms (GMFCS Levels IV-V) as well as a variety in children ages/sizes (2-5 years old). Marliese Delgado, a physical therapist at Hand In Hand provided a Big Red® switch, or a large button, as an easy operating mechanism for those with limited hand and arm motor function.

## SUMMARY OF IMPACT

This device will allow the children at Hand In Hand with the most severe disabilities to participate in outdoor horticultural activities. This allows them to be involved in outdoor activities with the less

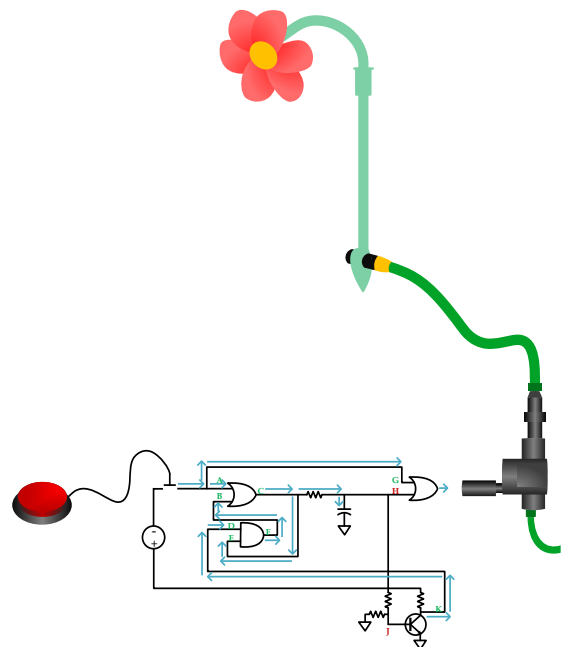


Fig. 16.1. Final circuit schematic including logic gates; the circuit links the switch to the sprinkler providing 10 second intervals of water discharge with each push of the switch.

severely disabled children of Hand in Hand, providing them with a sense of worth and accomplishment. It also provides the staff therapists with one more outside option to entertain the children on nice days.

## TECHNICAL DESCRIPTION

The completed device is an interactive switch-timer-valve assembly, including a switch, a latching solenoid valve, a hose, a shower head, and a logic gate circuit timer. Once the switch is pressed, current is sent through the logic gate timer, which opens the valve. While the valve is open, the RC circuit built

into the logic gate timer charges, allowing the appropriate watering time to be met (10 seconds). To account for the latching solenoid in the valve, the initial relay circuit was modified to include a logic gate circuit. As a result, the first pulse supplied by the logic circuit opened the valve, but a second pulse needed to be applied in the reverse direction to close it. Therefore, an H bridge and two LM555 timers were implemented. The H Bridge allows voltage to be applied across the valve in either direction. The two LM555 timers act more as safety mechanisms; the first

LM555 accounts for an extended button push, while the second LM555 regulates the long second pulse that results in closing the valve. A hose connects the valve to the shower head, while the shower head sticks directly into the soil. An enclosure contains the logic gate circuit, as well as the valve and switch connection wires, to ensure water-tight operation. The final circuit and device schematics are shown in Figure 16.2. The total cost for the completed device was \$1081.

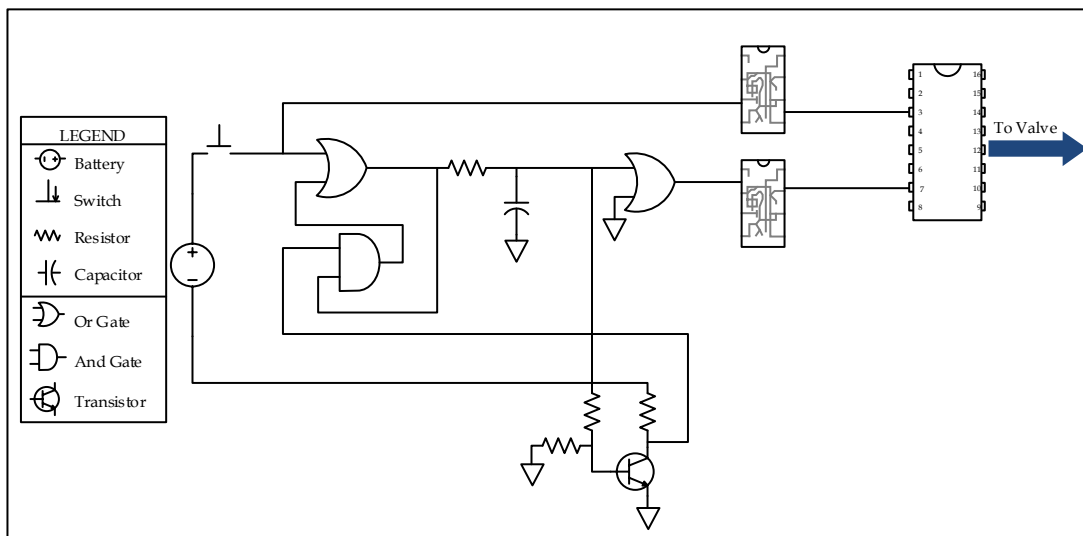


Fig.16.2. Final Device Schematics.



# AN APPARATUS TO INDUCE PRIMARY BLAST INJURY IN MICE

*Designers: Justin Chuang, Jose Roman, Adam Threet, Nathan Hadley*

*Client Coordinator: Candace Floyd, PhD, Department of Physical Medicine and Rehabilitation*

*Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD*

*Department of Biomedical Engineering*

*University of Alabama at Birmingham*

*Birmingham, Alabama 35294*

## INTRODUCTION

Explosive blasts have been the leading cause of casualties in recent wars, such as Operation Iraqi Freedom and Operation Emerging Freedom. Fifty-nine percent of soldiers that have been exposed to explosive blasts were diagnosed with traumatic brain injury (TBI), and in 44% of these cases, only a mild TBI was actually reported. It is thought that these TBIs are caused by blast overpressure waves produced from explosions. Overpressure is the immediate rise in pressure due to the explosive blast and is the maximum peak of blast wave. Primary injuries occur when the overpressure wave reaches the body and causes direct tissue damage. The current design focused on primary blast injury, that is, the direct damage from blast overpressure wave.

Our client's main research focus is the pathobiology or progression of central nervous system (CNS) injuries. Dr. Floyd's current research involves determining the brain injury threshold of a soldier after exposure to a blast wave. The present design project provides a primary blast injury device that was cost-effective, able to produce a repeatable injury, and able to mimic a mild human battlefield blast injury in a murine (mouse) model.

## SUMMARY OF IMPACT

This new device will permit our client to study how primary blasts are associated with subsequent disabilities caused by damage to the central nervous system. Operation of the final device is performed by a single operator, reducing operations costs. The apparatus is mounted on a laboratory bench or table using the included clamps and the wave absorber attached. A desired distance for the specimen restraint is chosen by moving the sliding base and set with clamps. The desired cartridge is loaded into the Hilti tool, and the tool closed. The sedated mouse is loaded into the specimen restraint and placed in the

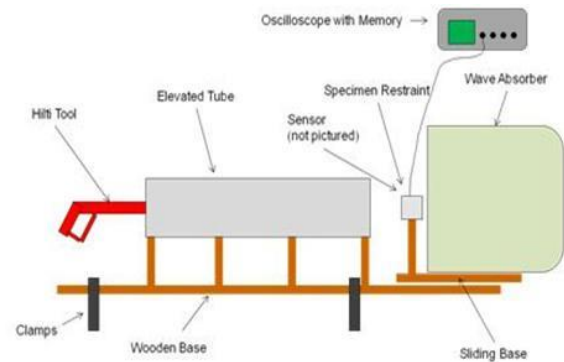


Fig.16.3. Two-Dimensional Schematic of final design listing all components.

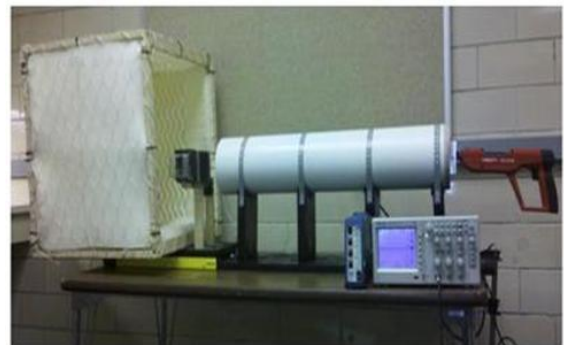


Fig. 16.4. Photograph of completed device installed in lab of Dr. Floyd.

mount at the appropriate orientation. The operator, with appropriate hearing protection, pushes the Hilti tool fully forward to disengage the safety, and then pull the trigger to initiate the blast. Afterward, the specimen is removed from the restraint and placed in a recovery area. Cleaning the specimen restraint, placing a fresh cartridge in the Hilti tool, and saving the data from the oscilloscope refreshes the set-up for the next specimen. Once all the data is collected, connection to a computer allows for use of the included GUI for analysis. This GUI processes the raw data and creates graphs and analysis of the data.

This processed data is sufficient to characterize the parameters of the blast wave.

## TECHNICAL DESCRIPTION

The completed design (Figure 16.4) consists of five subsystems: blast overpressure source, blast/shock tube, specimen restraints, pressure transducers, and rebounding wave absorber. The blast source selected was the Hilti tool, due to the very low maintenance and minimal modifications it required and its ability to produce reproducible pressures through the use of standardized charges. PVC (polyvinyl chloride) was the best alternative for the blast/shock tube. It was found to be the most cost efficient, easily manipulated, strong but lightweight, and would be the easiest to modify. The material used to construct specimen restraint was Plexiglas, due mostly to its low cost and easy manipulation. Design for specimen restraint consisted of a box to contain the specimen, while providing head isolation and stabilization. The

restraint was mounted to a sliding base so that different desired peak overpressures can be achieved. The pressure transducer chosen was a PCB Piezoelectric transducer Model 101A06 is an ICP (Integrated Circuit Piezoelectric) Low-Impedance Quartz Pressure Sensor. It has a measurement range of  $\pm 5$  Volts output with a maximum pressure of 3450 kPa. It has a built in amplifier that converts high impedance charge into a low impedance voltage that is displayed on the oscilloscope, which is the final piece of the system. This device displays the graph of the wave in Volts/Time. The voltage can then be converted into standard units of pressure using tables that are readily available. The rebounding wave absorber was made up of inexpensive mattress foam surrounding a wooden cube frame covered in chicken wire. In addition, a MATLAB Graphical User Interface (GUI) was developed in order to minimize the operator's fluency in programming language. The total cost of the design was \$1160.

# A WHEELCHAIR TILT-COUNTER TO SUPPORT THERAPEUTIC RESEARCH OF PAIN AND CEREBRAL PALSY

*Designers: George Waits, Chin Siu, Binh Vu, Russell Fung*  
*Client Coordinator: Laura Vogtle, PhD, OTR/L, Division of Occupational Therapy*  
*Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD*  
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 Birmingham, Alabama 35294

## INTRODUCTION

This design seeks to provide enabling technology to the UAB School of Health Professions by providing a means of measuring the tilt angle of a Tilt-in-Space wheelchair used by people with cerebral palsy and other conditions. Specifically, faculty member Dr. Laura Vogtle (Occupational Therapy) studies the painful effects associated with the sedentary habits of those with motor impairments including those with advanced levels of cerebral palsy and spinal injuries. To determine whether, and the extent to which, tilting behavior affects the level of pain experienced by wheelchair users, Dr. Vogtle requested a device capable of automatically measuring and recording the time-dependent tilt angle of various tilt-in-space wheelchair models. Once constructed, the device would be used on wheelchairs at Birmingham's United Cerebral Palsy daily-care facility LINCPoin.

## SUMMARY OF IMPACT

The tilt sensor system will be used by Dr. Vogtle and the staff at LINCPoin in order to test the tilt-pain hypothesis. This device will be used to study the tilting habits of those using wheelchairs as their primary mobility source. A self-report pain level scale will be employed as a means of associating the tilt behavior with pain data. The aim of these studies is to develop therapeutic tilting norms with the goal of reducing wheelchair-related pain.

## TECHNICAL DESCRIPTION

The student team arrived at an accelerometer-based design, stored on-board the sensor, through which tilt angle and duration data are transferred to a computer via USB where data analysis is facilitated using a MATLAB guided user-interface program (Figure 16.5). The program converts acceleration data to the tilt vs. time data specified by Dr. Vogtle. A tri-axial



Fig. 16.5. Accelerometer mounted on wheelchair.

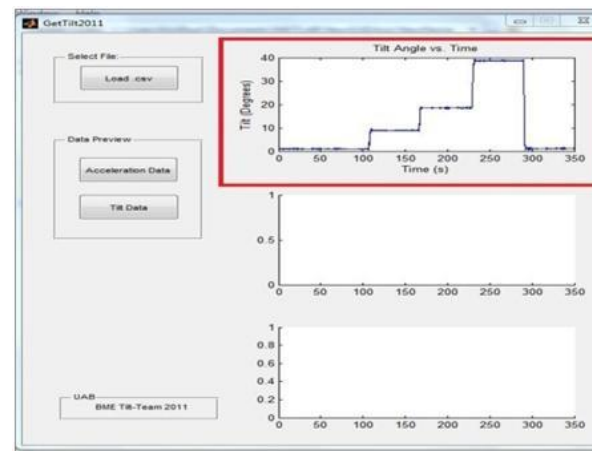


Fig. 16.6. GUI for data interpretation.

low noise Gulf Coast X6-2 Accelerometer is mounted on the wheelchair with a bicycle mount to enable sensor alignment. The long axis (X-axis) of the sensor is mounted parallel to the ground while the sensor

base is oriented perpendicular to the ground. Raw data logged by the X and Y-axes are saved in \*.csv format and transferred to the computer using USB drive. To convert raw data to tilt data, a user-friendly Matlab GUI was constructed. During data processing, the raw data is divided by a constant value of 16,384, as specified by the user manual, to obtain acceleration data. Since both the X and Y axes are experiencing a change of acceleration due to tilt motion, the following equation is used to convert

acceleration data to tilt angle:  $\theta = \arctan(g_x / g_y)$ , where  $g_x$  and  $g_y$  are the accelerations due to gravity in the x and y sensor axes respectively, as illustrated in Figure 16.7. Tilt data is then filtered by a stationary-magnitude filter and a moving average filter to reduce noise caused by translational motion. Finally, the GUI exports the data into an EXCEL spreadsheet \*.xls providing the client with tilt data in degrees corresponding with the time in seconds.

The final cost of the device was just under \$160.

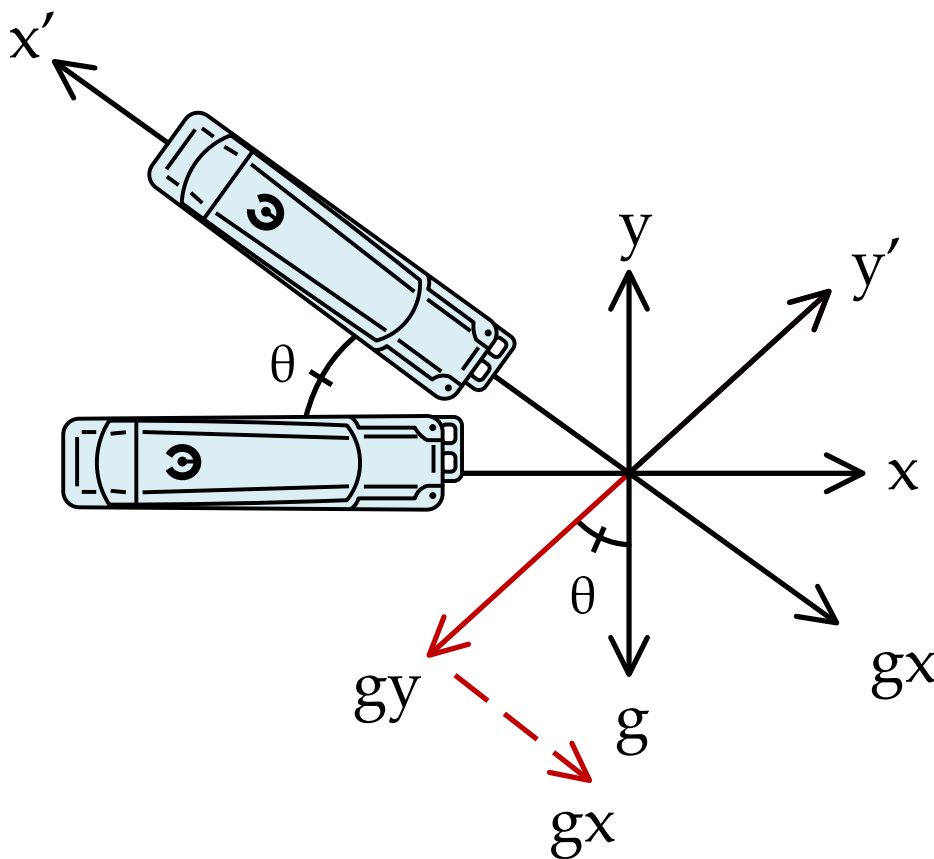


Fig.16.7. Sensor orientation and determination of tilt angle based on acceleration components.

# A BUBBLE TOWER FOR ADULTS WITH CEREBRAL PALSY

*Designers: Ron Baxter, Charles Moore, Joseph Pak*

*Client Coordinator: Jessica Morrow, PT, LINCPoint, UCP of Greater Birmingham*

*Supervising Professors: Alan Eberhardt, PhD, Dale Feldman, PhD*

*Department of Biomedical Engineering*

*University of Alabama at Birmingham*

*Birmingham, Alabama 3529*

## INTRODUCTION

LINCPoint is a non-profit organization that provides a variety of opportunities to patients ranging from treatment to a paid work experience. Patients with more severe developmental disorders, those most likely to take advantage of aural-visual stimulatory devices, are cared for by attending personnel and are provided everything from physical therapy and skill training to craft projects and other stimulatory tasks designed to improve quality of life. Patients with cerebral palsy (CP) can display sensation, perception, concept formation, and symbol formulation deficiencies, which can greatly inhibit learning, reasoning, and general cognitive function. Sensory stimulation is one of the older treatment methods used in the care of patients with CP and studies indicate that combined aural-visual treatment results in improved motor control for CP patient motor function.

Jessica Morrow, physical therapist at LINCPoint, requested an improved bubble tower based on a previous design for users suffering from a variety of mental and physical abnormalities that limit their range of muscle control. The design constraints included integrating the bubble tower with the LINC Point Multi-Sensory Room. There would be a base that will sit in a corner of the room with enough height for users to sit. A pad must be present on the top of the base on which users can sit. The tower itself must be a clear cylinder with dimensions of a 10" outer diameter and 5-7 foot height. There must be an option of giving a user of the tower control of forming a "burst" of bubbles by pressing a switch held by the user. Lights must be present within the bubble tower and within a bundle of fiber optic cables that can be held and must offer an array of changing colors.

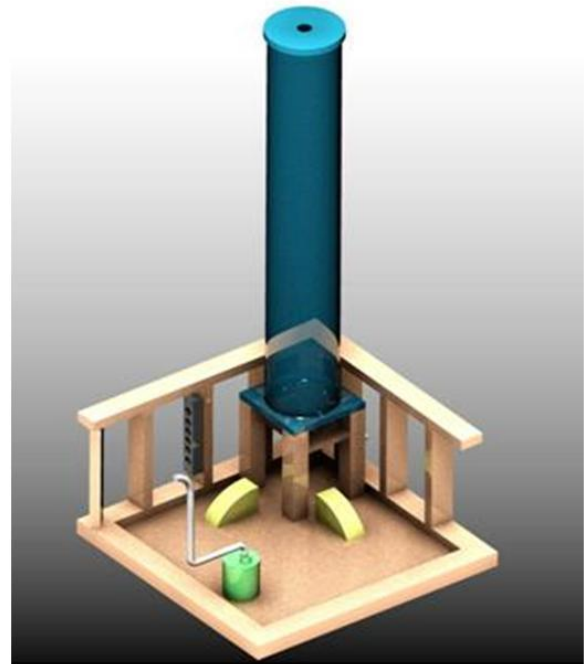


Fig. 16.8. CAD drawing of the bubble tower, which contains two pumps for generating bubbles lit by multi-colored LED lights, which are controlled by persons with disabilities.

## SUMMARY OF IMPACT

According to physical therapist Mr. Billy Ronilo, before an insurance company is willing to provide powered wheelchairs to children with cerebral palsy (CP), the children must demonstrate their ability to use the wheelchair effectively. The completed device allows Mr. Ronilo to more efficiently and effectively use his time in traveling to clients' houses to train their children disabilities to drive the wheelchair.

## TECHNICAL DESCRIPTION

The major components are the (a) base, (b) tower, and (c) the electrical components (lights, pumps, IR repeater, and power strips). The bubble tower



functions as a tower filled with water with air bubbles produced at the bottom via air pumps. Check valves are used to prevent water backflow into the air pumps. Illumination of the tower is produced by 4 LED lights with remote controlled synchronized color changing capability. The base dimensions are 40in x 40in x 20in, and a tube height of 5ft and diameter of 10in. The base frame is made with 2in x 4in studs along a 2in x 4in outline, secured with braces, with a plywood top and bottom. It boasts an upholstered and padded seating area and an internal compartment in the base housing the electrical components, including the power strips (2), LED

lights (4), tower support posts (4), air pumps (2), base support posts (3), base roof runners (3), infrared repeater (1), infrared receiver (1), and infrared transmitters (4). The tower has a Plexiglass bottom with access ports for the air pump tubing, and drainage system, and the tube has a removable Plexiglass lid with an air pressure release port. The drainage system, constructed of PVC, has a garden hose adapter that allows attachment with a standard garden hose to allow easy drainage.

A CAD rendering of the final device is shown in Figure 16.8. The total cost was just over \$1,500.

# BAMBOO CRUTCHES FOR ZAMBIANS WITH DISABILITIES

*Designers: 20 teams of 4-5 sophomore engineering students = 98 students*

*Client Coordinator: Alan Eberhardt, PhD*

*Supervising Professor: Alan Eberhardt, PhD*

*Department of Biomedical Engineering*

*University of Alabama at Birmingham*

*Birmingham, Alabama 35294*

## INTRODUCTION

EGR 200, Introduction to Engineering Design, provides transfer students at the University of Alabama at Birmingham an introductory engineering experience, including a 5-week design project. This year, the authors led a project that involved the design of crutches for use in a developing nation that featured the use of “appropriate technology” regarding materials and construction techniques. The target country was Zambia, Africa, which is one of the poorest countries in the world. In Zambia, the majority of the population lives on less than \$2 USD per day. Lack of medical facilities and doctors leads to many serious health issues. Infection often leads to amputation, creating a need for low cost crutches.

The assignment was to design and construct bamboo crutches for use by an average man, woman or child (6-10 years old) in Zambia. What made this project unique were the design constraints, which included the use of sustainable materials available to Zambians (bamboo, sisal twine, wood glue, leather and burlap). The use of power tools was also forbidden, since it is unclear whether the SIFAT Center will have a consistent source of electricity. The overall goal was to provide crutch designs that could be translated to the SIFAT Center for mass production and use by local Zambians. In the first related lectures, the students were introduced to the design problem, EWB and SIFAT, and the associated issues of sustainability in developing countries like Zambia. Next, they were exposed to concepts in engineering design such as engineering sketches & computer aided drawing (CAD, Pro-E, Needham, MA), statics & free body diagrams, column buckling, stress analysis, and material selection and analysis using the CES Edupak software (Granta, Cambridge, UK). The students were required to build the devices themselves, and therefore attended a general lab safety seminar and subsequently spent three class



Fig. 16.9. A winning design and associated team members at the final presentation.



Fig. 16.10. Example completed crutch designs.

periods working on their projects in the School of Engineering (SOE) Design Lab. The students were required to present their final projects as oral presentations (using PowerPoint) and to submit a final written report, both of which were done as a team.

## SUMMARY OF IMPACT

The UAB section of Engineers without Borders (EWB) is currently involved in the development of a SIFAT (Servants in Faith & Technology) Center in Zambia. The purpose of the SIFAT Center is to provide training for persons interested in making a difference in the lives of poor people around the world. Last year a team of Mechanical Engineering senior design students developed a bamboo wheelchair and brought the design to Zambia with the EWB, in hopes of developing a sustainable manufacturing center within the walls of the developing SIFAT Center. This year, we hoped to extend those efforts by adding bamboo crutch designs.

The overall design project and educational experience was an overwhelming success. Based on the IDEA surveys, the majority of students worked well in their assigned teams, the SOE Design Lab facilities were adequate and the restriction to use only hand tools resulted in a safe and satisfying design

experience. Feedback from the design experience was provided by the students through the IDEA course surveys. Students were also encouraged to provide comments related to their overall experience with the design activities, working in a team, and their levels of confidence and enthusiasm to continue in engineering.

## TECHNICAL DESCRIPTION

Overall, 19 different crutch designs were completed using the appropriate technologies proposed. Many included the bonus feature of height adjustability. Examples of completed crutches are shown in Figure 16.10. Their final reports and presentations included engineering sketches and Pro-E drawings, free body diagrams for column buckling and stress analysis, as well as material analysis using the CES Edupak software.

The total cost of the designs associated with this course was roughly \$600.

# BAMBOO TRANS-TIBIAL PROSTHESES FOR ZAMBIANS WITH DISABILITIES

*Designers: Four teams of three students = 12 freshman Science and Technology Honors students*

*Client Coordinator: Alan Eberhardt, PhD*

*Supervising Professor: Alan Eberhardt, PhD*

*Department of Biomedical Engineering*

*University of Alabama at Birmingham*

*Birmingham, Alabama 35294*

## INTRODUCTION

STH 201, Research Approaches in Engineering, is a course for freshmen in the Science and Technology Honors program, which involves an introduction to the principles of engineering mechanics and materials, with an emphasis on engineering design. The students are introduced to computer-aided drawing (CAD), computer-aided manufacturing (CAM), machining processes, mechanical testing and failure analysis using light and scanning electron microscopy. This year, a 5 week design activity was included, where 4 teams of three students worked to develop prostheses for a trans-tibial amputee, using sustainable materials found in the country of Zambia. The assignment was to design and construct bamboo prostheses for use by an average man, woman or child (6-10 years old) in Zambia, who had suffered from a trans-tibial amputation. The design constraints included the use of sustainable materials available to Zambians (bamboo, sisal twine, wood glue, leather and burlap) and the use of power tools was also forbidden. The overall goal was to provide devices that could be translated to the developing SIFAT Center for mass production and used by local Zambians. In the first related lectures, the students were introduced to the design problem, EWB and SIFAT, and the associated issues of sustainability in developing countries like Zambia. Next, they were exposed to concepts in engineering design including

statics & free body diagrams, column buckling, stress analysis, and material selection and analysis using the CES Edupak software (Granta, Cambridge, UK). The students were required to present their final projects as oral presentations.

## SUMMARY OF IMPACT

These projects were also developed along with the UAB section of Engineers without Borders (EWB) and the development of a SIFAT Center in Zambia. With this project, we hoped to extend the offerings to include lower limb prosthesis designs.

The overall design project and educational experience was an overwhelming success. Based on the end-of-the-term surveys, the majority of students worked well in their assigned teams, and were extremely pleased with the experience and felt empowered to continue in their respective engineering disciplines.

## TECHNICAL DESCRIPTION

Overall, four different prosthesis designs were completed, as shown in Figure 16.12. The final reports and presentations included engineering sketches and Pro-E drawings, free body diagrams for stress analysis, finite element simulations, as well as material analysis using the CES Edupak software. The total cost of these projects was roughly \$200.



Fig. 16.11. Completed prosthesis design and team.



Fig. 16.12. Completed trans-tibial prosthesis designs.





# CHAPTER 17

## UNIVERSITY OF CONNECTICUT

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Biomedical Engineering  
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### Principal Investigator:

*John Enderle*

(860) 486-5521

[jenderle@bme.uconn.edu](mailto:jenderle@bme.uconn.edu)

# THE SMART KART: A RECREATIONAL VEHICLE FOR CHILDREN WITH DISABILITIES

*Designers: Solomiya Teterichko, Robert Amatuli and Cameron Fulton  
Client Coordinator: Janice Lamb, Stonington, CT  
Supervising Professor: Dr. John Enderle  
Biomedical Engineering Department  
University of Connecticut at Storrs  
Storrs, CT 06269*

## INTRODUCTION

The Smart-Kart is a recreational vehicle that was designed to provide entertainment and social interaction for an 11-year old boy with spina bifida and other handicaps. This two-seater vehicle (see Figure 17.1) is a gas-powered, joystick-steered device that allows the client to drive the vehicle thus interacting with friends and practicing his motor coordination skills. After device completion, the go-kart was presented to the client and his family to take to their home where they can use it on their extensive property. The client is preparing to transition to an electric wheelchair in which he will have to use a similar electric joystick. This go-kart will allow him to gain extra practice while having fun and enjoying the company of his friends and family. Abundant measures are taken to ensure the safety of our client while using the vehicle.

## SUMMARY OF IMPACT

The design of the go-kart was shaped by the client's desire to control an electrical powered vehicle, interact with his friends and family outdoors while keeping safety the priority. Due to the client's manual wheelchair, it is difficult for him to interact with his fellow classmates, especially outdoors. He also cannot enjoy his family estate due to rough terrain. This all-terrain go-kart would allow him to bond with his classmates on much deeper level and allow him to explore the family property. The client's physical therapist and tutor at school expressed that he has made tremendous strides academically, physically and socially. In order to continue on this path, the client needs better means of transportation (electric wheelchair) and socializing with his peers. The Smart-Kart will allow him to do both- bond with his peers while practicing using an electric joystick.



Fig. 17.1. The Smart-Kart.



Fig. 17.2. Linear actuators for throttle (above) and braking (below).

## TECHNICAL DESCRIPTION

The chassis of the go-kart is constructed from steel pipes, which assures strength and integrity to the vehicle. A bought chassis was modified in length, width, and sheet metal side panels were installed. This extended chassis makes it a comfortable two-seater and encloses the sides for protective purposes. The go-kart is gas powered and electrically controlled via two controllers: 1) a joystick that the client is able to use to the left of the driver seat and 2) an X-box

controller on the passenger side. The control mechanism (joystick versus X-box controller) can be changed on the vehicle's dashboard. Along with these two controllers, there is an additional kill switch on the dashboard, which will turn off all mechanical and electrical components on the go-kart. The vehicle is fully automatic with reverse. Throttle and hydraulic disk braking is controlled via linear actuators, which are mounted on the back of the go-kart as shown in Figure 17.2. The steering is controlled via a linear potentiometer that receives an input signal from the controller translating the linear motion into rotational motion of the Dayton 1L469 gear motor that is attached to the rack and pinion system. Rotational speed reduction is accomplished with a sprocket and chain system that is added to the rack and pinion system (Figure 17.3).

To start the go-kart, the key on the dashboard must be turned until the engine is in idle mode. An additional switch on the dashboard turns on all electrical components of the go-kart. There is also the switch for type of controller one wishes to use, a kill switch, and a switch for headlights. An alternator is used to constantly charge the 12V-9A deep cycle battery, which powers the electrical components. All software controls use the PIC16F877 microcontroller, which is part of the 16 series 8-bit Microchip controllers. Because there is a need for several PWM

output signal pins, three microcontrollers are used to adequately control all system components steering, throttle, and braking. All three microcontrollers are programmed used embedded C language. The microcontrollers take two modes of analog input: the joystick and X-box controller. Depending on the mode chosen on the dashboard, the microcontroller will activate the appropriate output pin to deliver the PWM signal to the speed controller, which then delivers it to the two actuators and steering potentiometer. Due to the client's inexperience with electric joysticks, an ultrasound sensor system monitors objects in front of the vehicle and initiates braking when objects are within an eight-foot range in front of the go-kart. This feature can be deactivated with a switch on the dashboard. The driver's seat supports the client's weak trunk and neck. Additionally, a footrest is mounted onto the floor of the chassis to ensure that the client's feet are kept safely in one place. A five-point harness with a latch-and-link quick release is also used for the driver seat. The passenger seat has a regular backseat belt. Both seats have reclining mechanisms and the driver seat has an additional adjustable armrest upon which the joystick is mounted. All terrain tires and double A-arm independent suspension allows for driving on rough grounds.

The cost of parts/materials was about \$4000.



Fig. 17.3. Steering system.



# THE ALL-TERRAIN POWER CHAIR

*Designers: Prince Alam, Marcus Chapman, and Mathew Kozachek*  
*Client Coordinator: Janice M. Lamb, 142 Barnes Rd., Stonington, CT*  
*Supervising Professor: Dr. John D. Enderle*  
*Biomedical Engineering Department*  
*University of Connecticut at Storrs,*  
*Storrs, CT 06269*

## INTRODUCTION

The all-terrain power chair was designed to travel on light trails and other locations that lack pavement and to be operated by Nathan, our client. The all-terrain power chair provides a way for his family and school district to include him in recreational activities without worry about his safety or comfort. All of Nathan's current assisted movement devices serve singular purposes. For example, Nathan's Standing Dani can only be used while standing up, is manually propelled, and can only be used comfortably on perfectly flat surfaces. Also, many of his devices are not intuitive to use. This is essential, so that anyone that helps Nathan into his device does so properly and without damaging the device. With all that said, the design team will also work to make a versatile, safe, and comfortable power chair that can easily be used by Nathan and his family in all sorts of terrain.

It is important to mention that there are other solutions available. However, these solutions are very expensive. A comparable all-terrain power chair retails for about \$16,995. To put this into perspective, someone can buy a car for that price, so the high price of such a device makes it cost prohibitive for many hard-working families. In addition, customizations make the commercial products even more expensive. Also, the devices that are more reasonable in price have limited capabilities on rough terrain. In addition, Nathan's family has special needs for the purposes of his power chair. Therefore, the all-terrain power chair will be designed to be rugged and ready for rough terrain, all in an easy-to-use package.

## SUMMARY OF IMPACT

Our client, Nathan Lamb, is a peaceful, charming, and delightful person to be around. This was reiterated when his parents discussed with the team how he gets a lot of friendly attention at school. It was obvious that he enjoys being outdoors with his family, therefore an all-terrain wheel chair would greatly increase Nathan's mobility and ability to



Fig. 17.4. The power chair.

enjoy activities with his family. It was apparent that due to his medical conditions, Nathan tends to fidget a lot when seated. He also has the tendency to keep his right arm high in the air, by his head. Consequently, the family requested that seating have a lot of support and be tilted at the correct angle. The all-terrain power chair is designed to allow him to further enjoy life with his family and friends by allowing him access to more places.

## TECHNICAL DESCRIPTION

The overall structure of the all-terrain power chair was made from aluminum square tubing (2 by 2 by .125 inch). This gave the power chair a high strength to weight ratio, which is characteristic of aluminum, provided the necessary structural integrity and low weight requirement needed for a portable device. It was designed so the main structure was welded at 90 degree angles. All other components were fastened to the frame by bolts.

The power chair uses four arms, one for each wheel, as shown in Figure 17.5. Bearings are attached to the lever arm at the top, which are mounted to the upper frame, to allow the arm to rotate. The springs are



attached to allow shock absorption from the terrain and have built-in bearings to allow for rotation at each attachment point. The motors are attached to the lever arms via custom-made mounting brackets. Each motor has large wheels directly attached. The wheel diameter is calculated to be optimal based on the maximum speed of 5 miles per hour. There are fully height-adjustable arm rests, a foot plate, and a head rest. The seat is easy to remove for transporting purposes by lifting a latch in the front and unbolting two screws in the back.

It is operated by a left-hand mount joystick and powered by 24V DC motors. It uses a rechargeable 12V deep-cycle lead-acid battery capable of supplying the chair with power for up to five hours of continuous use. A commercial motor controller controls the speed and direction of the motors with input from an analog bidirectional joystick.

Overall, the cost of all the parts was about \$2100.



Fig. 17.5. An arm of the power chair.

# CUSTOM TILT-IN-SPACE WHEELCHAIR

*Designers: Katie Guineau, Julia Olczyk, Ben Marcus*

*Client: Julie Miller, Clinton, Illinois*

*Supervising Professor: Dr. John D. Enderle*

*Biomedical Engineering Department*

*University of Connecticut,*

*Storrs, CT, 06269-2247*

## INTRODUCTION

This custom wheelchair was designed for a 16 year old girl with cerebral palsy, a muscle and development disorder which affects her motor skills and ability to move around. Since she is currently in a wheelchair for the majority of the day, the family asked us to design a custom wheelchair with a tilt-in-space feature to accommodate for Abby's growing needs. Abby's current wheelchair does not support her correctly and the padding needs to be replaced often due to wear. There were many issues that the family had with the current chair that they asked us to address in the new design, for instance 1) functional support for her back 2) larger headrest 3) prevention from slipping forward in the chair 4) uniform solid footrest. The wheelchair frame was donated by NEAT Marketplace in Hartford, CT and modifications were made to this chair to accommodate the family's requests. This wheelchair will ultimately provide comfort and support for Abby and her family. The completed customized wheelchair made for the Miller family is shown in Figure 17.6.

## SUMMARY OF IMPACT

This wheelchair was built to maximize comfort for Abby and to also address the support issues with her previous wheelchair. She will now be supported in all directions due to the incorporation of inflatable bladders to maximize support. Her new uniform footplate will allow the family to push her around without the fear of injury. The new larger headrest will prevent her from slipping off and hurting her neck and the new wedged seat cushion and safety harnesses will help the family to keep her in her seat without her standing up or slipping off. All of these customizations to the chair will allow Abby to be comfortable while providing her family with peace of mind that she is safe.



Fig. 17.6. Side view of the custom chair.

## TECHNICAL DESCRIPTION

The wheelchair, donated by NEAT, was an older Quickie Tilt-in-Space model that was customized to fit the customer's needs. The chair was stripped and sanded in preparation for powder coating. The powder coating company, Central CT Coatings, chromed the frame and then applied a clear purple coating to achieve the desired purple finish that the Millers requested. The chair was widened to fit the 17" seat so a new seat plate and foot plate had to be fabricated. The seat back was donated also from NEAT in Hartford but it was too narrow so new mounting hardware and brackets had to be designed. Into the seat back, bladders were incorporated to allow the family to adjust the support according to

Abby's changing posture. Two inch memory foam padding was added on top of the bladders to increase comfort. The head rest was mounted on to the center of the seat back. The headrest is fully adjustable to account for Abby's positioning in the chair. A chest

harness and safety lap belt was added along with solid urethane tires. Accessories such as cup holders were mounted for both the operator of the chair and for Abby. This chair is built to last and be used daily for many years to come.



Fig. 17.7. Demonstration of the tilt.



# THE BICYCLE SIDECAR FOR ABBY MILLER (CP)

*Designers: Michael Wieczerszak, Nicholas Ouellete and Elida Babollah*

*Clients: The Miller family specifically Abby Miller*

*Supervising Professor: Dr. John Enderle*

*Biomedical Engineering Department*

*University of Connecticut*

*Storrs, CT 06269*

## INTRODUCTION

The bicycle sidecar was developed for a young girl who struggles with Cerebral Palsy. Since she is unable to ride a bike by herself, the family has asked the team to design and build a sidecar that can attach parallel with a bike. The family had a pull behind attachment for their bike a long time ago, but Abby has outgrown it. The family wanted her next to them when they were riding so that they could talk to her and get her more involved in the experience.

The sidecar's seat was purchased from a company that specializes in chairs to support and keep children with disabilities safe. It was critical that this chair was used since Abby cannot support herself completely. The rest of the project was fabricated by the team to the custom specifications that were given to them. This sidecar will allow Abby to enjoy being on a bicycle and outdoors while still safely supervised by her parents. The sidecar is shown in Figure 17.8.

## SUMMARY OF IMPACT

The impact of this project on the family is significant. This sidecar will allow the family to take Abby with them when they go for bike rides. Not only will it make her more a part of their outdoors activities, but it will allow Abby to interact more with them during the experience. Previously, she had little to no interaction while behind them in the previous design, but being directly next to them will allow for communication. This sidecar will make her more mobile outside in a safe, yet enjoyable manner. The seat that was integrated into the project was of the same make, just larger, as the one that was used in the past. Overall this will allow our client to be more active and for her to enjoy being more active.



Fig. 17.8. Bicycle Sidecar.

## TECHNICAL DESCRIPTION

The sidecar was created using various parts to create a safe and structurally strong product. The frame of the sidecar, which supports all of the components, was created with 1.5 inch 6016 aluminum tubing. Using this material was key to create a frame that was as lightweight as possible yet had to strength that was needed to support the weight of the project. All of the welds of the aluminum frame were done at a 90-degree angle to ensure that all of the frame's pieces were as precise as possible. For the attachment of the seat, fenders and the footrests, a combination of screws and bolts were used. The attachment of the sidecar to the bike was done using rubberized ring clamps to the frame of the bike and screwed into the frame of the sidecar. The use of the Carrie Tumbleform Seat was essential to making this sidecar safe for Abby. This type of seat provides the necessary support for the back, neck and head, which was very important to her family. This sidecar allows Abby to enjoy riding next to her parents in a safe environment.

Total Cost of Sidecar = Approx. \$1,550

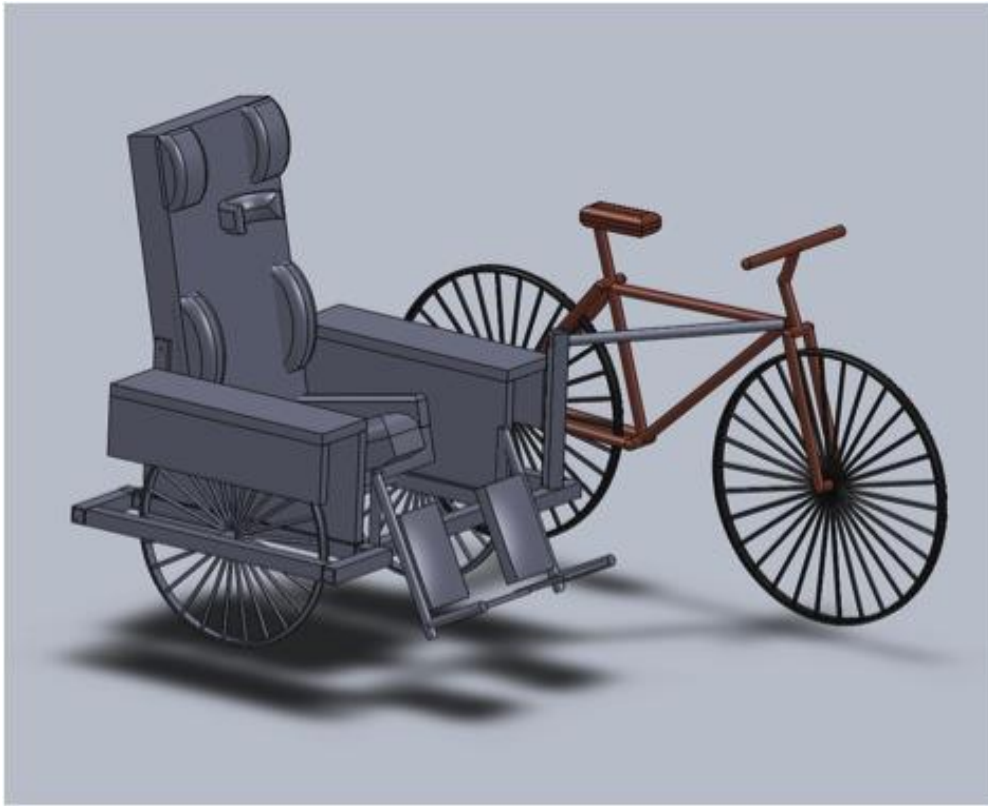


Fig. 17.9. SolidWorks Drawing of the Sidecar



# RECLINING BEACH WHEELCHAIR: A CHILDREN'S CHAIR FOR USE ON SAND

*Designers: Maya K. Alfonso and Kyle C. O'Brien*

*Client Coordinator: Marek Wartenberg*

*Supervising Professor: Dr. John D. Enderle*

*Biomedical Engineering Department*

*University of Connecticut*

*Storrs, CT 06269*

## INTRODUCTION

The beach wheelchair was designed to allow a portable and affordable beach transportation option for families with children with disabilities. A youth wheelchair was modified to take large, polyurethane tires, which will help the chair to float on top of sand. A defining characteristic of the chair is its ability to recline on a custom-built leg, attached to the back of the wheelchair. The reclining mechanism allows for the chair user to be tipped back (Figure 17.10), taking pressure off of the lower back and increasing comfort and circulation.

## SUMMARY OF IMPACT

The criteria for creating this beach wheelchair were outlined by the Davies family, a family with two twin boys who have spastic cerebral palsy. One of the boys, Jack, uses a wheelchair pushed by his family members to get around. The family vacations in Rhode Island every summer and has trouble getting the boys over the sandy terrain at the beach. Their request was for a portable wheelchair that would allow easy transportation of Jack over the sand, as well as provide the option to recline him to increase comfort and circulation. An additional goal of this project was to design a more affordable reclining mechanism, as many existing options are very expensive and not practical for occasional use.

## TECHNICAL DESCRIPTION

To create the structure of the Reclining Beach Wheelchair, a 16.5" youth wheelchair frame was modified. All of the modifications and attachments

mentioned were created out of aluminum, which was well suited because it is light and strong.

The first and most important modifications were completed to allow the attachment of large, polyurethane beach tires. The front tires and castors were removed, and replaced with custom-built mounts for the large beach castors. These mounts provided stability as well as a pre-defined distance from the chair frame, allowing near-full rotation of the castors below the chair and optimizing maneuverability of the beach wheelchair. To attach the back tires, two sets of braces were built to house the 1" axels and set the tires far enough away from the frame as to remain unencumbered. The axels were fitted with quick-release pins, allowing the family to remove the large tires when storing or packing the chair.

The reclining mechanism was built using square tubing to create an adjustable-length leg. It was attached to the existing arms of the wheelchair and supported using struts in a triangular shape (Figure 17.11). The arm can be locked close to the wheelchair or out in reclining position using two quick-release pins. The adjustable length of the leg allows for the angle at which the rider is reclined to be changed. A rotating footplate on the bottom of the leg disperses the weight of the rider, keeping the leg from sinking deep into the sand and allowing for the angle to be changed according to the desires of the rider.

The cost of the parts/material was about \$900



Fig. 17.10. The Reclining Beach Wheelchair.



Fig. 17.11. Reclining Mechanism.

# POSTERIOR BEACH WALKER FOR A CHILD WITH CEREBRAL PALSY

*Designers: Matthew Ellis, Danielle Lapointe  
Client Contact: Gregg and Laura McClement, Calgary, AB, Canada  
Supervising Professor: Dr. John D. Enderle  
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Storrs, CT 0626*

## INTRODUCTION

The beach posterior walker is designed for a 12 year old boy, Matthew Davies, who suffers from spastic cerebral palsy. The client is receptive, but has limited motor control and requires a walker or quad-canes to move around. Matthew is currently 5 feet tall and weighs just less than 100 pounds. His family goes to the beach often during the summer, so a design that would allow Matthew to use his walker easily over sand and other difficult terrain was requested.

## SUMMARY OF IMPACT

The posterior walker is designed for use by the client specifically for the beach. The walker was designed to not only be able to maneuver over sand, but also tough terrain, such as gravel, where commercial walkers would struggle. The walker was designed to expand as our client grows. The posterior beach walker provides our client with freedom to use his walker wherever he wants, especially on the beach and into shallow water.

## TECHNICAL DESCRIPTION

The posterior beach walker has a NIMBO youth walker frame. The original height of the NIMBO walker ranged from 23 to 30.5 inches. Our minimum height requirement is 28 inches, which was easily reached since our wheels added to the overall height of the frame.

A seat specially designed for the NIMBO walker frame was installed. This allows our client to be able to safely sit and rest whenever he needs to. Velcro strips were added to either side of the seat to ensure that the seat will stay upright while the client is walking, as seen in Figure 17.13.

Polyurethane balloon wheels were installed to the walker's frame. Two 8.7 inch wheels were installed for the rear wheels of the walker. 11.8 inch wheels



Fig. 17.12. The Posterior Beach Walker



Fig. 17.13. Side View of the Walker.

were mounted to swivel casters using custom made mounts, shown in Figure 17.15.

The front two wheels, along with the swivel casters, were too tall to simply install to the original frame. Clamps were designed and a new, shorter height

addition was fabricated and welded to the clamps to ensure that the walker met the client's minimum height need of 28 inches from the handlebars to the ground (Figure 17.14). A cup holder was added to the front of the walker for the client's comfort when on the beach.



Fig. 17.14. Clamps with Height addition.



Fig. 17.15. Fabricated Swivel Caster Mounts.



# THE ADAPTIVE POSITION CHAIR

*Designers: Jeffrey Peterson, Kevin Franzino and Kelly O'Neill  
Supervising Professor: Dr. John Enderle  
Biomedical Engineering Department  
University of Connecticut  
Storrs, CT 06269*

## INTRODUCTION

The Adaptive Position Chair (APC) was designed to add ease to the lives of a family with a child of limited motor and communication skills. In particular, our client is a three-year-old girl diagnosed with Rett Syndrome. Rett Syndrome is a chromosomal mutation characterized by poor motor skills and language reception and expression issues. Onset is usually between 6 and 18 months of age, when a developmental reversal is experienced.

Perhaps the most functional piece of the APC is the tray table. It has three planes of motion to allow for many uses relevant to our client and her family's daily life. The APC also includes support mechanisms to help compensate for her lack of motor control. These mechanisms include a pommel that fits between her legs and a butterfly chest harness. The chair is also adjustable in various ways to allow for growth.

## SUMMARY OF IMPACT

In order to communicate, our client uses a Tobii Eye-Gaze System to navigate a Pragmatic Organized Dynamic Display (PODD). She also uses the family laptop to read interactive children's books online. We hope that the APC will provide a place that she can comfortably eat and do these and other activities. The most important feature of the APC, in terms of its range of uses, is the acrylic tray table. The adjustability of the angle of the tray contributes to its versatility. Also important are the various supports, which are customized to the client. They provide safety as well as vital trunk stability. The legs of the APC are adjustable, allowing the client to be at a normal chair height or at eye level with an adult. We hope that the device will make the lives of our client and her family easier by providing a personalized space to perform day-to-day activities.

## TECHNICAL DESCRIPTION

The frame of the chair is fabricated out of low carbon steel tubing that is primed, painted, and coated with

rust-proof paint. There are sections of frame made out of square tubing and others made out of round tubing. The decision to use which tubing was based on functionality; for example, the seat back and bottom are square so that the components fit. The legs are telescoping to allow for height adjustability. This function was made possible by smaller tubes with a series of systematically drilled holes that fit snugly but smoothly into large diameter tubes. Clevis pins and cotter rings hold the legs at the desired height. Extra stability is made possible with leveling feet on the bottom of the legs. This compensates for any variability in ground that the chair is situated on, should this be an issue. By a similar telescoping mechanism, the platform for the client's feet is also adjustable. The adjustability in this case allows for the client's growth and will hopefully allow use of the chair for multiple years. The platform itself is sheet steel with a piece of acrylic on top. Chair back and bottom pads are mounted on plywood and consist of foam padding upholstered in vinyl. Another important component of the APC is the padded pommel that sits between the client's legs to provide trunk support. This pommel is also upholstered in vinyl, and slides back and forth along a slotted track cut into the steel frame from the bottom of the chair seat. The pommel folds down from the upright position when a button is pressed. This allows for ease of placing the client in and out of the chair. The armrests are also padded again with vinyl covered foam. They are detachable so that the steel frame can be easily cleaned if necessary.

In terms of design analysis, there are some improvements that could have been made had we had more time. Though functional, the tray table becomes a bit off-kilter in certain positions. Slight adjustments in the tubing structure would fix this problem, though after completing construction it was too late time-wise and money-wise to go back to redo this. Also, the steel frame means that portability of the chair is limited by weight and size. This is something that we might reconsider if we were to make another APC. That being said, the APC that we



constructed is fully functional and we hope that it will be useful to our client's family.

The total cost of the project was approximately \$380.00.



Fig. 17.16. The Adaptive Position Chair.

# THE ASSISTED SKIING DEVICE

*Designers: Jeffrey Peterson, Kevin Franzino and Kelly O'Neill  
Supervising Professor: Dr. John Enderle  
Biomedical Engineering Department  
University of Connecticut  
Storrs, CT 06269*

## INTRODUCTION

The Assisted Skiing Device (ASD) was designed and fabricated for Samantha Gillard and her family. Samantha Gillard is a 3 year old girl who has been diagnosed with Rett Syndrome. Rett Syndrome is a neurological disorder that negatively affects muscle motor control as well as expressive language skills and physical development. Samantha's parents Geoff and Jenny Gillard are avid skiers, who frequently visit Samantha's grandparents who live at the base of a ski mountain in New Hampshire. While Samantha is physically incapable of skiing on her own, with the assistance of a skilled skier and the Assisted Skiing Device, she will have the ability to get outside and hit the slopes.

## SUMMARY OF IMPACT

While Samantha has difficulty conveying her thoughts and feelings, her parents have informed us that she likes to be outside, and she likes to "go fast". In addition to this, with mountain access, and a family of skiers, the ASD seemed a perfect fit. The integration of the ASD into their lives will allow the Gillard's the opportunity to spend time together as a family, while doing something that they love that would not be possible for Samantha to participate in otherwise. The ASD will always require a "pilot" to drive from the rear position, but allows Samantha a small amount of control through leaning side to side, this will help to provide her with exercise and motivation to move while strengthening her core.

## TECHNICAL DESCRIPTION

Prior to beginning design of the ASD, we spent time researching existing assisted skiing equipment. In addition to learning that most of the equipment on the market came with an astronomical price tag, many included either two skis acting in tandem, or a single main ski with outriggers for balance and turning control, as well as suspension systems, and in some cases, hydraulic assisted mechanisms for getting the rider on and off of ski lifts.



Fig. 17.17. The Assisted Skiing Device.



Fig. 17.18. Lowered piston riding position (top) and raised piston chair lift position (bottom).

We were able to obtain a TumbleForms® TriStander from NEAT Marketplace. The piston assembly in the TriStander closely resembled the pistons used to provide comfort through passive suspension as well as maneuverability to adjust the ski sled to be ski lift accessible. The core of the TriStander became the basis for our design, and was quickly incorporated into the early CAD model.

We were also able to obtain a donation of two Teleboards® and a snowboard to use in conjunction with the TumbleForms® TriStander. One of the Teleboards® was cut in half and became outriggers for stability and balance. The remaining Teleboard® and snowboard were both retrofitted to fit the frame of the stander to allow the future operator(s) to switch between boards to alter the performance capabilities of the ASD.

Similarly, the outriggers can be adjusted to four different operating positions, or removed entirely, this way, as the pilot (person driving the ASD) improves their level of skill in the operation of the device, they will be able to increase the angle of lean during turns, and ski faster.

Once the ski sled was assembled, the piston would adequately allow the operator to raise and lower the seat, with the lowered position intended for decent down the mountain, and the raised position intended for access to a chair lift to ascend the mountain.



Fig. 17.19. TumbleForms TriStander after having the piston assembly isolated out.

The ASD also features a polyurethane foam TumbleForms® potty chair, for comfort, and durability, as well as resistance to the elements. The potty chair was adapted to fit the frame, and fit with a four point safety restraint harness. At the head of the of the chair attachment frame, we attached a semi-circular piece of aluminum with holes drilled at nine different fixation points for the pilot handle bars. At the base of the chair frame a steel loop was welded into place to attach a rope. The rope is then attached to a climbing harness worn by the pilot. As a last resort safety measure, it is intended to act as a tether and prevent the ASD from getting away from the pilot in the event of a fall.

# THE RIDE-ON REMOTE-CONTROLLER CAR

*Designers: Jeffrey Peterson, Kevin Franzino and Kelly O'Neill  
Supervising Professor: Dr. John Enderle  
Biomedical Engineering Department  
University of Connecticut  
Storrs, CT 06269*

## INTRODUCTION

The ride-on remote-controlled car (RRC) was constructed to give a child with limited or no mobility the freedom of movement without another person directly propagating their movements. The client is a three-year-old girl who was diagnosed with Rett Syndrome. Rett Syndrome affects the development of the nervous system. Symptoms usually consist of developmental reversal around six months of age resulting in poor motor skills and language expression issues. The client is unable to walk, crawl, speak, or feed herself. The client's family requested our assistance in providing a means for her to enjoy the outdoors. She lacks the motor skills to explore and enjoy the outdoors on her own.

## SUMMARY OF IMPACT

To give the client a sense of mobility and freedom, the ride-on remote-controlled car was constructed. The vehicle would not be controlled by the client but would allow her to be mobile without someone immediately next to her propagating and sustaining her movements; a freedom she was not able to enjoy until the RRC. With the client strapped into the RRC, her parent or guardian can drive the vehicle using a standard RC radio controller. Children with an immobilizing disability don't experience any independence from their care givers. The RRC provides a means of transportation into nature and the surrounding environment giving the client a new sense of freedom.

## TECHNICAL DESCRIPTION

To construct a ride-on remote-controlled car, a Fisher Price® brand Power Wheels® was acquired and modified to be remote control, more rugged and safer. Structurally, the Power Wheels® remained unaltered. The battery, battery connector plug and electric motors were left unaltered. The manual switch transmission and all associated wires were removed. The remote control (RC) system was purchased separately and installed into the Power Wheels®.



Fig. 17.20. The Ride-On Remote-Controlled Car.

The RC system has several key components: a radio transmitter and receiver, battery elimination circuit, an electronic speed controller, and a steering servo.

The radio transmitter broadcasts the desired movements of the RRC via two channel communications, one for forward or reverse and one for steering left or right. The transmitter uses multiple pulse width modulation (PWM) signals to communicate with the radio receiver. The radio receiver deciphers the transmitter's communications and divides the signals for each channel into separate channels outputting a standard RC signal. A standard RC signal uses pulse width modulation for communication. Typically, signal duration is 10ms. A pulse of 1ms indicates low, 1.5ms neutral and 2ms high.

The battery elimination circuit functions as a power supply for the radio receiver, eliminating the need for a separate battery for the receiver. The battery elimination circuit also functions to provide sufficient current to the steering servo motor. Using a battery elimination circuit built into a speed controller may not provide sufficient current for the steering servo to achieve the maximum amount of torque possible.

The electronic speed controller receives the PWM signal and translates it from low, neutral, high to reverse, stopped, forward. The electronic speed controller feeds the proportional amount of voltage from the Power Wheels® battery to the electric motors, establishing the drive system for the RRC.

The steering servo receives the PWM signal and translates it from low, neutral, high to  $-45^\circ$  rotation (left),  $0^\circ$  rotation (center),  $45^\circ$  rotation (right). The steering servo is an electric motor with a potentiometer to measure the degree of rotation of the motor shaft. The servo receives the RC PWM and

moves the servo to the appropriate degree of rotation using the potentiometer's position feedback and returns to center when the signal received is neutral. The servo acquired was a 5:1 gear ratio high torque servo. The motor shaft had a servo horn mounted on it. The servo horn was attached to the existing rack and pinion steering system. The servo replaced the function of the pinion, pulling the rack from side to side.

The approximate cost of all parts including the Power Wheels® was \$575

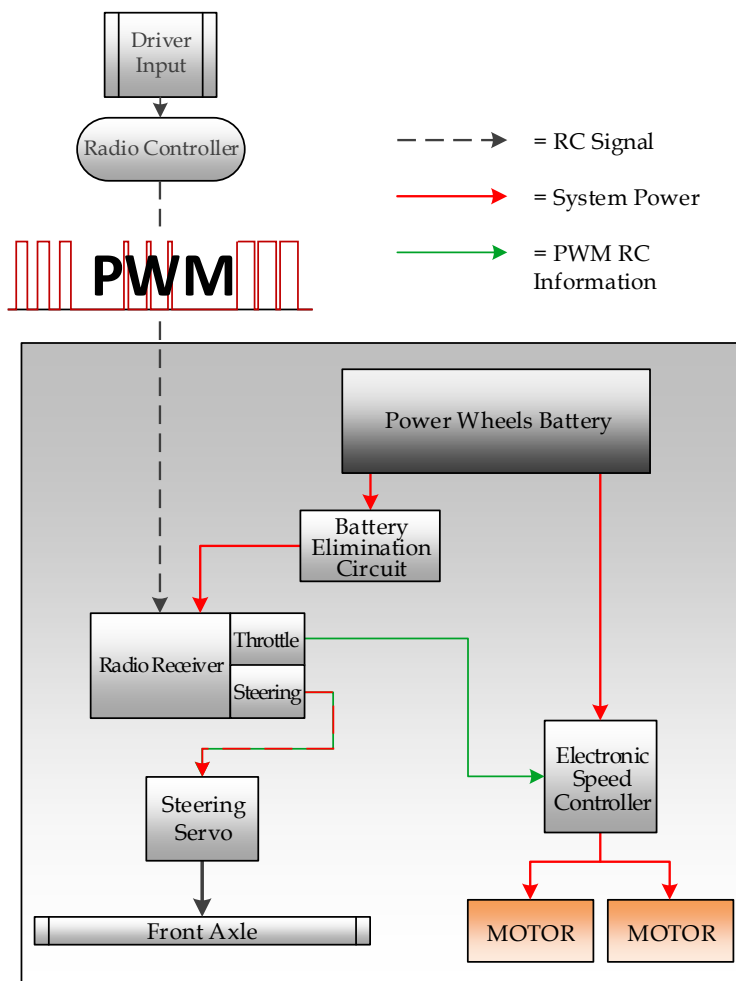


Fig. 17.21. Electronic Setup.



# DESIGN OF SWIMMING HOT TUB LIFT

*Designers: Katelyn Burkhart, Martin Collier, Isis Curtis, Eileen Molloy, and Victor Nguyen*

*Client: Mr. Ronald Hiller, Ashford, CT*

*Supervising Professor: Dr. John Enderle*

*Biomedical Engineering Department*

*University of Connecticut at Storrs,*

*Storrs, CT 06269*

## INTRODUCTION:

Ronald Hiller is a 56 year old man who was diagnosed with multiple sclerosis, also known as MS, when he was 16 years old. Over time, as a result of this disease, leisure activities such as swimming became a challenge for Mr. Hiller. Though he has been living with MS for decades, only within the past ten years has it affected him enough to require him to use a wheelchair. With this challenge, came about the need for an assistance device; something to allow the task of going into water. When asked to construct a lift for Mr. Hiller, several factors had to be taken into consideration when approaching the project: weight requirements, weather conditions, and stress and strain and so on.

While there are lifts available on the market for hot tubs, many are very expensive, costing upwards of \$1000, and most are designed for indoor hot tubs with cement decks surrounding them. Mr. Hiller has an outdoor hot tub on top of a deck behind his house, so the lift needed to be cost effective as well as customized for an outdoor hot tub.

## SUMMARY OF IMPACT:

Those with disabilities are often left at a disadvantage in society today, with a loss of accessibility to certain activities which bring them joy. For our client, Ronald Hiller, we were able to bring some of that enjoyment back into his life by constructing a lift for his hot tub. Diagnosed with multiple sclerosis, Mr. Hiller found it to be a challenge when trying to relax in his hot tub. Moreso, Mr. Hiller's neurologist recommended use of his hot tub to him as a way to try to reactivate some of his nerves. However, he currently cannot get in or out of his hot tub. This leisure activity became more of a hassle for him and we needed to make it fun again. Over a year and several challenges, we were able to construct a lift which can be used for Mr. Hiller to get into and out of his hot tub which is beneficial for therapeutic purposes. It makes it possible to have friends over or to just relax with ease.



Fig. 17.22. Hot tub lift.

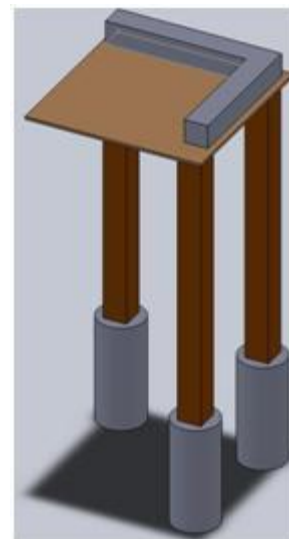


Fig. 17.23. Schematic of Pylons and Supports.

Mr. Hiller has let us know on multiple occasions how truly grateful he is that we built this project.

### **TECHNICAL DESCRIPTION:**

This project incorporated previously used Bruno scooter lifts which were scrapped for parts and then put back together. They were modified to be 55 inches in height, compared to the original 32 inches in height, and are compact enough to avoid creating a hazard around the hot tub. The lift has two motors: one at the base for rotation, and another at the top of the boom for movement in the axial direction. The lifts are connected to 12V Marine Deep Cycle batteries, which can be charged after extended use. The circuitries of the lifts were waterproofed with an acrylic conformal coating. This non-conductive material prevents corrosion and moisture buildup. The entire lift is coated in a corrosion- and water-proof spray-paint to protect from the effects of the chlorine it is exposed to and weather effects. There are also plastic protective covers over the motor and rotational gears to protect from weather effects. The

rope used is a polypropylene material that does not expand when wet and has a strength that can hold 400 pounds. The rope extends 2 feet below the base of the lift, so there is ample room to be lowered into the hot tub. The seat is mesh and weight rated for 600 pounds. This will allow the seat to dry between uses and avoid buildup of mildew or other bacteria. The seat will be attached using two carabineers and a metal hoop to allow ease of use for Mr. Hiller. This also allows easy exit once he is in the hot tub.

Under the lift, below the hot tub deck, are a set of pylons held in sonotubes filled with cement. These sonotubes and pylons are inserted 42" into the ground to comply with Connecticut State Building regulations. A schematic of the pylons is shown in Figure 17.22. The silver L on top of the deck represents the base of the lift.

The total costs of the lift and its parts was approximately \$300. The contractor for the pylons and supports cost about \$600 for material and labor, giving a total project cost of \$900 dollars.

## DESIGN OF SWIMMING POOL LIFT

*Designers: Katelyn Burkhardt, Martin Collier, Isis Curtis, Eileen Molloy, and Victor Nguyen*

*Client: Mr. Ronald Hiller, Ashford, CT*

*Supervising Professor: Dr. John Enderle*

*Biomedical Engineering Department*

*University of Connecticut at Storrs,*

*Storrs, CT 06269*

### INTRODUCTION:

Ronald Hiller is a 56 year old man who was diagnosed with multiple sclerosis, also known as MS, when he was 16 years old. Over time as a result of this disease, leisure activities such as swimming became a challenge for Mr. Hiller. Though he has been living with MS for decades, only within the past ten years has it affected him enough to require him to use a wheelchair. With this challenge, came about the need for an assistance device; something to allow the task of going into water. When asked to construct a lift for Mr. Hiller, several factors had to be taken into consideration when approaching the project: weight requirements, weather conditions, and stress and strain and so on.

While there are lifts available on the market for pools, many are very expensive, costing upwards of \$1000, and most are designed for in ground pools with cement decks surrounding them. Mr. Hiller has an above ground pool, so the design for the lift needed to be cost effective as well as customized for an above ground pool.

### SUMMARY OF IMPACT:

Those with disabilities are often left at a disadvantage in society today, with a loss of accessibility to certain activities which bring them joy. For our client, Ronald Hiller, we were able to bring some of that enjoyment back into his life by constructing a lift for his pool. Diagnosed with multiple sclerosis, Mr. Hiller found it to be a challenge when trying to go swimming or simply relax in his hot tub. This leisure activity became more of a hassle for him and we needed to make it fun again. Over a year and several challenges, we were able to construct a lift which can be used for Mr. Hiller to get into and out of his pool which is beneficial for therapeutic purposes. It makes it possible to have family over and go for a swim, or just relax on a hot day with ease. Mr. Hiller has let us know on multiple occasions how truly grateful he is that we built this project.



Fig. 17.24. Swimming pool lift.

### TECHNICAL DESCRIPTION:

This project incorporated previously used Bruno scooter lifts which were scrapped for parts and then put back together. They were modified to be 55 inches in height, compared to the original 32 inches in height, and are compact enough to avoid creating a hazard around the pool. The lift has two motors: one at the base for rotation, and another at the top of the boom for movement in the axial direction. The lifts are connected to 12V Marine Deep Cycle batteries, which can be charged after extended use. The circuitries of the lifts were waterproofed with an acrylic conformal coating. This non-conductive material prevents corrosion and moisture buildup. The entire lift is coated in a corrosion- and water-proof spray-paint to protect from the effects of the chlorine it is exposed to and weather effects. There are also plastic protective covers over the motor and rotational gears to protect from weather effects. The rope used is a polypropylene material that does not

expand when wet and has a strength that can hold 400 pounds. The rope extends 2 feet below the base of the lift, so there is ample room to be lowered into the pool. The seat is mesh and weight rated for 600 pounds. This will allow the seat to dry between uses and avoid buildup of mildew or other bacteria. The seat will be attached using two carabineers and a metal hoop to allow ease of use for Mr. Hiller. This also allows easy exit once he is in the pool.

Under the lift, below the pool deck, are a set of pylons held in sonotubes filled with cement. These

sonotubes and pylons are inserted 42" into the ground to comply with Connecticut State Building regulations. A schematic of the pylons is shown in Figure 17.24. The silver L on top of the deck represents the base of the lift.

The total costs of the lift and its parts was approximately \$300. The contractor for the pylons and supports cost about \$600 for material and labor, giving a total project cost of \$900 dollars.

# THE L.A.D. ELECTRIC WHEELCHAIR TO RIDING LAWNMOWER ASSIST DEVICE

*Designers: Michael Chen, Matthew Desch and Joshua Aferzon  
Supervising Professor: Dr. John Enderle  
Biomedical Engineering Department  
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Storrs, CT 06269*

## INTRODUCTION

The L.A.D. was designed to allow mount and dismount of a riding lawnmower without the need for lower body input. After the L.A.D was completely built and ready to be operated, it was presented to Ronald Hiller of Ashford, Connecticut. Mr. Hiller has Multiple Sclerosis which has progressed over the past four years and limits his lower body mobility and confines him to a power wheel chair. He does however possess full upper body functionality. It is his wish to be able to care for his lawn as he did before his ailment worsened, and therefore it is necessary to have a safe and effective lift for him to mount and dismount his riding lawnmower without needing to use his lower body. The ultimate intention of the L.A.D is to enable Mr. Hiller to mow his lawn, specifically to mount and dismount his mower, safely whenever he chooses.

## SUMMARY OF IMPACT

The design criteria for the L.A.D were requested by Mr. Hiller and his wife. The device needed to safely displace the distance between his power wheelchair and the seat of the lawnmower. In order to achieve this, a barber chair pump was utilized. An attachment mechanism to connect the L.A.D to the lawnmower would allow for transfer from the lift to the chair. Mobility was required in order for the lift to be positioned next to the lawnmower regardless of lawnmower position. In addition, the wheels would require independent breaking systems to hold the lift in place as Mr. Hiller transferred himself to the lawnmower seat. For safety purposes, safety belts would be required on both the L.A.D and lawnmower. Comfort in the seat was provided by dual layers of egg crate cushioning.

## TECHNICAL DESCRIPTION

The L.A.D was made from many smaller subunits that join together to allow proper function. Mechanical parts include the seat which was



Fig. 17.25. The L.A.D Electric Wheelchair to Riding Lawnmower Assist Device.

cushioned using a dual layer of egg crate cushioning. The seat was made to a length of 16 inches, width of 15½ inches, 1½ inches in height without back support and 18 inches in height with back support. The hydraulic pump was a Keller Int. NGI Hydraulic Pump model. The wheels used were ¾ inches wide Coolcasters Medical/Industrial grade model with a built-in breaking mechanism. The base of the L.A.D was taken from a standard 5-point base office chair. To connect these components together, custom connectors were fabricated (see Figure 17.26). The connector between the seat and the hydraulic pump was constructed using steel and connected to the seat



via a shoulder bolt to allow the seat to swivel 360 degrees. The connector between the hydraulic pump and the base was constructed using aluminum and attached to the pump via four 8 mm screws.

The total cost of the L.A.D, including fully paid for, discounted, and free parts for use in a senior design project, was \$833.33, which was under our allotted budget of \$1000. This system is much cheaper than other similar lifts which range from \$6650-7150.

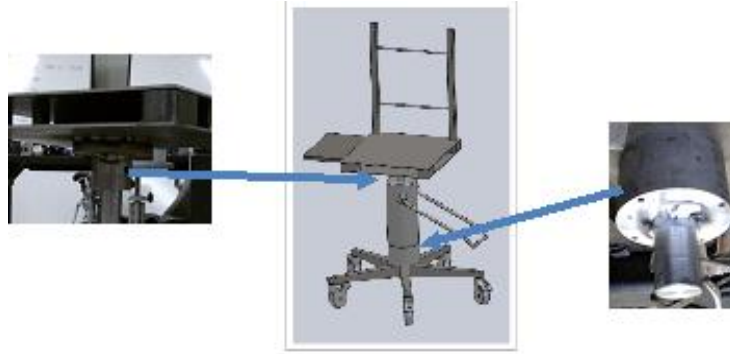


Fig. 17.26. Custom connectors, incl. pump to chair (L) and pump to base (R).

# A MOTORIZED ASSISTIVE JUMPING DEVICE

*Designers: Michael Ballintyn, Elyssa Polomski, Tianyi Xu  
Supervising Professor: Dr. John Enderle  
Biomedical Engineering Department  
University of Connecticut  
Storrs, CT 0626*

## INTRODUCTION

The motorized assistive jumping device was designed for a child with cerebral palsy so that the child would have more freedom to stand and jump. Due to the cerebral palsy, the child's ability to stand is limited and therefore requires assistance to be held in that position for long periods of time. This device allows for the child to be fully supported in an upright position, independent of any assistance from parents or caretakers. This device also has a motorized component that will allow for the device to be remotely controlled by both the child and the parents. The use of a joystick by the child will help to prepare for the use of a motorized wheelchair. The device will not operate unless under the supervision of a parent. This device will increase the quality of life of the child by allowing them to remain in an upright, standing position for an extended period of time, allowing the child to enjoy an experience they do not normally have while also strengthening the muscles of the lower body.

## SUMMARY OF IMPACT

Because the child is described as one hundred percent dependent and wheelchair bound, physical therapy must be conducted to maintain the muscle tone and strength of the lower body. For this, the child receives therapy sessions to assist in strengthening physical and cognitive abilities. To strengthen the lower body, the child must be removed from the wheelchair and held in an upright, standing position. When this happens, the child becomes very excited and happy because of the opportunity to work muscles that are not normally active. This device will facilitate this type of therapy by allowing the child to remain in an upright position for extended periods of time without assistance from others. The child will be able to strengthen leg muscles that are normally dormant due to inactivity when the child is in the wheelchair. This device will improve the child's overall quality of life as well as help with the child's physical therapy. Also, due to the dual controller system, the child will



Fig. 17.27. The Completed Motorized Assistive Jumping Device.

be able to gain experience using a joystick in preparation for use of a motorized wheelchair.

## TECHNICAL DESCRIPTION

The structure of this device is composed of 80/20 T-Slotted Aluminum. The aluminum pieces were constructed to create a rectangular frame that could support and suspend the child from various bungees attached to the frame. The dimensions of the frame are 31" by 34" by 72". This particular frame was selected because the material is strong, lightweight and vibration proof, and components can be attached easily using the T-slots.

To suspend the child, a SafetyWaze construction harness was customized to fit the child's small frame. Once placed in this harness, a series of six Keeper and Knot bone bungee cords are attached to the D-rings

located on the hips and back of the harness. The bungees are adjustable and can be moved to provide the child with the best fit while in the device. The bungees are attached to the frame via eye hooks and bolts that are fitted for the T-slots.

This device is also motorized and able to be moved through the use of a remote control. A dual transmitter system was implemented. One simple transmitter was custom made for the child and only contained a joystick, indicator LED and a power switch. Similarly, the parental controls contained these same features as well as an emergency stop button and an override feature that would allow their controller to override any movement of the child's joystick. These transmitters send a signal to the programmable receiver which in turn converts the movement of the joystick into a pulse-width modulation (PWM) signal. From here, the signal is then transmitted to two separate speed controllers. A differential steering system was implemented using two identical speed controllers and motors. The PWM signal from the receiver is then split and sent to each of the two speed controllers. The speed controllers then adjust the amount of output voltage to each of the motors which drive the system.

Also connected in parallel with the speed controller is a relay. This component acts as a safety mechanism for the system. The relay cuts all power going to the speed controllers and motors if certain actions take place. If the emergency stop button is pushed, or if one of the two receivers is not powered on, the relay will not allow any voltage from the battery to pass to the rest of the system. This is an important safety measure that ensures that there is parental supervision at all times when the device is in motion.

To power the entire system, a 12V automotive battery was used and wired into the system. The parental controls also require the use of D cell batteries. All of the motor components were then mounted to the bottom platform of the device and the motors were mounted using a custom-welded plate attached to the 80/20 frame. Once the motor system was completed, it was housed in the lower portion of the device. Small caster wheels were attached to the front of the frame while larger 12 inch wheels were attached to the motor shafts via customized couplers. All of the remaining components were mounted to the device and made operational before donating the project to the child.

The cost of the parts and materials was approximately \$1700.

# PROJECT FOR STEVEN MACARY: MODIFIED ALL TERRAIN VEHICLE (ATV) OR BARNEY MOBILE

*Designers: Joseph Yi, Savio Chris, Judy Kachittavong*

*Client Coordinator: June Macary*

*Supervising Professor: Dr. John Enderle*

*Biomedical Engineering Department*

*University of Connecticut*

*Storrs, CT 06269*

## INTRODUCTION

The modified ATV or quad was designed to provide a child with a better and improved device that is user-friendly. This device is a typical battery-operated vehicle that integrates a joystick mechanism and remote control system, along with lumbar support, as seen in Figure 17.28. Upon completion, the modified ATV will be given to Steven Macary, who is an enthusiastic 12 year old boy with cerebral palsy. His speech is impaired and limited to making noises. Also, his motor skills lack muscle control and coordination to do daily tasks, such as opening and closing doorknobs and applying adequate pressure on his feet. Steven cannot use his quad independently in its original state. He does not have enough muscle strength in his leg to push down the pedal, neither does he have sufficient arm strength to control the manual steering, and the quad does not provide proper support for his back. Finally, the modified ATV is intended to improve Steven's quality of life and access to normal childhood activities.

## SUMMARY OF IMPACT

The design criteria for the modified ATV were defined by the need for independence.

Previously, Steven could not ride his quad independently, even though he enjoyed riding it. Although his parents help him ride the vehicle, they cannot always be there to help him ride it. The impact of this project will provide more convenience for Steven and his parents, while also successfully increasing his happiness quotient. In the end, the modified ATV will help Steven become more active and free, while enjoying the outdoors in a vehicle.

## TECHNICAL DESCRIPTION

The overall structure of the modified ATV was based on the Peg Perego Polaris Sportsman 700. A seat was mounted onto the base of the ATV, using Aluminum



Fig. 17.28. The Modified ATV.

plates. These plates were necessary to provide stability and support to mount the seat onto the vehicle. Egg grate was used for cushion to pad bolted area and covered with a seat cover to add comfort.

A steering servo power gearbox from ServoCity was used for the steering mechanism which provides a powerful and accurate rotation that handles tremendous loads. The pistol grip transmitter was chosen for better comfort and user friendly steering, with a compatible receiver. The 2 servo joystick was essential in our electrical components, since it can simply plug in a power supply and connect the servos to control them via the joystick. The Traxxas EVX-2 features 2 motor connection terminals; along with a high burst amperage on the motor needed for the system. Two single-pole-double-throw (SPDT) switches, with a center-off mode, were implemented for the pulse-width modulation (PWM) signal wires coming from the joystick and receiver - one for the

steering servo and the other for the electronic speed control (ESC). This allows the user to switch modes of control from the joystick to remote control. A dashboard was created from a sheet of aluminum which was bent accordingly and mounted onto the ATV. This is to create a flat surface, where the joystick will be mounted, along with switches. All the wires and electrical components are secured on the inside of the ATV with wire ties and Velcro tape,

respectively. Finally, the vehicle is painted green and purple— the color scheme of Barney. Figure 17.29 illustrates the electrical wiring assembled in the modified ATV. This schematic consists of all the components mentioned above.

Total Cost of Modified ATV was approximately \$1117.

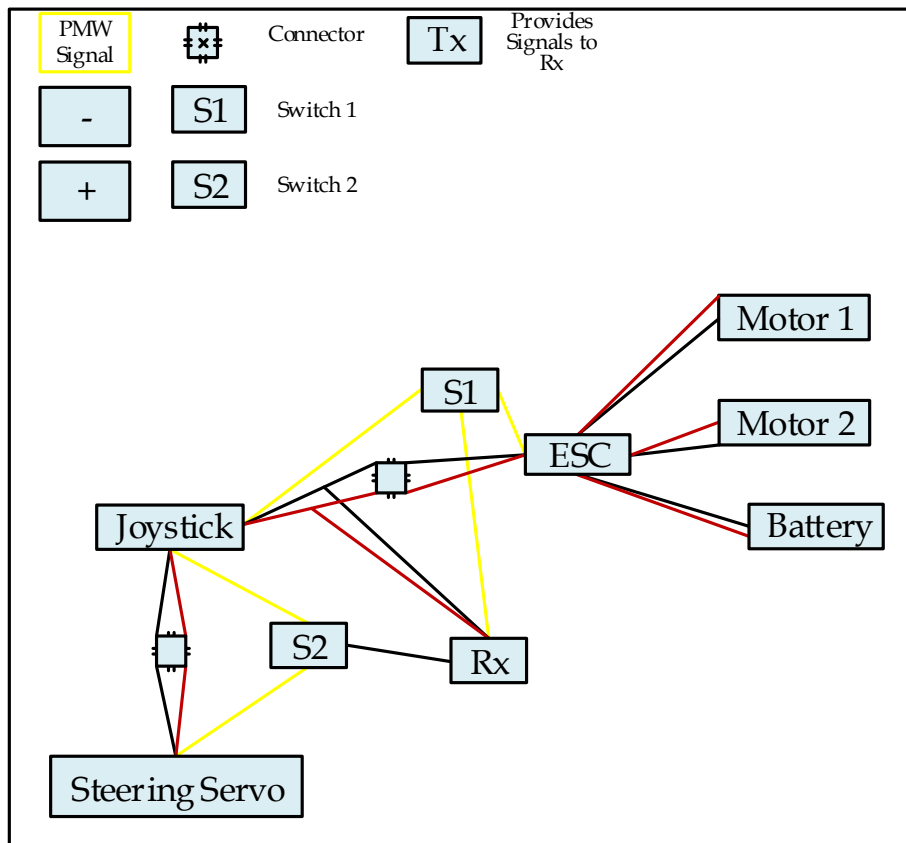


Fig. 17.29. Electrical Wiring Diagram.





# CHAPTER 18

## UNIVERSITY OF MICHIGAN

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### Principal Investigator:

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# TELEREHABILITATION DEVICE FOR RECOVERING STROKE PATIENTS:

*Designers: Bailey Fagan, Nicole Flavell, Mike Nikodemski, Tim Wilkins*

*Client Coordinator: Susan Brown, Associate Professor, School of Kinesiology, and Jeanne Langan, Physical Medicine and Rehabilitation Department.*

*Supervising Professor: Alan Wineman  
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## INTRODUCTION

Strokes affect more than 700,000 individuals in the United States each year; this is approximately one person every 45 seconds. Stroke patients often suffer from loss of motor control in both their upper and lower limbs. Research has indicated that upper limb rehabilitation is much slower than the lower limb, due to the immediate need to walk following a stroke. Practicing moving and squeezing objects has been shown to improve upper limb motor control and a device which helps patients do this could allow for quicker rehabilitation.

Dr. Susan Brown, professor at the University of Michigan's School of Kinesiology, has created a telerehabilitation program. This program, named Upper Limb Training and Assessment (ULTrA) is an intensive motor training program aimed at the functional recovery of upper limbs. Her research has indicated that upper limb movement has a slower rate of recovery compared to lower limbs for cerebral palsy and stroke patients. This research has led to the creation of the ULTrA program. Specifically this program's objective is to incorporate arm reaching movements, hand manipulation, and tactile discrimination tasks. A unique feature of this program is that it is designed for home use with a feedback system to the doctor via an internet connection. No program like this presently exists. Currently, Dr. Brown's program only addresses arm reaching movements. She, along with Dr. Jeanne Langan, Research Fellow at the University of Michigan's Physical Medicine and Rehabilitation, worked together to begin the creation of the hand manipulation portion of this program. This team's project was to create the device and program that will eventually become a part of the ULTrA program. Drs. Langan and Brown needed a hand manipulation program to assist patients with their ability to grasp

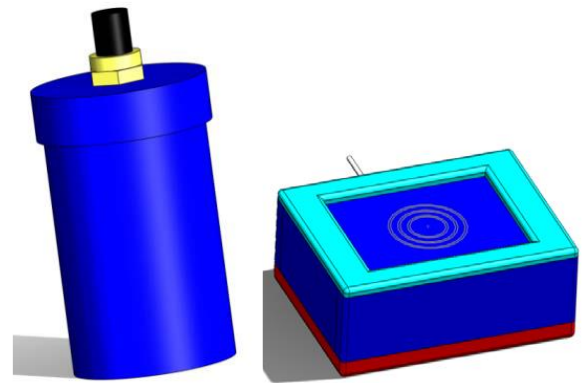


Fig.18.1. Grasping and pinching devices for telerehabilitation.

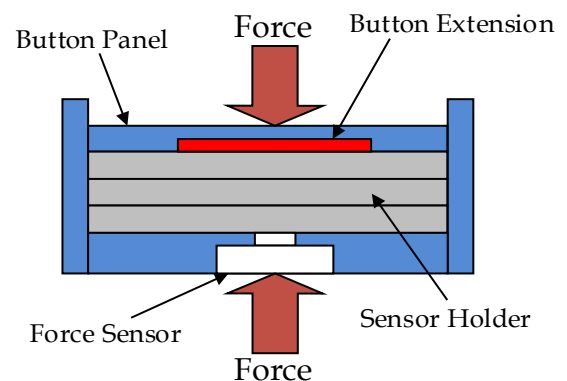


Fig.18.2. Cross section view of pinch sensing device.

(hold things with their entire hand) and pinch (hold things with thumb and a finger). The student team created a device and accompanying program that allows patients to practice and test their ability to grasp and pinch in their homes.

## SUMMARY OF IMPACT

This system will be incorporated with the ULTrA to expand the program. Initial research has indicated that no program exists that is exactly like the one that will be created. Existing programs only incorporate arm movement and not grasping or pinching force, which are essential to the patient's rehabilitation.

## TECHNICAL DESCRIPTION

The grasping device resembles a water bottle but with internal sensors. The main advantage to using the water bottle design is its ability to measure the applied force regardless of where the patient applies force. The patient's applied force causes a change in pressure in the bottle and a pressure sensor reports the change to the computer. The grasping device has three main parts: the bottle, the manufactured fiberglass piece, and the pressure sensor. The manufactured fiberglass piece is a circular piece used to reinforce the top of the water bottle. This piece provides extra strength to the top of the bottle and prevents possible rupture. The pinching device is a rectangular box similar to a garage door opener remote. There are ten different fiberglass pieces that

compose the pinching device. Four outer wall pieces make up the pinching device's housing. The button panel piece is where the patient applies the pinching force to the force sensor. The force sensor and the button panel are separated by a rubber plug. Two more pieces of fiberglass are used to hold the force sensor in place. These pieces also provide extra support for the outer walls and a place to insert the bolts. A square top lip piece ensures that the button panel stays inside the pinching device. The last two fiberglass pieces are the two bottom pieces. The bottom consists of two pieces to resist the button push force and to hold the device together. A section view of the pinching device (Figure 18.2) is provided to further detail the assembly. An amplifier circuit was constructed to amplify the voltage signal supplied from the sensors to the data acquisition system (DAQ). LabView was used to interpret the voltage signals and provide the user interface. The LabView user interface allows for four different modules which use the pinching and grasping sensors to rehabilitate the patient. Figure 18.3 shows a screen shot of one of the modules running in the LabView code.

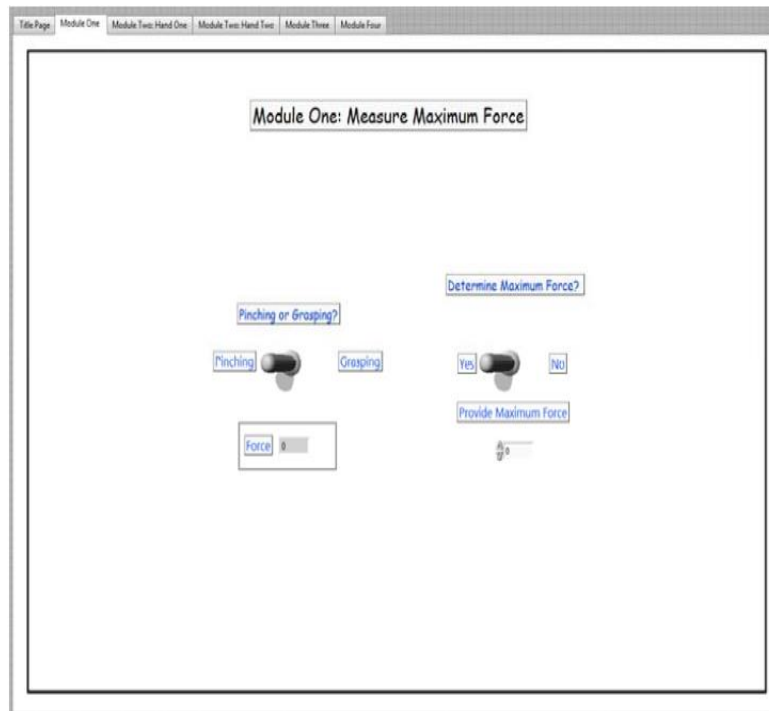


Fig.18.3. Example LabView module for maximum force measurement.



# HAND TELEREHABILITATION DEVICE FOR RECOVERING STROKE PATIENTS

*Designers: Coburn Bland, Claudio A. Hernandez, Justin Hresko, Sean McLain*

*Client Coordinator: Susan Brown, Associate Professor, School of Kinesiology, and Jeanne Langan, Physical Medicine and Rehabilitation Department.*

*Supervising Professor: Albert Shih  
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## INTRODUCTION

This project is a continuation of the Telerehabilitation Device for Recovering Stroke Patients project described previously. The sponsors wanted the telerehabilitation device to be more portable, to combine the pinching and gripping tests into one device, and to improve the aesthetics and functionality of the LabView program and user interface. The system developed is shown in Figure 18.4 as a package with sensors and cables for communication with the computer.

## SUMMARY OF IMPACT

Making the telerehabilitation device more portable allows the user to practice in the comfort of their own home. This is important because the recovery period can be decreased since the user will be able to interact with the program more often if they can use it at home. Increasing the aesthetics and functionality of the LabView program helps the user stay dedicated to the program. A pleasing display and better functionality helps keep the interest of the user, making it more likely that they will complete the rehab.

## TECHNICAL DESCRIPTION

The final design consists of three main components: Vernier Hand Dynamometer, LabView user interface, and a hard Transport Case with retractable force measurement devices. The Vernier Hand Dynamometer sensor ranges from 0 – 600 N and has a resolution 12 bit, or 0.2 N when used within LabView. An NI-USB-6008 DAQ from National Instruments was selected to interface the dynamometers with the LabView program. The user interface, shown in Figure 18.5, is a simplistic, centralized, and aesthetically pleasing display, which guides the user through six different modules to help with the patient's rehabilitation. The Transport Case

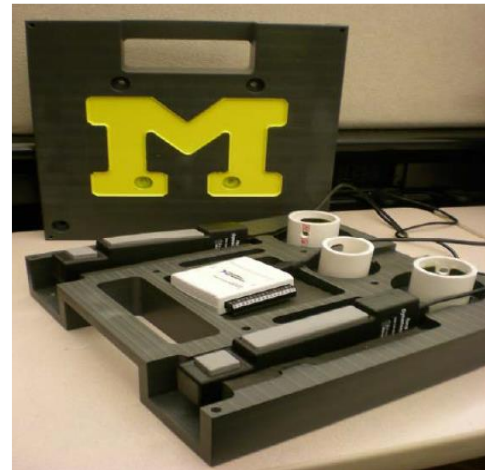


Fig.18.4. Hand Telerehabilitation Device for patients recovering from stroke.

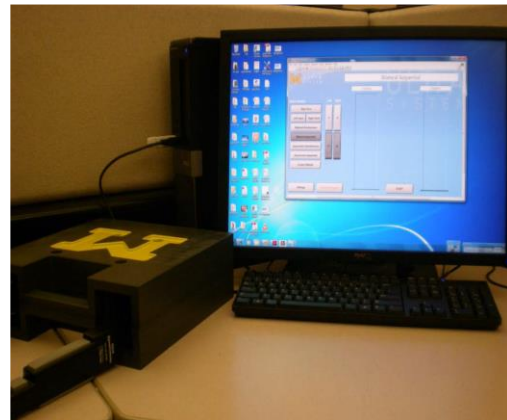


Fig.18.5. Hand Telerehab Device and Accompanying LabView program.

is a high-density polyethylene case with wire retractors to retract the Hand Dynamometers and a USB cable to connect to the computer. The case body is separated into two halves; a top and bottom. Each is two inches thick with outer dimensions of one foot by one foot. The case is bolted closed during all stages



of patient interaction, preventing the wiring from accidental disconnection or tampering. Users access the USB cable and Hand Dynamometers by pulling them out of the slots in the case. After use, springs retract the USB cable and Hand Dynamometers to protect them from damage. An exploded view of the protective case is shown in Figure 18.7. The wire retractors (1) are assembled in tandem with the lower half of the Transport Case. The wire retractors fit into the channels in both the top and bottom sections of the Case to fix the axis of rotation. The power spring is fixed through the slit in the stud (3) on the bottom section of the Case, and is held in place by the cap (4). Cable is passed through the hole in the wire retractor and out the top into the cable channel. All cables run through these channels and are wired into the DAQ (7). The two sections of the Case are fixed together with bolts through six fixture holes (8). The wire clips (9) are be screwed into the bottom of the Case. The cost of parts/material was about \$230.

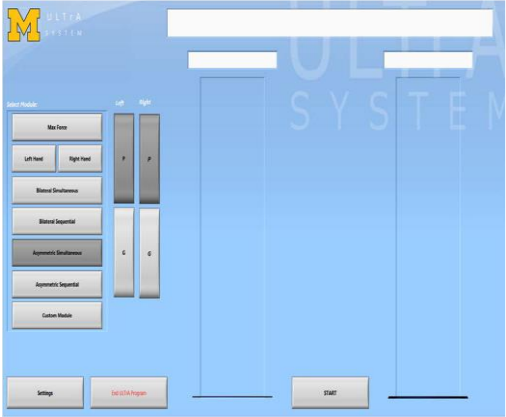


Fig.18.6. LabView user interface.

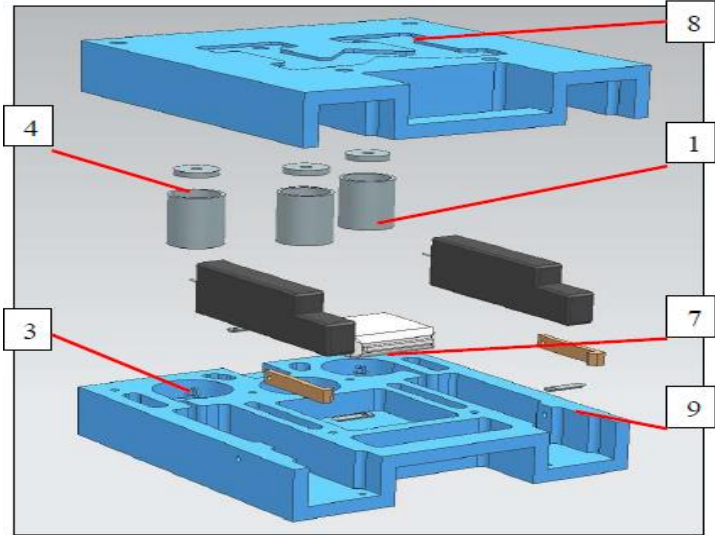


Fig. 18.7. Exploded view of protective case.

# SHOWER CURTAIN FOR BATH ASSISTIVE TRANSFER BENCH USERS

*Designers: Yung Leong Lee, Brandon Nichols, Adam Singletery*

*Client Coordinator: Naomi Gilbert, Occupational Therapist, and Susan Murphy, Assistant Professor, Physical Medicine and Rehabilitation Department, University of Michigan*

*Supervising Professor: Dr. Albert Shih*

*Department of Mechanical Engineering*

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## INTRODUCTION

Assistive transfer devices for the bath tub help geriatric patients safely bathe while maintaining privacy, allowing them to live a more independent life. Working with Naomi Gilbert, an Occupational Therapist at the University of Michigan Med Rehab, and Dr. Susan Murphy, an Assistant professor for Physical Medicine and Rehabilitation Department at the University of Michigan, this student team improved current assistive bath transfer benches by designing a new shower curtain that closes around existing transfer benches, keeping water from spilling outside the tub while the patient is using the transfer bench. The curtain fits most bathtubs and major models of transfer benches.

## SUMMARY OF IMPACT

The student team researched the weaknesses of the transfer benches in the market through online product reviews by customers. They found that efforts were made to include cuts in the transfer bench seats to allow the shower curtains to close. However, despite the efforts, the shower curtains were difficult to adjust and could not close fully; water still flowed out of the tub. The new assistive shower bench curtain contains all the shower water and allows for adjustments.

## TECHNICAL DESCRIPTION

The final design of the assistive transfer bench shower curtain is an extra-long shower curtain with a "tent" cut in the middle. The final dimensions of the curtain are 107" long by 72" tall and the material used is ethylene vinyl acetate. User surveys suggested that most people prefer putting the transfer bench about 60% of the curtain away from the shower head. The team used an extra-long curtain and cut the tent in the middle to allow the user to select their ideal position, rather than just picking 60%. The tent structure was



Fig.18.8. Shower curtain designed for assistive transfer bench users.

designed to fit most major transfer benches, plus, an additional 2" of material on each side to allow room for adjustability. The final dimensions of the tent are 23" wide, 12" tall, and 5.75" long. At the end of the tent are weighted pouches. The pouches are thin PEVA pouches filled with plastic and copper pellets, sealed in the shower curtain and are approximately one pound. The curtain also has a cover flap over the tent structure to prevent water spill while the transfer bench is not in use. The cover flap has a length of 30" and a height of 26" and is attached 6" above the tent structure.

We also have a new idea after the end of the project to use two shower curtains and two shower rods to close the transfer bench. This concept was also proven feasible and a web-site will be established to demonstrate the use.

The cost of parts/material was about \$120.

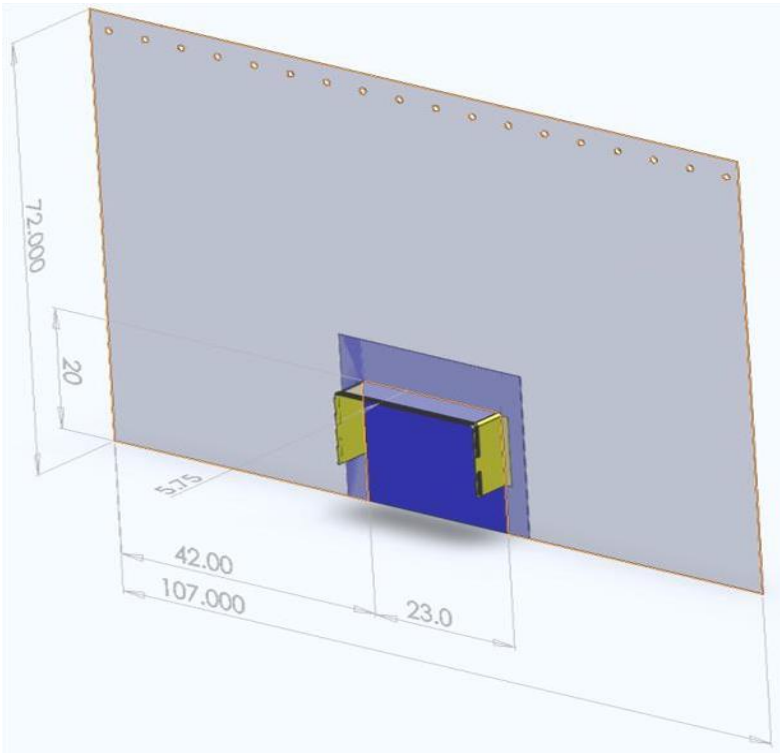


Fig.18.9. CAD picture of assistive transfer bench curtain with dimensions.

# EDEMA SWELLING MEASUREMENT DEVICE

*Designers: Marty Lueck, Chris Spangler, Kyle Schilling, Eric Zwart*

*Client Coordinator: Geeta Peethambaran Physical Therapist and Clinical Specialist, Department of Physical Medicine and Rehabilitation, University of Michigan*

*Supervising Professor: Dr. Albert Shih*

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## INTRODUCTION

Edema is swelling caused by excess fluid trapped in the body's tissues, most noticeably in the feet, ankles, hands, and face. Clinically, there is a great need to accurately measure the level of swelling to justify treatment methods to patients as well as the hospital and insurance companies. This student team worked with Geeta Peethambaran, a physical therapist at the University of Michigan Hospital, to design a new measuring device specifically for body measurements. The devices currently used are relatively low-tech, including standard, fabric tape measures. The device needs to have flexible tape to allow for accurate measurements of curves and be easy to use to allow patients to chart their progress from home.

## SUMMARY OF IMPACT

The device, as shown in Figure 18.10, is a first attempt at producing a precise, easy to use, and cheap measuring device for use by physical therapists and patients. Measuring tape is an important tool for physical therapists because it allows them to chart the patient's progress, to justify the therapy methods or medication being used to treat the problem.

## TECHNICAL DESCRIPTION

The exterior of the Edema swelling measurement device consists of a hard plastic case, an LCD screen, a locking button, and laminated vinyl tape with a clip on the end for measuring arms and legs. Inside the device are two wheels sitting on top of a spindle mount. One wheel functions as the locking

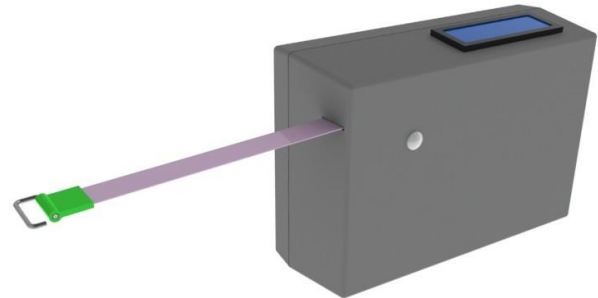


Fig.18.10. Edema Swelling Measurement CAD model.

mechanism while the other acts as the spool that the tape wraps around. The rotary encoder is connected to the bottom half of the case below the spindle mount. A steel shaft connects the rotary encoder to the main spool. The rotary encoder counts revolutions of the main spool and converts the count into a distance. The interior components can be seen in the section view in Figure 18.11. The microprocessor sits next to the spindle mount assembly and the LCD screen is recessed into the side of the plastic case.

The cost of parts/material was about \$160. We have provided the drawing, design and prototype to a Taiwan digital tape manufacturer for potential commercialization. They did not respond to our request.

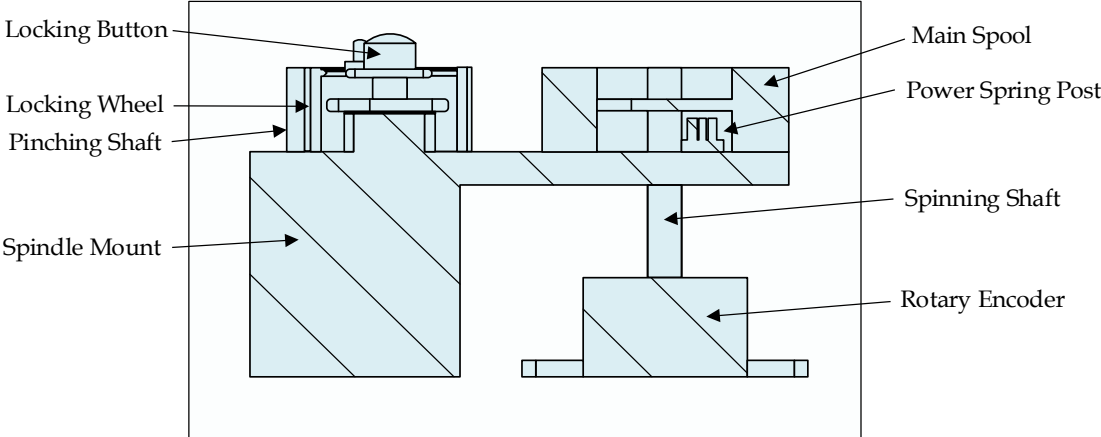


Fig.18.11. Section view showing interior components of Edema swelling measurement device.



# SURGICAL LIFT WITH A SEAT FOR A NEUROSURGEON WITH SPINA BIFIDA

*Designers: Aditya Chabria, Dmytro Dmytrenko, Lokesh Janarthanam, Kah Wee Liew*

*Client Coordinator: Dr. Karin M. Muraszko, Chair of the University of Michigan Neurosurgery Department*

*Supervising Professor: Dr. Albert Shih*

*Department of Mechanical Engineering*

*2350 Hayward St.*

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## INTRODUCTION

This student team was tasked with redesigning a lift for Dr. Karin M. Muraszko, Chair and pediatric neurosurgeon of the Neurosurgery Department at the University of Michigan, to use during surgery. Dr. Muraszko has a mild form of Spina Bifida which hinders her mobility, requiring her to use a lift during surgery. Her father built her a lift 20 years ago but she needs a new one now. A new lift assembly was manufactured by Protomatic who supervised two previous student teams working on this project, but Dr. Muraszko demanded more change with the lift, particularly to add a seat for her during a long surgery.

## SUMMARY OF IMPACT

Dr. Muraszko requires a stable seat (see Figure 18.12) because of the delicate nature of neurosurgery. There is no room for error when she is performing surgery, so the lift must minimize or eliminate bending and deflection. A stable and comfortable lift will greatly help Dr. Muraszko continue to treat her patients.

## TECHNICAL DESCRIPTION

The seat design consists of a support block which attaches to the current lift, a main shaft that goes through the support block, two sleeve bearings which allow the seat to swivel around the main shaft, a locking mechanism to stop the swivel motion when the seat is in the correct position, a truss structure to support the weight of the user, and the seat. The support block is a 3 in. x 3 in. x 10 in. block placed under the platform of the lift so that it is hidden from view and lowers the center of gravity. Holding the support block in place are 6 bolts which are 0.5 in. in diameter that carry all the shear and tensile forces. The main shaft is a precision, 17 in. long and 1.5 in. diameter shaft press fitted through the precision hole bored in the support block. This shaft will remain stationary and locked while the truss structure will

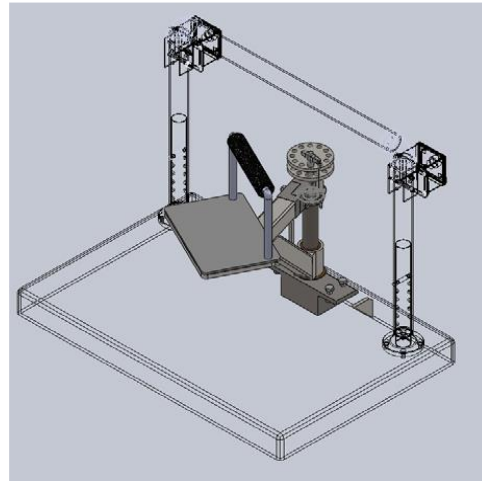


Fig.18.12. CAD drawing of the seat assembly attached to the original lift and Dr. Muraszko with the lift in operating room at University of Michigan Mott Children Hospital.

swivel around this shaft on the two sleeve bearings. The locking mechanism consists of two disks with holes drilled in them, located at the top of the shaft. The lower disk is welded to the upper part of the truss and the upper disk is bolted and fixed to the main shaft. A locking pin is placed through a hole in the top disk and a hole in the bottom disk, preventing the truss from swinging. The truss structure is made of square steel tubing to provide strength while not being too heavy. The truss structure is a common 45-

45-90 right triangle. The seat attaches to the truss structure through a bearing press fit into the end of the truss, allowing the user to swivel the seat independently from the rest of the mechanism. A detailed view of the truss structure design and the locking mechanism for seat is shown in Figure 18.13.

This lift was used by Dr. Muraszko in surgery at the University of Michigan's Mott Children Hospital.

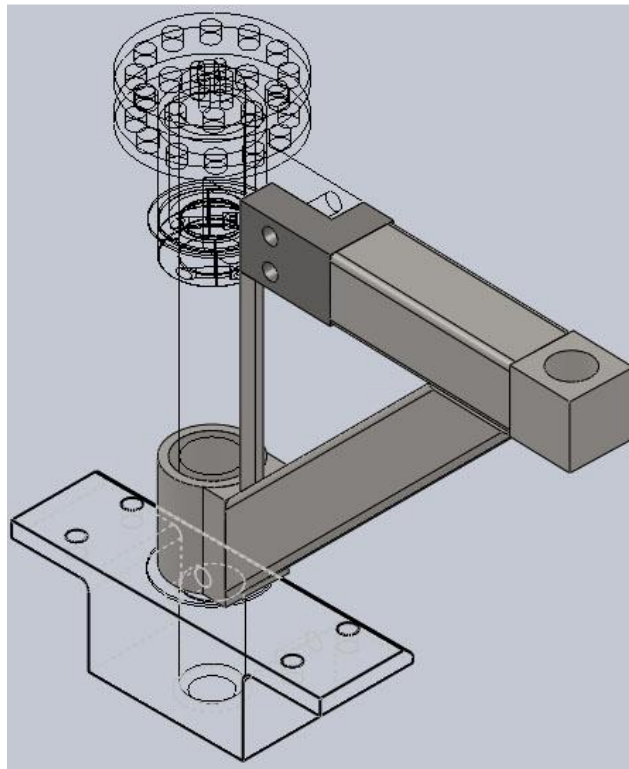


Fig.18.13. Main truss structure which allows the user to swivel.

# BATHTUB SHOWER ASSISTIVE TRANSFER CHAIR

*Designers: Yangbing Lou, Mitchell Polavin, Wu Xiao, Linxiang Wang*

*Client Coordinator: Naomi Gilbert, Occupational Therapist, Susan Murphy, Assistant Professor, Physical Medicine and Rehabilitation Department, University of Michigan, Albert Shih, Professor of Mechanical Engineering and Biomedical Engineering*

*Supervising Professor: Dr. Alan Wineman, Mechanical Engineering  
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## INTRODUCTION

The bathroom is an inconvenient place for people with disabilities. It can get even more dangerous when water is involved. Getting into and out of the bathtub is a particularly difficult task for the elderly and disabled. There are several shower chairs available, but none of them allow the user to sit down on the chair outside of the bathtub and allow transfer to the inside with the curtain resting inside the bathtub. This is necessary because it keeps the water from running down the shower curtain and collecting on the floor. Water makes the floor slippery and the bathroom becomes an even greater hazard for the elderly and disabled.

## SUMMARY OF IMPACT

Showering in a bathtub is a key barrier for the rapidly growing geriatric generation. This team took previous teams' ideas and expanded upon them to advance the shower chair towards commercial use. The new shower chair keeps elderly people safe and independent when bathing. It also folds up in the shower to allow others to use the shower. The device will help geriatric patients safely bathe while maintaining privacy and stability.

## TECHNICAL DESCRIPTION

The assistive transfer chair device, as shown in Figure 18.14, consists of four main parts: the swivel seat, the sliding beam, supporting beams and folding mechanism. The swivel seat was purchased from Eagle Health Care Company. It is made of plastic and has dimensions of 17.5" by 13.5" with a back height of 12.5". The swivel seat enables users to turn in 90° intervals and has a secure locking mechanism ensuring stability for patients entering and exiting the shower. The sliding beam allows the user to extend the seat out to the edge of the tub where they can easily sit down on it and to retract to the middle of the tub when using the shower. This device allows clearance between the inside edge of the bathtub and the mechanism so that the curtain can be closed. Heavy duty drawer sliders were used for the sliding beams and 6063 aluminum rectangular tubes were used for the supporting beams. The supporting legs were taken from Drive Medical Design and Manufacturing's folding chair. The chair legs are aluminum and are adjustable from 16" to 18". A pair of torsion springs help users fold the seat up and down safely. The force of the springs helps the user fold the mechanism and slows down the chair while unfolding.

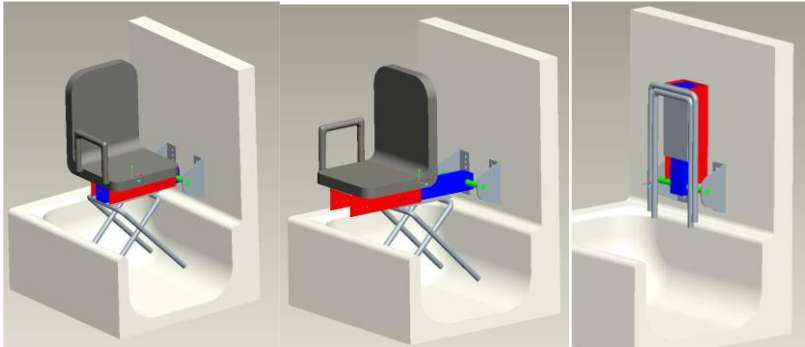


Fig.18.14. Bathtub shower assistive transfer chair for geriatric patients. Left to right: shower in use position, enter and exit position, and stored position

# VEHICLE INGRESS/EGRESS ASSISTANCE DEVICE

*Designers: Michael Merritt, Lisa Romelhardt, Ben Sutton, Pete Ward*

*Client Coordinator: Johnston Controls, Inc.*

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## INTRODUCTION

The aim of this project, sponsored by Johnson Controls, Inc. (JCI), was to provide a device which can be installed in a vehicle to assist elderly people with ingress and egress. Many baby boomers are turning 65 every day, fueling a new market niche for devices aimed at assisting seniors with everyday life.

## SUMMARY OF IMPACT

Creating a device to help elderly people get in and out of their vehicles will allow them to maintain independence; by having the ability to choose what to do and when to do it, they will also maintain a higher quality of life. The device has to be non-obvious, easy-to-use, and effective.

## TECHNICAL DESCRIPTION

The student team's prototype consists of an extending handle between the door and the dash, and a mechanism allowing the door to be locked. The extension of the bar is accomplished using a telescoping steel tube, two inches in diameter. The two ends are on fixed pivots, located on the corner of the dash and the end of the door. The locking mechanism consists of a geared DC motor, a rubber brake, and two compression washers. When the motor is engaged, it compresses the rubber brake on the inside of the tube, preventing motion. The telescoping extension bar is two pieces of steel tube stock, which utilize different diameters for telescoping. The largest diameter is 2", which is small enough to wrap a hand around, but large enough to be comfortable in arthritic hands. The 12-volt DC motor outputs 18.1 ft-lbs and turns at a maximum of 37 RPM. It is mounted within a machined aluminum sleeve to locate it within the smaller bar. This sleeve is allowed to translate but not rotate by the use of a keyed notch between the sleeve and bar. A set screw is used to mount a steel coupler to the motor shaft, which allows a threaded rod to be driven. The threaded rod is threaded through a steel cap, which



Fig.18.15. Vehicle Ingress/Egress Assistance Device.

is welded onto the end of the smaller bar. A cylinder of neoprene rubber, 1/8 inch steel washer and brass thrust bearing are then placed onto the rod, and two nuts are locked onto the end of the rod. As the threaded rod spins, the steel washer is pulled towards the cap, compressing the rubber. As the rubber compresses, it applies a normal force causing friction force between the rubber and large bar locking the mechanism in place. Two brackets are used to mount the handle in the car. Both brackets are made of 4130 steel square stock. For the door-side bracket, one of the walls was milled to make a U-shaped bracket. Two 0.3125" holes were drilled and reamed to hold a clevis pin for the handle to pivot on. Aluminum spacers are used to locate the bars vertically in the bracket. The dash bracket is the same material and for the prototype, is 14.75" in length. Once the door was mounted to the model car exterior, we were able to measure the exact length the dash would be based on the door panel. At the hinge end, the two vertical sides were milled out along 2" of the tube to allow for clearance for the handle. Two 0.3125" holes were drilled and reamed for a clevis pin, and aluminum spacers locate the bar in the center of the bracket opening.



# INNOVATIVE DOOR DESIGN TO AID PEOPLE WITH DISABILITIES AT HOME

*Designers: Zach Stoklosa, Seng Wui Lee, Aleksandar Siljanovski, Michael Locher*

*Client Coordinator: Dr. Mark Ziadeh MD, a rehabilitation and physical therapy doctor at the University of Michigan Hospital.*

*Supervising Professor: Dr. Albert Shih  
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## INTRODUCTION

The goal of this project is to design, build, and test an innovative door system that showcases several concepts that can make the simple act of opening and closing a door at home as effortless as possible for the aging populations of the world. The percentage of the world's population that is elderly is increasing every day, and the need for engineering solutions that increase their independence and quality of life is growing as well.

## SUMMARY OF IMPACT

The goal of this project is to design a system, as shown in Figure 18.16, which would make opening and closing of doors in the home effortless and also create a space to maneuver in tight interior space at home. This system would allow elderly people to maintain their independence, increasing their quality of life.

## TECHNICAL DESCRIPTION

The team chose to make their easy open door similar to a garage door style system. The door is constructed from Quiet Barrier MD, a sound dampening fabric, which is rolled up and down by a motor and spool system mounted above the doorway. By rolling up vertically, the full width of the open doorway is available to the user, which is very advantageous to those confined to wheelchairs or walkers. The door is guided by a T-track system mounted vertically on each side of the doorway from the floor to four inches below the motor. This track system not only guides



Fig.18.16. Easy open home interior door design for wheelchair users.

the door, but also slightly encapsulates the door material on each side of the door, which prevents light from passing through the door as well as increasing the sound dampening abilities of the door. At the bottom of the door material is a guide that attaches to the bottom of the material and slides into the t-track, keeping the material in line. The entire system can be activated by a remote, a wall-switch, or a pressure sensor mounted in the floor, depending on user preference.

# RETRACTABLE CAR CANOPY

Designers: Luis Munoz, Kuo Sun, Yilu Wang

Client Coordinator: Dick and Norma Sarns

Supervising Professor: Dr. Albert Shih

Department of Mechanical Engineering

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## INTRODUCTION

Entering and exiting a vehicle with inclement weather is a challenge for everyone. Often we are inclined to make a quick dash to an automobile to avoid rain and snow. However, persons with physical disabilities do not have that luxury. Interviews of patients with physical disabilities have revealed that there exists a great struggle to access the passenger seat. Patients with disabilities can spend as much as two minutes to comfortably enter and exit a vehicle and they are not able to carry an umbrella to shield them from rain, snow, and wind. Most patients utilize walkers and need to use both arms to support their body weight. Individuals that help disabled patients become victims of the weather as well because they must focus their attention to assist patients rather than protect themselves from the inclement weather. There exist a great need for a sheltering canopy that can efficiently shield patients and assistants from exposure to rain, snow, or wind.

## SUMMARY OF IMPACT

We are working with Mr. and Mrs. Norma Sarns, to design and construct an umbrella-like canopy that can be easily utilized by a handicapped person to protect them from heavy weather when entering/exiting a car. For Mr. Dick Sarns, this is a more personal mission as his wife, Mrs. Norma Sarns, is currently dealing with Multiple Sclerosis. This product has the potential to help them out greatly. Our base prototype will be designed to suit Mr. Sarns Chrysler Town and Country minivan.

## TECHNICAL DESCRIPTION

The car canopy (Figure 18.17) shields an area of 19.6 square feet. The total weight is about 6.3 lbs. The car canopy is comprised of 5 aluminum ribs that are attached at a pivot point. The pivot point is a shaft inserted into a drilled hole at the end of each rib. Each rib is separated from the next rib with three washers, two plastic and one steel. The shaft ends are threaded and locked into place with matching thread caps. The

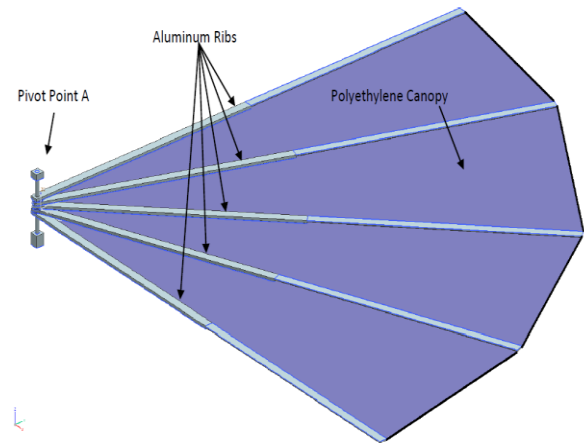


Fig.18.17. Retractable Car Canopy.

entire assembly is secured to a stainless steel drawer slide. The drawer slide is mounted atop the roof rack of the vehicle with a custom keyed fastener. The fixed rib attached to the drawer slide is 60"×1"×¼" and is made of 6061 Aluminum. Each of the 4 6061 Aluminum rotating ribs are 60" long and weigh 0.36 pounds. The total weight of each rotated bar is 1.1 lbs. The fixed rib will weigh 1.46 lbs. Both the fixed and rotating ribs have a 19/32" (0.594") hole drilled at the base. The distance from the center of the hole to the base edge is ½", the distance from the sides of the rail is also ½". Each rib will contain a plastic sleeve bearing that is press fit into the machined hole of each rib. The outside diameter of the sleeve bearing is 0.594 ± 0.005" and the inside diameter is 0.5 ± 0.005". The sleeve bearing will protect the pivoting machined surface of the aluminum bar from the outer surface of the steel shaft. The pivoting assembly is comprised of 8 polycarbonate plastic washers, 4 steel washers, 2 aluminum threaded caps and one steel threaded rod. The washer assembly can be seen in Figure 18.18. The threaded caps were machined from 1" square 6061 aluminum bar stock. They are 1.5" high and are drilled and taped to a thread fit of Class 2A. The purpose of the threaded caps is to secure the shaft

from slipping out of the assembly. Additionally the threaded caps compress the assembly together to promote rigidity when the canopy is opened. The door clip is used to secure the canopy on top of the

passenger door. It has two slotted spaces, one 1/8" thick and the other 1 3/4". The 1/8" slot clips into the top rib of the canopy and the lower 1 3/4" slot clips to the passenger side door.

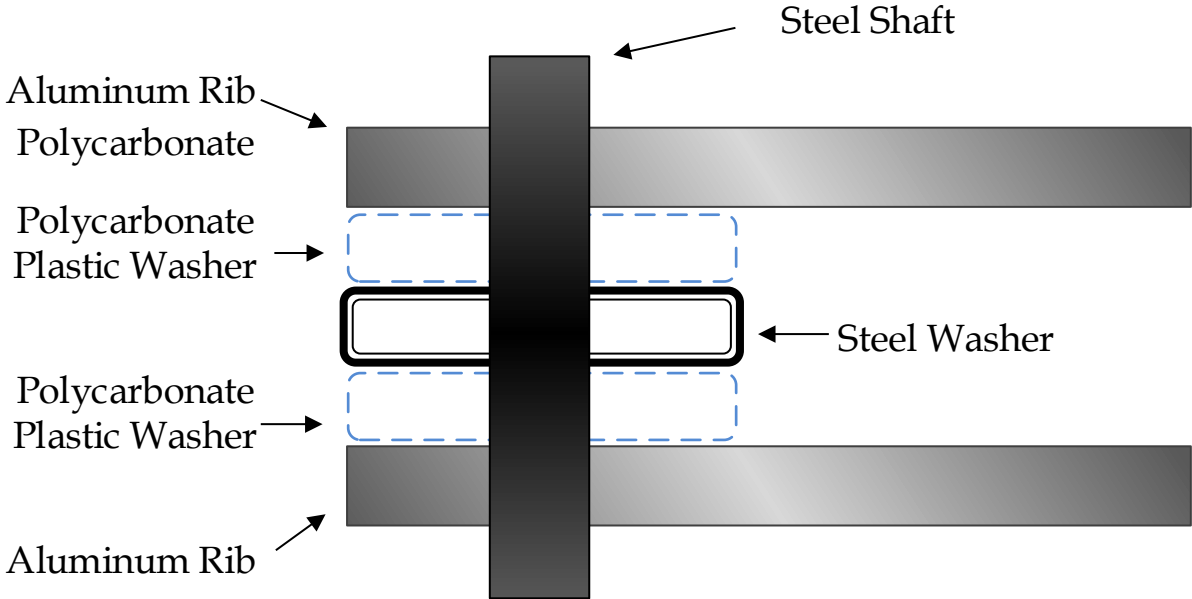


Fig.18.18. Cross section view of part of the pivot assembly.

# POSITION ADJUSTMENT MECHANISM FOR A CROSS TRAINER

*Designers: Alexandra Doan, Kayla Gordon, Lyndsey Pohl, Justin Whitney*

*Client Coordinator: Dr. Mark Ziadah, Physical Medicine and Rehabilitation, and Matthew Weber, Engineer, NuStep Inc.*

*Supervising Professor: Dr. Albert Shih  
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## INTRODUCTION

Ann Arbor based NuStep makes exercise equipment designed for people with physical disabilities. Since exercise for obese patients is very beneficial though challenging due to physical considerations, the T5XR Recumbent Cross-Trainer accommodates patients up to 600 lbs. T5XR users are typically assisted by therapists who manually adjust the machine to be ergonomic, ideally positioning the seat with the user in place. Due to the 7° angle of the rail the seat rides on, ideal seat adjustment is often difficult. This project aims to develop a method for therapists and users to easily adjust seat position in the forward and reverse directions.

## SUMMARY OF IMPACT

The NuStep T5XR Recumbent Cross Trainer is a full body exercise machine that accommodates a wide variety of users including the disabled, elderly, and obese for both clinical and home use. Many of these users have difficulty adjusting the seat forward and backward by themselves or with the help of a clinician due to physical inability (i.e. stroke, paraplegic, old age, weight). NuStep desires a more effective way for users and clinicians to adjust the T5 XR seat. Universal accessibility and convenience will allow patients to exercise in the comfort of their own homes, improving their health and quality of life.

## TECHNICAL DESCRIPTION

The design achieves linear motion of the seat along the rail by utilizing a motorized lead screw system embedded within the supporting rail that the seat trolley rides on. The overview of the design is shown in Figure 18.20. A 12V DC motor with integrated worm-gear transmission is housed in the base frame at the rear of the rail and is mounted to the rail such that its output shaft is roughly centered within the rail and is parallel along the length of the rail. This motor shaft interfaces with a coupler via a Lovejoy



Fig.18.19. Position Adjustment Mechanism for NuStep Cross Trainer.

spider coupler and is held in place by a dowel pin that aligns the through hole in the shaft. A setscrew covering the open hole in the coupler holds the pin in place. The coupler consists of two different shaft diameter hubs connected together with a rubber spider in the center to allow for misalignment between the shafts. The coupler end, opposite that of the motor, interfaces with the lead screw via a 3/16" x 3/16" hardened steel key. The threads of each end of the lead screw shaft are removed. These ends are each mounted inside a bearing housing assembly that is mounted to the rail at each end. Double-sealed needle roller bearings are pressed in bored holes in the bearing housings that face away from the lead screw. A hardened race fits between the machined shaft and each ball bearing within the bearing housing. Thrust needle bearings are sandwiched between thrust washers and sit along the machined lead screw shaft between the bearing housings and the lead screw. The washers facing the bearing housings are piloted in the bearing housing. A 0.005" gap is placed between the lead screw step and thrust washer on the motor side to allow for thermal expansion. These bearing housings are bolted to

brackets and protrude from the bottom of the rail, where vertical and horizontal slotted holes are used for an adjustable, rigid attachment to the underside of the rail. A lead nut threads on the lead screw and rides between each bearing housing. This nut is connected to the seat trolley such that the trolley moves linearly with the nut as the lead screw spins. The off-the-shelf lead nut has an external thread, on which a custom-made bracket is threaded. This lower bracket stays upright inside the rail, and has two slip-fit dowel pin holes reamed in its top. The trolley has mounting holes and slots on its bottom plate that allow the upper bracket to mount from the inside, dropped via access window. The upper bracket is attached using two bolts and flanged threaded inserts that are inserted from underneath the bottom plate of the trolley. This upper bracket has two dowel pins pressed into its underside that mate with the two holes atop the lower bracket. Two parallel slots run the distance of travel on the top of the rail, which allow this upper bracket to connect to the lower bracket within the rail and slide along the direction of

movement. These parallel slots are less than 0.39" to account for EN safety requirements. User interface controls will include a "Forward", "Backward", and emergency stop buttons. The remote with these controls will be center-mounted on the console, and wireless. The controls will ideally be integrated in the machine's computer in production, using position information from the trolley seat sensor to indicate when the seat has reached the limits of its forward and backward travel to indicate to disable motion in the appropriate direction. Signal to move the seat will only be sent while the selected button is depressed. In production, a safety feature will disable the motor if an obstruction (body part or otherwise) becomes pinned between the trolley and front body housing. This could be done by monitoring the current drawn by the motor and acting on a threshold, or using a sensor or bumper to identify an obstruction. This seat adjustment mechanism will be powered by plugging into a standard 120V AC wall outlet, which will be converted to 12V DC via a 102 W power supply.

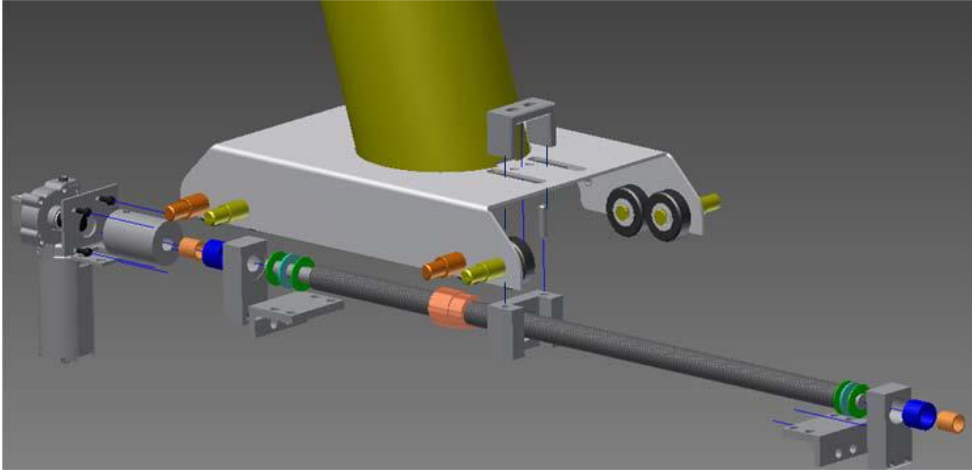


Fig.18.20. Exploded view of lead screw design.



# COOLING SYSTEM FOR MULTIPLE SCLEROSIS PATIENTS IN A EXERCISE MACHINE

*Designers: Satyajeet Deshmukh, Aria Kashani, Donald Maynard, Shikhar Mohan*

*Client Coordinator: Dr. Mark Ziadeh, Physical Medicine and Rehabilitation, and Matthew Weber, Engineer, NuStep Inc.*

*Supervising Professor: Dr. Albert Shih*

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## INTRODUCTION

Multiple Sclerosis (MS) is a neurological disorder affecting about 2.5 million people globally. In the absence of a known cure for the condition, exercise has been found to be the most effective way of controlling MS in patients as it increases fitness levels, reduces fatigue, improves bowel and urinary control and reduces joint spasticity. Due to inadequate thermal regulation, a secondary effect of MS, patients face extreme discomfort and are often unable to continue exercising. The objective of this project is to develop and fabricate an integrated cooling system for the NuStep T5 Recumbent Cross Trainer to aid MS patients using it by providing adequate cooling while ensuring comfort.

## SUMMARY OF IMPACT

Exercise has been found to be the most effective way of controlling Multiple Sclerosis. Patients who exercise regularly have increased fitness levels, reduced fatigue, improved bowel and urinary control and reduced joint spasticity. Patients with MS often suffer from elevated core body temperatures preventing them from continuing to exercise. A device which alleviated this secondary effect and allowed patients with MS to continue exercising would go a long way towards helping patients get in better shape and controlling the symptoms of MS.

## TECHNICAL DESCRIPTION

The device uses five conductive metal plates as the conductive medium to remove heat as seen in Figure 18.21. These plates, with a cumulative area of 0.09 m<sup>2</sup>, are cooled using individual Peltier modules which in turn cool the patient through conduction. The Peltier assembly consists of the Peltier module, an extruded fin array and a blower embedded within the seat foam. The cooling pads are flush with the upper

surface of the seat foam, creating a uniform seating surface that, once covered with a vinyl material, should provide a cool and comfortable seating area for the patient. It was determined that numerous smaller pads were more comfortable in comparison to having a single large pad of the same cumulative area. Smaller pads allow the individual surfaces to conform to the patient's weight and shape, along with the seat foam material. The location of these cooling pads was also constrained by the existing structure of the T5. To minimize significant modification to the T5 seat, the pads must be placed in locations such that the entire cooling module does not come into contact with the seat frame structure. The seat bottom pads are split into three portions: one for the rear (12" x 4") and two smaller pieces for the thighs (3" x 5"). The seat back utilizes two pieces, one mid-section piece (6.0" x 4.5") and one upper piece (6" x 4.5"). In order to effectively package our module inside the seat, the inner foam structure of the seat had to be hollowed out in the areas above the Peltier modules. For both the seat bottom and back, 1/8" hollow-outs corresponding to the areas of the cooling pads were made to allow the cooling pads to sit flush with the existing foam. Two holes for each module were drilled through the cooling and tapped using a metric m8x1.25 tap. All-thread m8x1.25 rods, with a length of 2.5 inches, were cut and inserted into the plate. The fin structure has two small 8mm tabs screwed onto each side so that it attaches to the plate using the all thread rods. The Peltier device is not permanently mounted to the copper plate, but rather sandwiched between the fin and copper structure using force provided by the all-thread rods and fasteners. To facilitate good conduction between the Peltier unit and the copper, as well as the fin structure, Arctic Silver thermal paste was used on the entire contact surface with an average thickness of 0.001 inches per manufacturer recommendation.

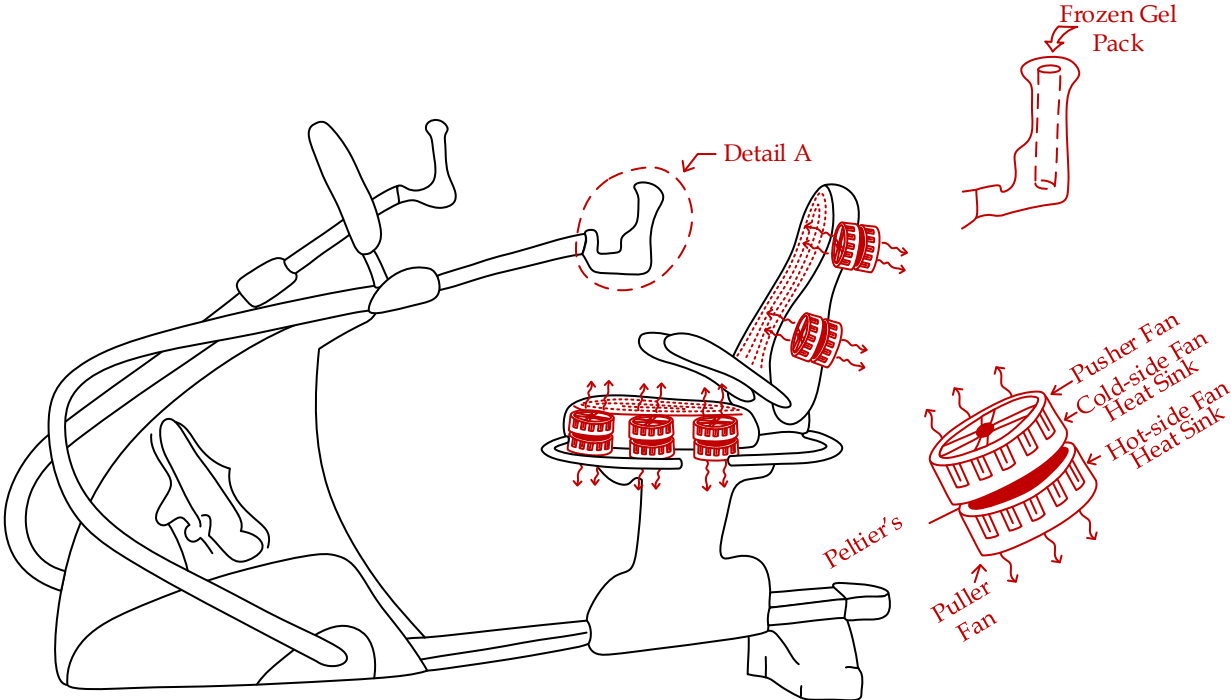


Fig.18.21. Cooling System for Multiple Sclerosis Patients using NuStep T5 cross trainer.



# CHAPTER 19

## UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

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# ASSISTIVE TECHNOLOGY FOR BOX ASSEMBLY AND CHANNEL TUBE PRODUCTION

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Client Coordinator: Barry Wright, Community Workforce Solutions  
Supervising Professor: Richard Goldberg  
Department of Biomedical Engineering  
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## INTRODUCTION

Todd and Sarah (pseudonyms) are adult employees who work at Community Workforce Solutions (CWS), a local organization based in Raleigh, NC, that employs people with disabilities. Each of the clients would like to be able to perform their jobs independently and rapidly, as they get paid according to the amount of work that they can complete.

One of Todd's tasks at CWS is to assemble a cardboard box in an eight-step process from the initial unfolded cardboard template. Because of his cognitive disabilities, he has difficulty with multi-step processes, and needs to be reminded which step comes next. We developed a box folding template that reduces the process to only four steps, making this task much easier for Todd (Figure 19.1).

One of Sarah's tasks is to cut two pieces of reinforced filament tape and place them in a cross pattern over the end of a clear plastic tube. She has limited fine motor control, which results in some shakiness. As a result, she cannot easily grasp and use cutting tools, so it is difficult for her to cut tape, in particular filament tape because it is resistant to cutting. It is also difficult for her to place the tape over the end of the plastic tubes due to her poor motor control. We developed a cutting device that makes it simpler to cut the tape and helps to create the cross pattern.

## STATEMENT OF IMPACT

Before the completion of our devices, neither Todd nor Sarah could independently complete these tasks. With the Box-Folding Assistant and Turntable Cutting Device, they can complete their tasks and do so in a timely manner that will allow them to make



Fig.19.1.The Box Folding Assistant.



more money per hour. Barry Wilson, production manager of CWS, stated: "I think this will really help Sarah and Todd. They want to do anything they possibly can do; a lot of times they have to have an assistant person helping them out, telling them what to do. These devices are going to help them learn to do it by themselves, which give them more and more confidence." Todd exclaimed, "I like it, I'm the man!" after several successful rounds of folding boxes. With regards to the turntable cutter, Sarah explained "it is much easier than using scissors."

## TECHNICAL DESCRIPTION

The box folding assistant consists of four connected pieces of 1.3" PVC piping that form a square inset. An unfolded box is placed above the inset, and the user then presses the center down through the PVC supports. The curvature of the PVC pipe assists increasing the box template as this motion is completed. Four shorter sections of pipe at the four corners of the device encourage the short side flaps to fold upward first, facilitating the rest of the box folding task. This forms the basic shape of the box, all in one step.

To help with the placement of the box template over the folding assistant, three acrylic pieces that mimic the shape of the box template are placed around the folding assistance component. This helps instruct the user where to place the box before beginning the folding process. The acrylic pieces stand at a height of two inches, offset from the side of the box folder by 1.5" inches on either lateral side. The shape and bright color of these pieces both draw the user's attention and allow the user to quickly recognize how to align the box during device use.

The final component aids the user to crease the unfolded template. A flat acrylic piece in the shape of a cross with a handle for easy use is provided, as seen in Figure 19.1. This component aids in creating the creases along several flaps. In particular, the 0.177" thickness of the acrylic corresponds to the width of the double-crease of the side flaps. This allows the user to fold the flap over the acrylic to easily form the double-crease, which had been the most difficult part of creasing the box for our clients.

The turntable cutting device consists of a turntable, a handle, and a shuttle with a rotary cutting blade. To operate this device, the user pulls one piece of tape across the Teflon pieces on the turntable, and then

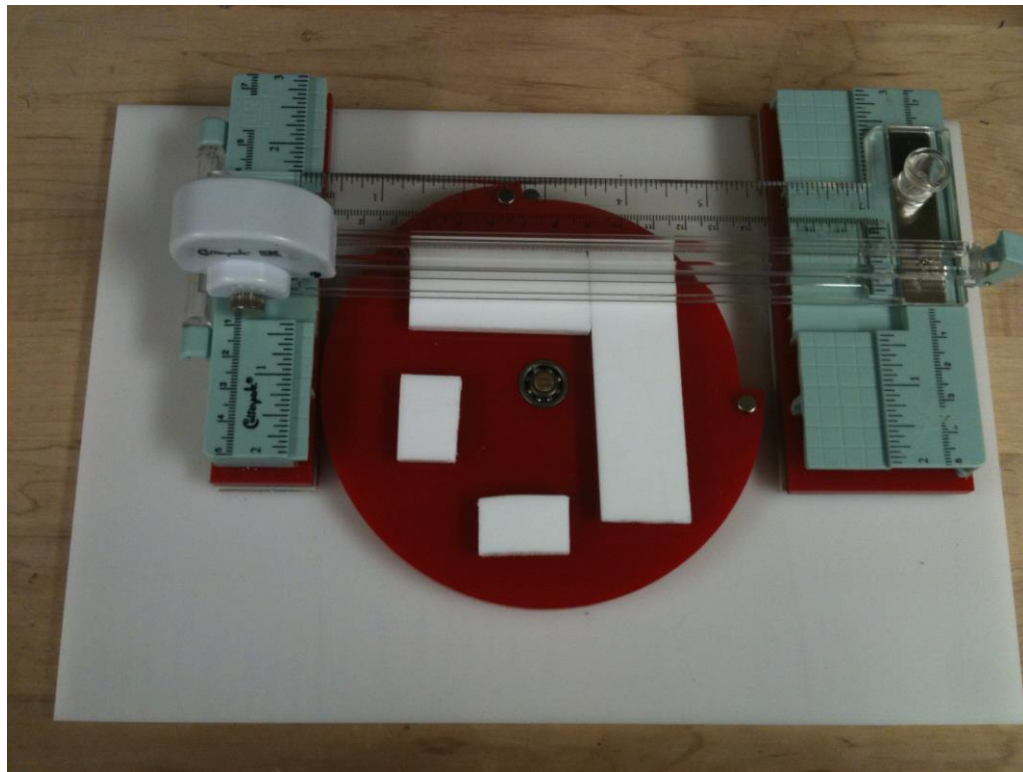


Fig. 19.2. Turntable Cutting Device.

runs the shuttle along the track across the tape, as with a paper cutter. The user then rotates the turntable 90° to repeat the process for a second piece of tape. The tape can then be removed from the turntable, already in the necessary cross pattern and ready to be placed on the end of the tube.

The handle of the device has been created from a commercially available paper trimmer (Cutterpede Mini Paper Trimmer). This paper trimmer uses a rotary blade attached to a rounded shuttle which runs along a track. The track runs the length of the handle (~8in), and the handle of the shuttle must be depressed in order for the blade to extend. This provides a safety guard for the essential blade of the device. We separated the base of this commercial product into three segments: two end pieces, which we kept in our design, and the middle, which we discarded. Both ends of the device were mounted on rectangular acrylic pieces to bring the handle to the level of the turntable face.

The spinning turntable for this device is created from three circular pieces: the base, a spacer, and the turntable face. The acrylic base provides a level area upon which all components of the device are

mounted. The uppermost acrylic piece has four Teflon pieces, attached 1" from the center. This forms two orthogonal sets of surfaces over which the tape is cut, allowing the tape to be precut in the cross pattern necessary for this task. To enable rotation of the turntable, we placed a rod through the center of each of the circular components. One ball bearing is inserted into the center of the rotating face. In addition, a stopping mechanism limits the rotation of the turntable to 90 degrees, and magnets help to hold the turntable at the two endpoints of rotation.

By client request, a second face plate was created. At CWS, employees often share jobs, and in this case, one employee would cut the tape to be placed on the channel tube, while the second would place the tape. To accommodate this arrangement, the second face plate was designed to allow repetitive cutting of single 3" pieces of tape. Two parallel pieces of Teflon are attached to the face 3" apart, allowing the user to rapidly produce single pieces of tape. This plate replaces the rotating turntable face and is immobilized as it locks over the stopping mechanism.

The total cost of both devices was \$200.



Fig.19.3. Client using the Box Folding Assistant.



Fig. 19.4. Client using the Turntable Cutting Device.



# THE PORT-O-YAK

*Designers: Stamp Walden and Jason Wright  
Supervising Professor: Richard Goldberg  
Department of Biomedical Engineering  
University of North Carolina at Chapel Hill  
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## INTRODUCTION

Our client Emily (pseudonym) is an athlete with Myelomenigocele Spina bifida, which over the years has worn away the cartilage in her hips. She uses a manual wheelchair as her primary source of transportation, resulting in excellent upper body strength and range of motion. She can stand and walk, but she easily tires if she is standing for a minute or two. While standing, she is not able to pick up heavy objects.

Emily is an accomplished kayaker, having competed at the Paralympic level. She has a 17 foot, 32 pound, carbon fiber kayak and a practice location that requires her to drive with the kayak from her home to the launch spot. However, she is not able to transport the kayak on and off the roof rack of her van, and to and from the water. As a result, she needs assistance both at home and at the launch site when she wants to go kayaking. For this project, we have modified a commercial roof rack (Figure 19.5-Top) to enable Emily to load and unload the kayak from her van by herself. We have also designed a cart (Figure 19.5-Bottom) that helps her move the kayak between her van and the kayak's storage location at home, and to and from the water at the launch spot. Both the rack and the cart are safe and resistant to the harsh elements associated with kayaking including high humidity, moisture and sand.

## STATEMENT OF IMPACT

As a competitive athlete, our client wants to be able to train without needing help from her friends and family. Our client's passion is to be active and independent. With the Port-O-Yak, our client is able to load her kayak on her van, take it to the launch location, unload the kayak, and go out on the water. After some time on the lake, she can reverse the process. When we asked her about the impact of this project, she replied, "This is simply going to be amazing".



Fig.19.5. Modified roof rack and custom cart.

## TECHNICAL DESCRIPTION

Our design exists in two parts, a kayak rack and a cart. The rack is designed by modifying a Thule Hullavator rack. The cart is designed to transport the user and kayak to and from the water. She can propel the cart by sitting on the attached seat and pushing on the ground with her feet.

The purpose of the extending car rack is to lower the kayak from the roof of the van to a level where Emily can access it from her wheelchair. It was made by modifying a Thule 897XT Hullavator, which attaches to Thule basic square bars that fit onto the factory

tracks that came with our client's van. The Hullavator rack rotates the kayak down to the driver side of the car. In order to further lower the kayak, we constructed a custom sliding mechanism. The sliding piece is comprised of 1.5" H aluminum bar that was ground down to 0.85" on one side. The shorter side fits snugly in the track on the top of the Thule Hullavator. The H bar has a 0.5" bridge that provides the stiffness to allow the slider to hang below the commercial rack without it flexing or swinging. The H bar holds the rack cradle, pins and safety hardware. Spring loaded pins are attached on each aluminum H bar in order to allow for the sliding extender to stay locked in place until the user is ready to fully slide down the new extension. As an extra precaution against unexpected release during road travel, we added a universal 0.75" cotter pin that gets placed through the extender and the commercial rack to hold them in place. We attached rubber pads to the back of the Hullavator to protect the side of the van when the rack gets lowered to that position. After the full extension process and once the sliding H bars have been released and eased down, the kayak is then ready to be unstrapped and rolled onto the cart.

The cart is designed to support our client, the kayak and 50 lbs. of gear. The steering tiller and back chassis system is from a commercial garden pull cart. It has four 13" inflated rubber wheels, tested to 500 lbs., which allows the cart to firmly roll over the rough terrain. The back of the cart is fitted with a light plastic seat, a steering tiller, and a brake lever. The seat is situated to the right of the kayak and fully supports the user over the back wheels near the steering tiller. An aluminum brake lever with a rubber stopper pushes against the back right wheel for braking. On the left side of the cart, the kayak fits into a custom built cradle. The cradle is made from four 3' curved aluminum tubes. Each section is made from  $\frac{3}{4}$ " aluminum tubing with a  $\frac{1}{4}$ " side wall. They are all bent to fit the shape of the top and bottom of the kayak. This allows the kayak to sit on its side with the bottom facing away from the client. All aluminum tubing is coated in 1" rubber insulating tubing to protect the kayak from bruising on the metal.



Fig. 19.6. The starting position with kayak on top of the van.



Fig. 19.7. The client moving lifting the kayak from the rack in its lowered position, and moving it to the cart for transporting it to the water.

The cart is built in two pieces for easier storage in the back of the van during transport. The rear chassis is a U shaped aluminum square bar of 1.5". To assemble the cart, the user slides the two prongs of this U directly over the 8" steel prongs that extend from the back of the front chassis. It is held together with 5" standard safety pins. The cart's total length is 3' and its total width is 16".

The total cost of the rack and cart was \$386. This includes the cost of a used Thule Hullavator rack for \$100, but the client purchased the Thule square bars separately.



# TITLE: HORSEPLAY SIGNALING SYSTEM

*Designer: Rocco DiSanto*

*Client Coordinators: Margie Muenzer, PT, and Lissa Lutz, instructor, NC Therapeutic Riding Center*

*Supervising Professor: Richard Goldberg*

*Department of Biomedical Engineering*

*University of North Carolina at Chapel Hill*

*Chapel Hill, NC 27599*

## INTRODUCTION

The primary client for this project is Jim (pseudonym), a young adult who participates in horseback riding at the North Carolina Therapeutic Riding Center (NCTRC). Jim has been diagnosed with spastic quadriplegia, cortical field vision, and uses a wheelchair. Jim is able to independently maintain his balance on a horse but has visual impairments, characterized by poor forward vision and blindness at some angles.

When riding, he follows a course around an arena that is marked by weaving poles. Riders with visual impairments have difficulty knowing when they reach a pole, so volunteers tap the poles to indicate their position using sounds. This task occupies volunteers' time and prevents them from assisting other riders. I have developed a wireless navigation system (Figure 19.8) that automatically emits audible beeps when the rider approaches a pole. This will enable Jim and riders with visual impairments to navigate their horse independently with minimal input from volunteers.

## SUMMARY OF IMPACT

A therapist who works with our client commented that: "The system's adjustability in terms of range, volume, and tone, as well as its portability, will enable it to be tailored to a wide variety of riders to suit individual needs. Because the device is triggered by the rider, it removes the instructor and volunteers from the loop and allows the rider more independence than would otherwise be possible." Our client indicated that he finds the system to be helpful in indicating the location of the weaving poles. When using the system, he was able to independently guide the horse along a course.

## TECHNICAL DESCRIPTION

The system is comprised of two devices: a radio beacon worn by the rider and a set of 5 radio detectors, each mounted to a weaving pole. As the



Fig. 19.8. The five radio beacons, with speakers mounted inside, that get mounted on weaving poles, and one radio detector that is worn by the user on a hip belt.



Fig. 19.9. The client wearing the hip belt and preparing to ride in the outdoor arena.

rider approaches a pole, the detector will begin producing a tone so that the rider knows the relative location of the pole. When the rider passes the pole, the detector will silence as it loses radio contact with the beacon. This process repeats as the rider moves around the course.

Every beacon and detector contains a radio transceiver (nRF24L01, Nordic Semiconductor) that operates in the 2.4 GHz range. The beacon transmits a signal five times/second, while the detector's transceiver constantly listens for the beacon's signal. The system relies on microcontrollers (PIC 18F2420, Microchip, Inc.) to setup the communication protocol to process the data exchanged between the radio transceivers. Communication between the transceivers and microcontrollers uses SPI, a serial protocol for exchanging data. A computer program was written in the C programming language to implement the SPI protocol on the microcontroller and perform the signal strength measurements. A custom circuit board was designed and fabricated for both the beacon and detector.

The beacon is worn around rider's torso and its electronics are contained inside an "amphipod belt". The beacon's circuitry is encased in an acrylic housing and is principally comprised of the radio transmitter, antenna, and the microcontroller. Other circuitry includes a voltage regulator to protect the circuit and LEDs to indicate the beacon's transmission power level.

The beacon's microcontroller configures the radio transceiver to act as a transmitter. The

microcontroller controls all aspects of the transmission, including the transmitter's power level, the data sequence to transmit, and the number of transmissions per second. The transmitter's signal strength can also be adjusted by the user; this feature allows the range of the system to be optimized for a particular activity.

The detector includes the same electronic components as the beacon, but the microcontroller is running a different program and the circuitry also includes a speaker to generate audible tones. The detector's components are mounted inside a marine grade 4x4x4" plastic electrical box which is attached to a weaving pole using bungee cords.

The detector's microcontroller is programmed to continuously search the airwaves for the signal transmitted by the beacon. When the detector finds that the received signal has reached a minimum power level, it will begin counting the number of successful data receptions within a given period of time. This measurement is used to determine the signal's strength. When the signal strength reaches a critical level, the detector will begin sounding; guiding the rider towards the pole. Each detector generates a different sound to make the system less confusing to the rider. The distance at which the sounding begins is proportional to the beacon's transmission power and can be set for distances between 5' and 25'.

The total cost of this project is \$421 for 1 detector and 5 beacons.

## VIEW IT

*Designers: Kailey Boyce and Aameeka George  
Client Coordinator: Diana Garrett, COTA/L, Durham Public Schools  
Supervising Professor: Richard Goldberg  
Department of Biomedical Engineering  
University of North Carolina at Chapel Hill  
Chapel Hill, NC 27599*

### INTRODUCTION

Our client, Bob (pseudonym), is a young boy with septo-optic dysplasia, which is a visual impairment, and autism. He has decreased vision in both eyes and can only see in certain spots of his visual field. He therefore must move his head until the object of interest appears in one of those spots. His visual impairments most greatly affect his reading and writing; Bob is only able to read and write when his eyes are a few inches from the page. For example, to read a 26-point font, he needs to have his eyes only 2-3 inches from the page, and to read a smaller font, he must be at an eye-lash distance.

As a result, Bob must bend over his classroom desk to do all of his reading and writing activities. His teacher and occupational therapist were concerned that this would cause long term damage to his spine. Commercial devices, such as a slant board, are helpful but still do not position the materials at an appropriate location. We have developed a device that allows him to maintain an upright position at his desk while performing his classroom assignments. To accomplish this task, we have customized a portable Versa Table to fit his needs (Figure 19.10).

### STATEMENT OF IMPACT

The View It Display Stand allows Bob to sit vertically while reading and writing. The device therefore prevents damage that would be caused to the client's spine if he were to continue bending over his desk to perform his classroom activities. Also, according to the client's teacher, this device helps Bob to stay focused in the classroom: "during your weekly visits, you are able to get him to do more work with your device than I get him to do in the entire rest of the day".

### TECHNICAL DESCRIPTION

The device is a work surface mounted to a supporting arm with adjustable positioning. The work surface is capable of holding books and papers while reading



Fig. 19.10. The View It stand.



Fig.19.10. The client using the View It stand to draw.

or writing. After being attached to a desk in front of the client, the work surface is positioned vertically at the appropriate distance. The distance is adjustable to allow Bob to see different font sizes or give him

room to write. With this device, Bob is able to remain seated completely upright while accomplishing his classroom activities.

The base of the device is a 12" by 12" piece of oak which is coated in a polyurethane finish and the commercial Versa Table is permanently attached to this base using construction glue. A clamp, which tightens by turning a star knob, secures the device to the client's desk using a bolt with a rubber stopper. When the star knob is turned, the rubber stopper tightens against the underside of the desk and prevents the device from sliding. The clamp, which holds the bolt in place, is screwed into the bottom of the base. To make the device sit flat, the clamp was set into the wood by milling out a section of the oak. This ensured that the bottom of the clamp would be flush with the bottom of the oak base.

The position of the device is controlled by the tension of four bolts attached to separate plastic knobs. The bottom knobs control the height and front to back motion of the work surface, while the top knobs adjust its tilt. To position, just loosen the appropriate knob(s), adjust to the desired location, and re-tighten the knob(s). The angle of the work surface has a 90 degree range from completely vertical to completely horizontal. The horizontal position is useful for

storage because the device is in its most compact state.

The work surface is a 12" x 16" piece of white birch veneer with a lacquer finish. Fastened to the surface's front is a 12" x 16" magnetic dry erase board. The dry erase board is black to create a strong contrast between the background and Bob's reading or writing materials. Since the white pages stand out against the black of the dry erase board, this helps Bob to focus on his assignments and makes it easier for him to see. The dry erase board can also be used as its own writing surface and is easy to clean, which is important because it will constantly be in contact with the client's hands and face.

There are three methods of holding books or papers on the device. The first is by using magnets to hold papers to the magnetic dry erase board. The second is a clip board which is screwed into the top of the work surface and can be used for both books and papers. The third is a book holder which uses two vertical projections to keep books open and secure. The book holder is detachable so it can be out of the way while not in use. It slides on and off the work surface's bottom ledge and the books are placed on the board behind the projections of the holder.

The total cost of this device is \$255.







# CHAPTER 20

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# DEVELOPMENT OF AN ACCESSIBLE AND ADAPTABLE YOUTH GOLF CART

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## INTRODUCTION

The objective of this project was to modify a standard power cart for use on a golf course by a young boy, who has limited use of his legs. An Invacare Lynx-L3, shown in Figure 20.1, was modified in order to allow this “client” maximum independence and accessibility while providing all of the necessary features for a golf cart. To accomplish this, two main modifications to the power cart were made: a redesign of the rotating seat to incorporate a tilting function and a safety harness, as well as a redesign of the front axle of the cart to change it from a three wheel design to a more stable four wheel design. An electric actuator mounted at the bottom of the seat base was used for the tilting mechanism. The design features two bar parallel linkage on each side of the seat that allows the backrest to remain vertical while in the tilted position. The steering system of the front axle design includes a bracket on the steering column, tie rods and spindles. The tie rods attach to the bracket and connect it to the spindles which allow the cart to steer. New larger off-road tires were also added to provide the appropriate traction for maneuvering the golf course. A golf bag holder was also added to carry the essential golf items. The adapted golf cart is depicted in Figure 20.2.

## SUMMARY OF IMPACT

People with disabilities have little access to activities such as golf due to limited wheelchair accessibility or the need for assistance from other people when participating in the activity. This is unfortunate, because activities such as these can be very therapeutic for an individual, allowing them to play the sport they love. Eric Rine, a ten year old boy with spina bifida, currently loves to play golf, but has very



Fig. 20.1. Invacare Lynx LX-3.



Fig. 20.2. Adapted Gold Cart.

limited access to play because he uses a manual wheelchair which cannot maneuver on a golf course. There are several adaptive golf carts on the market

today, such as those available from EV Rider, GolfXpress and SoloRider, but these carts are designed for adults and are difficult and unsafe for smaller people to operate. These carts are also very expensive, ranging in price from \$3,990 to \$9,950.

A mobility cart, an Invacare Lynx-L3, was modified to allow Eric to play golf, accessing all areas of the golf course with complete independence. The adapted golf cart allows its user to efficiently maneuver about a golf course and to golf while remaining seated. Figure 20.3 depicts Eric using the cart and Figure 20.4 depicts Eric along with the members of the design team.

Because Crosswinds Golf Club has a youth program in which several children with physical disabilities are involved, the golf cart will be kept there, where it will be available to any child with a physical handicap to use. Therefore the golf cart will have a positive impact on the lives of many children in the greater Toledo area no matter their physical ability.

## TECHNICAL DESCRIPTION

The objective of this project is to adapt a power cart to efficiently maneuver about a golf course and allow the user to golf while remaining seated. The main design criteria are safety, ease of use, reliability, comfort, and usability. The adaptation of the power cart required adding a seat tilt function to allow for a better swinging motion for the user, and to change the cart design from three wheels to four wheels to add stability. This required the redesign of the cart seating and steering systems.

**Seat Design.** Modifications performed to the seat include the addition of a tilting function as well as a safety harness to hold the passenger securely in place while golfing. The added tilting function allows the user to golf from a position that will drop their knees and enhance their swinging motion. Electric actuator, hydraulic cylinder, and a manual lever designs were considered to actuate a linkage that would raise the rear of the cart's seat. Using a House of Quality, the electric actuator design was chosen for its ease of use, its limited space usage, and an infinite number of inclination angles for the user to position the seat within its motion range. This will allow the user to position the seat in the most comfortable position from which to swing. The hydraulic system would require the user to pump a lever to tilt the seat and use a release valve to lower the seat, which is more complicated and harder to use than the electric



Fig. 20.3. Client using the Adapted Golf Cart.



Fig. 20.4. Client and design team members.

system. The manual system tilting system would be the most cost-effective method. However, it would use one lever on each side of the seat attached directly to the tilt linkages and the seat would lock into several predetermined tilt positions as it was raised. The manual system would thus require more user effort to operate and is not as adjustable as the hydraulic or electric systems, due to the limited number of locking positions.

A linear electric actuator was mounted at the bottom of the seat base and connected to the center of the rear of the seat bottom. The design of the seating system also features a two bar parallel linkage on each side of the seat that adds stability to the seat and allows the backrest to remain vertical while in the tilted position. A diagram outlining the electric tilt mechanism is shown in Figure 20.5.

A three dimensional working model of the current seat and all of its hardware was developed using

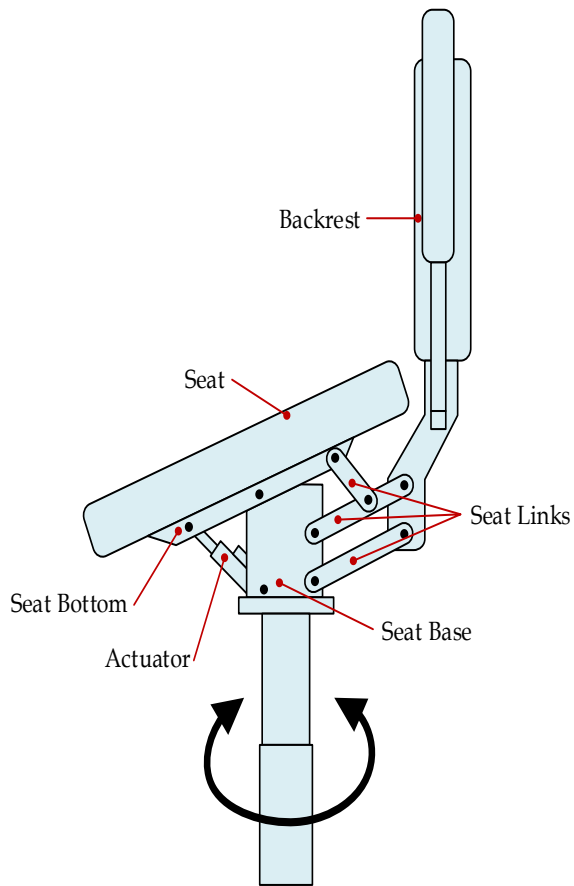


Fig. 20.5. Diagram of Electric Tilt Mechanism.

SolidWorks. An approximate tilt seat linkage was then modeled and adapted to the existing seat model. After a working assembly of the seat was created, dimensions of the various linkages were changed to produce the desired tilting motion. The actuator was then incorporated into the model. The seat assembly is shown in Figures 20.6 (Top) and 20.6 (Bottom) with the actuator fully retracted and then with the actuator fully extended, respectively. Figure 20.7 is a view from the back side of the seat which shows the final placement of the actuator.

With the desired kinematics modeled, calculations were performed to determine the maximum load that would be exerted on the actuator. To do this, the geometries of the seat base, seat bottom, and linkages were analyzed and the pieces were approximated as rigid beams. Using the various angles of the linkages and actuator relative to the seat base and assuming a rider weight of 250 pounds, the maximum rider weight for which the Lynx L-3 is rated, actuator

reactions were calculated throughout the tilting range of the seat. Rider weight was approximated as concentrated force acting at the center of the seat. This process was iterative as calculations had to be performed based on geometries that would accommodate readily available actuators with a predetermined load rating and extension range. The maximum calculated actuator force was 93 pounds at an inclination angle of zero degrees. The actuator that was eventually chosen is manufactured by Firgelli Automations and provides two inches of extension (2" stroke) while supporting loads of up to 150 lbs.

After determining an appropriate seat linkage and actuator selection, analysis was performed on the seat's various components. First, the shear stresses and bearing stresses were calculated for the pins on which the seat linkages pivot. Stresses were calculated using the maximum reaction force of 209 pounds calculated at the main pivot point between the seat bottom and the base. From the results of these calculations, the maximum shear stresses and bearing stresses were computed for the pivot pins and actuator mounting bolt. The lowest factor of safety found for the pivot pins was 14.571 and the lowest for the actuator mounting bolt was 22.174.

Next, Finite Element Analysis (FEA) was performed on various components of the seat. An assembly was made of the base and seat bottom and included a solid link to simulate the actuator. A 250 pound load was applied to the seat bottom and the analysis was used to verify the hand calculations for actuator load. Figures 20.8 and 20.9 depict the finite element model in the fully retracted and fully extended positions of the actuator, respectively.

The load calculated by the FEA analysis for the fully retracted actuator position was 93.1 pounds. When compared to the hand calculated value of 92.6 pounds, there is only a 0.54% difference. For the fully extended actuator position, the FEA analysis yielded a load of 72.9 pounds on the actuator compared to 70.2 pounds calculated by hand, which represents only a 3.7% difference and verifies the accuracy of the hand calculations.

The next analysis that was performed was on the new seat bottom. This is the piece that the actuator pushes on to tilt the seat. This piece was designed using 11 GA (.120 in) AISI 1008 carbon steel sheet. For the analysis, the seat bottom pivot point and the actuator





Fig. 20.6. SolidWorks Model Showing Tilting Motion of Seat, with the actuator fully retracted (top) and with the actuator fully extended (bottom).

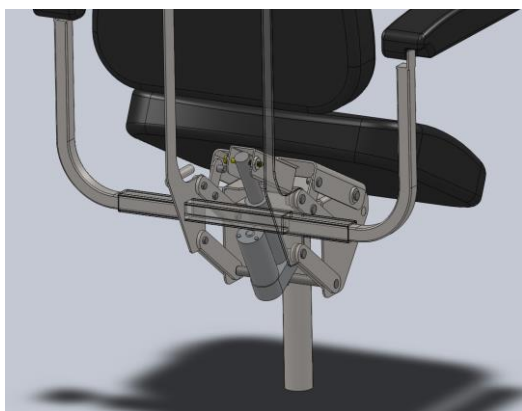


Fig. 20.7. Schematic view of the back side of the seat showing the final placement of the actuator.

mounting hole were both constrained as fixed hinges. This constraint allows rotation about each hole but does not permit translation in any direction as would be the case when the actuator is not moving. Then, a 250 pound load, representing the weight of the rider, was distributed across the top of the piece. The seat bottom was analyzed in the fully retracted actuator position as this would be the highest stressed case. Figure 20.10 shows the FEA model of the seat bottom for this tested condition. A minimum factor of safety for the piece was calculated as 3.32 and occurred just above the main pivot holes.

In addition to the seat bottom, FEA analysis was also performed on the seat base. This piece, which fits into the original seat mounting post, serves as the attachment point for the seat linkages as well as the actuator. It is constructed from 11 GA AISI 1008 carbon steel sheet and also includes the pivot point for the seat bottom. In the analysis, the mounting post, which allows the base to rotate about its attachment post on the cart's frame, was constrained as fixed geometry, preventing it from rotating or translating in any direction. Then, the previously calculated loads (maximum calculated force of 93 lbs. acting on the actuator when fully retracted and maximum reaction force of 209 lbs. calculated at the main pivot point between the seat bottom and the base) were applied to the actuator mounting holes as well as the seat bottom pivot holes. Figure 20.11 shows the FEA model of the seat base for this tested condition. A minimum factor of safety was calculated as 1.77 around the weld of the main pivot post.

Analysis was not performed on the different links of the linkage system as they only serve to hold the backrest of the seat vertical throughout the tilting range of the seat. Because of this, the only load they will see is due to the weight of the seat back and any force the rider exerts on the backrest. With 8 links made from 3/16 inch thick steel flat bar, they will have no problem supporting this loading. As a final check, the bending stress in the actuator mounting bolt was checked. This check was performed because the actuator load is applied directly to the center of a 6 inch long bolt, creating a large bending moment. With a 3/8 inch SAE Grade 8 Bolt serving as the actuator mount a maximum bending stress of 26,950 psi was calculated providing a factor of safety of 4.825.



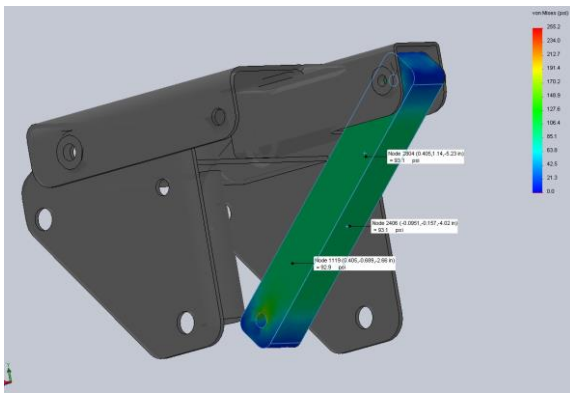


Fig. 20.8. Fully retracted actuator load FEA.

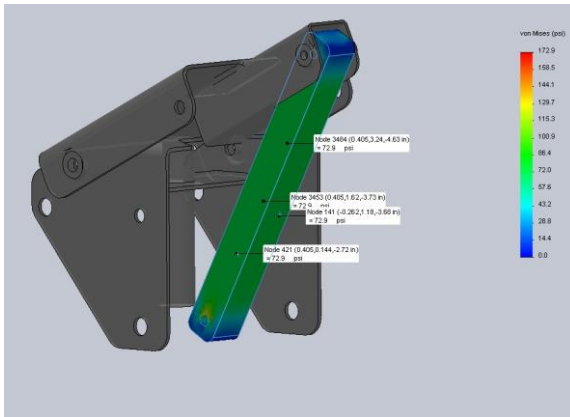


Fig. 20.9. Fully extended actuator load FEA.

Steel for the seat construction was donated by Custom Metal Works, Inc. in Norwalk, OH and the parts were fabricated by the team members. This fabrication included all of the linkages as well as the seat bottom and base. The pivot pins were machined by the University of Toledo machine shop and the actuator and control switch were purchased online through Firgelli Automations.

The safety harness used is a 2 inch lap belt connected to a 2 way anti-submarine belt to fully support the rider's weight. This setup was purchased through Crow Enterprises. During the final assembly, the seat was painted and the actuator was connected to wires spliced into one of the cart's two 12 volt batteries.

**Front Axle Design.** Three main design options were proposed in order to modify the front axle system: to install a wider front tire and otherwise keep the three wheeled design of the cart, to modify the front axle to accommodate two front wheels, or to add dolly wheels to the front sides while keeping a single wheel in the front.

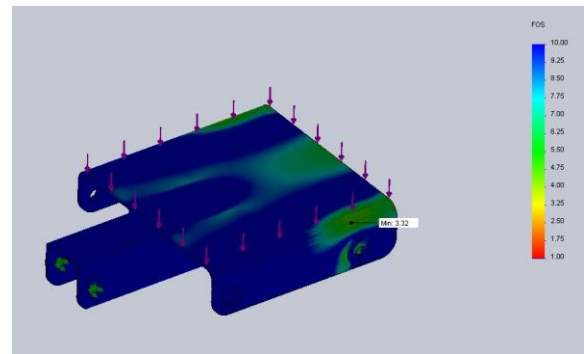


Fig. 20.10. FEA factor of safety plot for seat bottom.

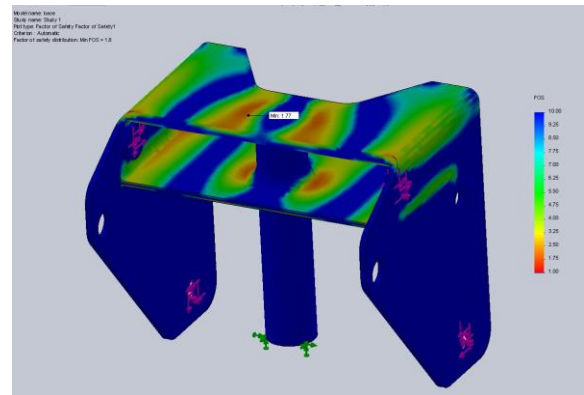


Fig. 20.11. FEA factor of safety plot for seat base.

Using a House of Quality, the four wheel design was found to offer the most stability of the three designs while also being the safest, and thus was determined to be the best design. The two front wheels are contained within the frame of the cart and do not interfere with the swinging motion of the golfer or travel of the golf ball. However, the four wheel setup will result in an increase in the turning radius of the cart, resulting in decreased maneuverability. A schematic of this design is shown in Figure 20.12.

Installing a wider front tire, while maintaining as much of the three wheeled design of the cart has several advantages including a tight turning radius, ease of implementation, and the ease at which the handlebars could be steered. It was also the most cost effective option. However, the main disadvantage of this design is that it did not provide a great amount of stability for the cart. The four wheel design provides an increased stability and ground contact areas. Incorporating dolly wheels into the cart's original three wheel design provides more stability than just the three wheels, and is less costly than modifying the front axle to accommodate two front

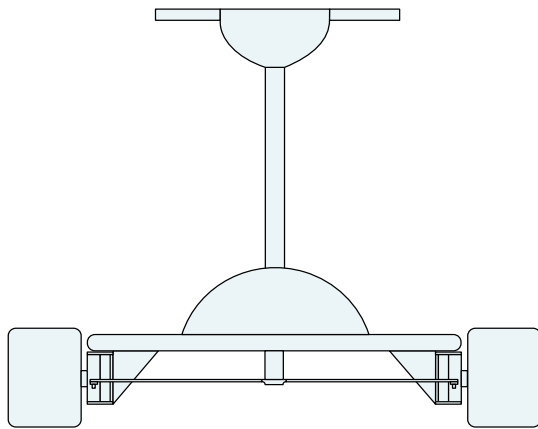


Fig. 20.12. Schematic of four wheel design.

wheels. The drawbacks to the dolly wheel design were that it would require the cart to tip a little before the wheels would come into contact with the ground. Also, the dolly wheels could possibly stick out into the swinging radius of the golfer. The four wheel design provides a superior stability and ease of use.

The tires needed to be small in diameter in order to retain as much of the cart's driving force as possible. They also needed to be fairly wide to increase ground contact area and include a tread for enhanced off road traction. The tires ultimately selected were Carlisle Turf Saver® 9x3.5-4 tires rated at 260 lbs. per tire. A contact area comparison was calculated to compare their ground contact areas with that of the original cart tires. The cart originally used three Cheng Shin brand tires that were 8 inches in diameter and 2 inches wide. Contact area was increased by 40% for the entire cart by using the Turf Saver® tires.

To determine spindle loads, it was first recognized that there are two main forces that act on them; one of these is a vertical force generated by the weight of the cart and rider and distributed among the four wheels and the other is a force axial to the spindle caused by friction at the tires' contact patch when turning. To determine the vertical force acting on the spindle, the weight of the cart and rider together was assumed to be 350 pounds. Then, to account for uneven weight distribution that could be encountered on hilly terrain, it was assumed that 75% of this weight acted through one tire as a worst case scenario. This resulted in a normal force from the ground of 262.5 pounds. The calculation of the turning force was slightly more involved. Since the actual turning force is dependent on the coefficient of

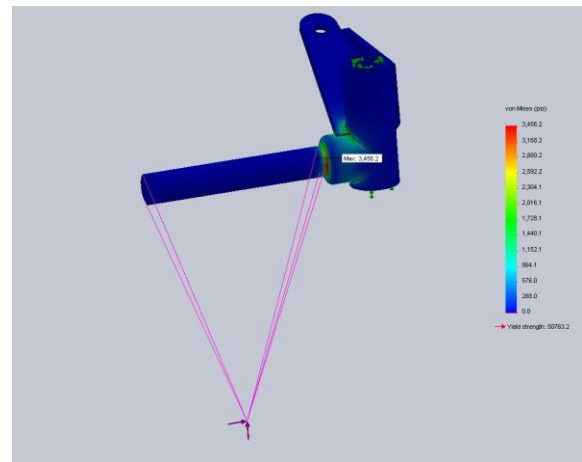


Fig. 20.13. FEA stress plot of spindle under turning loads.

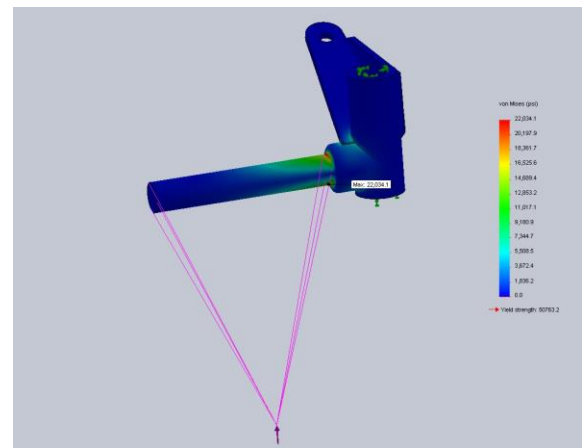


Fig. 20.14. FEA stress plot of spindle without turning loads.

friction between the tires and the ground, it would be very difficult to calculate because of the wide variance of friction coefficients that could be encountered in off road terrain. Therefore, the force was derived by calculating the maximum centrifugal force experienced by the cart when turning at maximum speed at the tightest possible turning radius. The centrifugal force calculated using this method was 137 pounds. Then, once again due to possibilities of uneven weight distribution, it was assumed that 75% of this force acted through one tire. By doing this, a turning force of 103 pounds was determined.

Three dimensional spindle models were then created, and FEA analysis was performed on the spindles. Two cases were studied to simulate the non-turning (only the maximum normal force applied) and the turning (both the maximum normal force and turning

force applied) conditions. Because of the opposing direction of the bending moments generated by each force, it was determined that the most stressed case for the spindles was when the cart was not turning. The material for the spindles was assumed to be AISI 1020 cold drawn steel. In each analysis, the inside of the pivot tube of the spindle was constrained as fixed geometry and the loads were remotely applied to the face against which the wheel mounts from the location of the tire's contact patch. Figures 20.13 and 20.14 show the FEA spindle models under turning loads and without turning loads, respectively. From the FEA results, a maximum stress of 3,456 psi and factor of safety of 14.7 was calculated for the turning simulation and for the non-turning simulation the maximum stress was 22,000 psi, resulting in a factor of safety of 2.3. Hand calculations were also performed for each case by finding the Von Mises stress at the point where the spindle bolt is welded to its pivot tube. This stress was computed based on the calculated axial, bending, and shear stresses acting at this point. The results showed a maximum stress of 3,238 psi and a factor of safety of 15.44 for the turning case and a maximum stress of 19,800 psi with a factor of safety of 2.525 for the non-turning case. Percent differences between hand calculations and FEA analysis were 6.3% for the turning scenario and 10% for the non-turning scenario.

A three-dimensional model of the frame of the existing cart was then created using SolidWorks. The models of the tires, wheels and spindles were then placed into an assembly with the frame based on desired track width, wheelbase, ride height, and clearance requirements. Once placed, the various components were moved through their range of motion within the model to check for any possible clearance issues. Figure 20.15 shows the frame of the cart and the final placement of the two front wheels.

The steering system was then added to the model. The steering system includes a simple triangular shaped bracket on the steering column to which the tie rods attach. The tie rods connect this piece to the spindles and allow the cart to steer. The tie rod attachment bracket was designed to provide a motion ratio such that the wheels could sweep their entire range of motion without having to turn the handlebars too far. The attachment bracket was

positioned such that it would not cause binding in the tie rod ends at any point in its range of motion. The length of each tie rod was determined from the 3D model. Figure 20.16 shows the finalized assembly of the front end of the cart with the steering system in place.

Parts, which were purchased to implement the redesigned front axle, include the tires, inner tubes, wheels, wheel bearings, tie rod ends, and spindle kits. Spindle kits included spindles, spindle attachment brackets, and all necessary mounting hardware. Fabricated parts included the new square tubing frame additions, the bumper, the tie rods, and the tie rod attachment plate. The new frame components and bumper were cut to length from 1 inch A500 structural square tubing and welded into their correct positions. The tie rods were made from 3/8" hot rolled steel rod, cut to length and threaded. The tie rod attachment plate was then fabricated and welded in place to the extended steering column.

Once all of the parts were fabricated, the front end was assembled and tested. The cart was then test driven to be sure there were no unforeseen problems with the design. With everything finalized and working properly, the frame was disassembled, painted, and reassembled for the finished product.

The total cost of all required materials is \$1000. Generous donations to the project were made by several sponsors. The Ability of Center of Greater Toledo donated the Lynx cart, a value of \$350, to the project. Rich Evans, a member of the American Society of Mechanical Engineers, donated \$100, which was used to cover the cost of the linear actuator. The Andersons, Inc. donated \$225 towards the purchase of the rims, bearings, and tires. The machine shop of the Department of Mechanical, Industrial and Manufacturing Engineering at the University of Toledo donated several parts costing about \$130. The actual charges made to purchase parts totaled about \$200. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address:  
<http://www.eng.utoledo.edu/mime/design/clinics/2011/Spring/sites/2011-01-03/Website/>

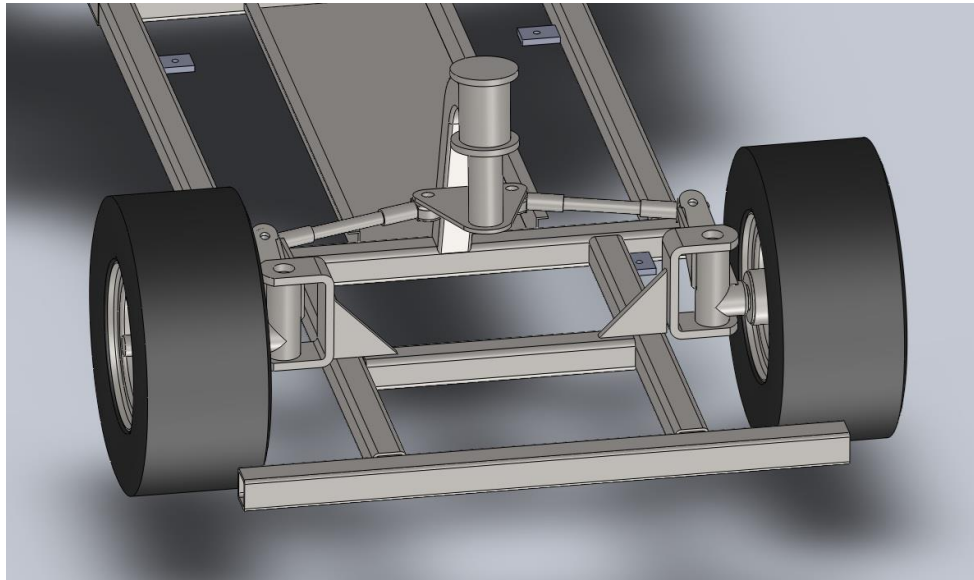


Fig. 20.15. Model of frame showing final wheel placement.

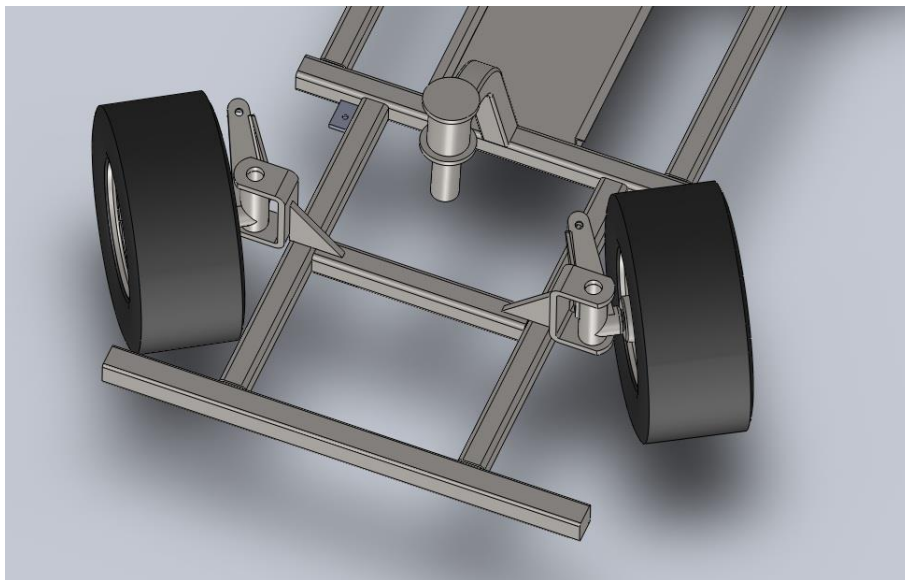


Fig. 20.16. Finalized Assembly of Front End.

# DEVELOPMENT OF A DRINKING SYSTEM FOR QUADRIPLEGICS

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## INTRODUCTION

The goal of this project was to develop a safe, adaptable, easily accessible, and leak proof drinking system to be used by individuals with spinal cord injuries (SCI) who have independent control of only head movement. The system was designed to be activated by the users with their mouth using a bite switch. The system includes two fluid containers, two solenoid valves, a micro-controller and the bite switch. The micro-controller is set for two different predetermined times corresponding to a short bite less than 1 second and a long bite over 2 seconds. On a long bite, the micro-controller switches between the two solenoid valves. On a short bite, the selected solenoid valve will be opened and a predetermined amount of the contents of the corresponding container is delivered to the user. The developed circuit board was contained within a control box. Steel brackets and pole mounts were used to support the two fluid containers and the electronic box. Tygon tubing was used to connect all system components. The tubing was run through a goose neck while the wiring was wrapped around it. Figure 20.17 shows the completed prototype and Figure 20.18 shows the circuit board and its circuitry.

## SUMMARY OF IMPACT

During the acute care management of individuals with limited mobility below the neck, a significant amount of time is spent by the nursing staff assisting the patient to drink 3 liters of water each day to maintain body hydration. The developed drinking system would reduce the demands on the nursing staff allowing them to have more time to focus on other aspects of SCI care. The developed system would also give the patient the ability to control their own water consumption allowing greater



Fig. 20.17. Completed prototype.

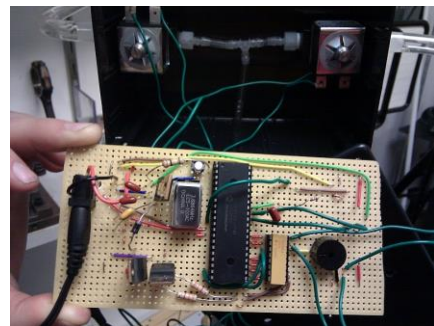


Fig. 20.18. Close up view of the circuit board.

independence and comfort. The adaptability of this product from a post mount to a wall mount will be beneficial to many different individuals in different situations. Hospital patients can benefit by attaching the system to most IV stands and individuals that are



unable to leave their bed at home can use a post mount or a more permanent wall mount.

## TECHNICAL DESCRIPTION

Several factors were considered in the design. Adaptability to individuals in different living situations was taken into consideration, either in a hospital or living at home. Weight was also a concern for the caretaker; therefore a lightweight, portable design was necessary. Safety was another important factor that was considered in the design. Since there are electrical components in the system, it must not leak to prevent the user from getting wet or causing a short in its electrical circuitry. Two fluid containers were included in the system. The user could thus have their favorite two drink choices. A programmed micro-controller was used to control the system which includes a three way valve, a bite switch, and two solenoid valves. The switch bite is used by the user to control the delivery of the liquid. The microcontroller was set for two predetermined times of 1 second and 2 seconds. On the long bite, the micro-controller will switch between the two solenoid valves. This will allow the user to independently switch fluids by biting down on the switch bite. On the short bite, the selected solenoid valve will be opened to provide a specific volume of liquid to the user. The fluid will flow for a preset amount of time of 1 second. This time was determined using fluid flow analysis and will allow delivering one dose of liquid of 30 ml. The micro-controller is the key design aspect of the system. The micro-controller will wait for an input from the patient's switch. The micro-controller will switch to the opposite mode if it receives a long input from the patient's switch. Each mode corresponds to which solenoid would be activated by a short input from the patient's switch. The solenoid valves only remain open for a programmed amount of time which will be unaffected by the length of time the patient activates the switch. This will prevent possible lockjaw leading to large amounts of water harming the patient. In order to get these features, logic was programmed into the micro-controller. A speaker and LED system

was also hardwired into the system, helping the patient understand what command the system is performing. The selected micro-controller chip operates at 5 volts and would be damaged by higher voltages. On the other hand, the solenoids require 12 volts to operate correctly. To overcome this problem, transistors and voltage regulators were installed to provide a barrier between the systems while allowing interaction between the components. An electrical design of the micro-controller has been developed and its wiring diagram is shown in Figure 20.19. Included in the circuitry is an override toggle switch. This switch can be activated to hold either valve open continuously. With this switch, the contents of the containers can be quickly removed for refilling and/or cleaning. Two steel brackets made of 1/8" thick and 3/4" wide 1015 cold rolled steel and bolted to two 1/8" thick steel pole mounts were used to support the two containers and the electronic box. The fixture can be attached to either a wall fixture for household use or a mobile IV stand. Finite element analysis was also performed using SolidWorks to ensure that the unit can safely handle the normal loading and foreseeable unwanted loads from personnel. The bite switch and mouth piece are mounted via a flexible gooseneck tube that can readily be positioned in front of the user. The tubing was run through the gooseneck while the wiring was wrapped around the outside. Short lengths of 3/8 inch tubing were used to connect the containers and solenoid valves, and 1/8 inch tubing was used to carry the liquid the remaining distance from the solenoid valves to the mouth piece. Barbed tube fittings were used to easy connect-disconnect. The tubing, barbed fittings, and liquid containers were sealed properly. The prototype was completely assembled and tested for full functionality. The project has a total cost of \$342.89, with the majority of the cost consisting of electronic components. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address: <http://www.eng.utoledo.edu/mime/design/clinics/2010/Fall/2010-03-01/>

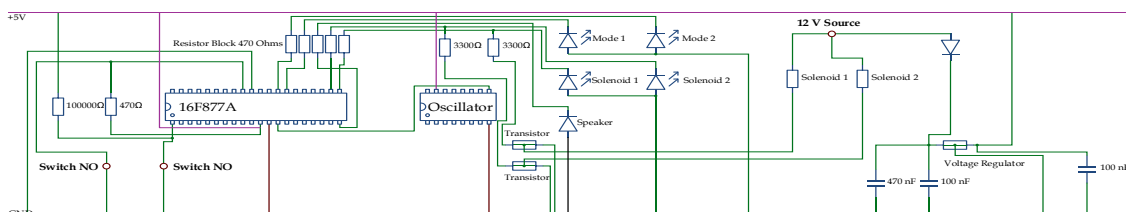


Fig. 20.19. Electrical wiring diagram of the microcontroller.

# DEVICE TO LOAD AND UNLOAD A WHEELCHAIR IN AND FROM A CAR

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## INTRODUCTION

Sunshine Foundation is a non-profit organization which cares for the needs and services of people with a wide range of developmental disabilities. One of the tedious tasks required of the staff at Sunshine is to load and unload wheelchairs from the trunk of vehicles. While performing this task, many staff members have injured themselves, either due to poor grip on the wheelchair, wrong posture and/or lifting positions. The objective of this project was to develop a portable device that allows someone to load and unload a wheelchair to and from the trunk of a car safely and easily. The unit that was developed is shown in Figure 20.20 and includes a wedge and a J-hook which are both placed inside the trunk of the vehicle. The J-hook is the only moving part while performing the task of loading or unloading the wheelchair. The wheelchair is placed on the J-hook which is lifted by the assisting personnel. A sliding motion is used to slide the J-hook into the trunk, and once inside the trunk, lays inside the wedge as shown in Figure 20.21. The unit was made out of aluminum making it lightweight.

## SUMMARY OF IMPACT

There are few devices on the market that assist in lifting a wheelchair, but they are all electric, expensive, heavy, and difficult to move from vehicle to vehicle and they hang outside the trunk of the car. The developed unit was specifically made for Sunshine Foundation which is a non-profit organization where there are a large number of residents using wheelchairs. The unit will be used by staff members at Sunshine and family members assisting in the loading and unloading of wheelchairs. However, anyone assisting in the task of loading or unloading a wheelchair from the trunk of a car will also benefit from this design. The unit was



Fig. 20.20. Picture of the device.



Fig. 20.21. Picture of the wheelchair on the unit inside the trunk of a car.

tested by staff members and was found to meet all expectations. The final design is easy to use, lightweight, portable and ergonomic as it eliminates twists, bends and improper hand placements, making it safe and reliable.

## TECHNICAL DESCRIPTION

The main objective of this project was to design and construct a system that assists in the loading and unloading of a wheelchair safely in and out of the trunk of a car. Design criterion included portability, ease of use, lightweight, size, safety, and cost. An ergonomic design was desired to eliminate twists and bends when lifting the wheelchair. Also, the system had to be portable and hence lightweight so it can be moved from vehicle to vehicle, and can be placed easily inside the trunk of the vehicle.

An electrical system that employs two linear actuators to tilt and slide a platform on a wedge on which the wheelchair would be placed was first considered. The user of this system does not have to do any lifting or bending since it is controlled by actuators. Although very convenient, this design required batteries to operate which are bulky and need to be replaced or recharged. Instead, a manual design was adopted which consists of a wedge and a J-hook. Figure 20.22 depicts a rendering of the system. The wheelchair is placed on the J-hook and then would be lifted and rolled into the trunk of the vehicle. The wheelchair is still attached to the J-hook when inside the vehicle. The advantages of this design are it is lightweight, ergonomic, reliable, and low cost. A disadvantage of this device is that human effort will be needed to load or unload the wheelchair.

The hook was made of T6 aluminum round tubes and aluminum square tubes were used to construct the wedge. The dimensions of the wedge and J-hook were determined using trunk dimensions of a mid-size car and the dimensions of a wheelchair. A locking hinge was placed at the bottom of the J-hook so that it lays flat on the ground to facilitate loading the wheelchair. Springs were used in the locking hinges along with round bars and steel casings. Tracks made of aluminum angle bars were placed on each side of the wedge for the wheels attached to the J-hook to roll on. The front of the J-hook consists of an aluminum bar that serves as a handle to lift the J-hook. To avoid any clearance issues, the wedge was

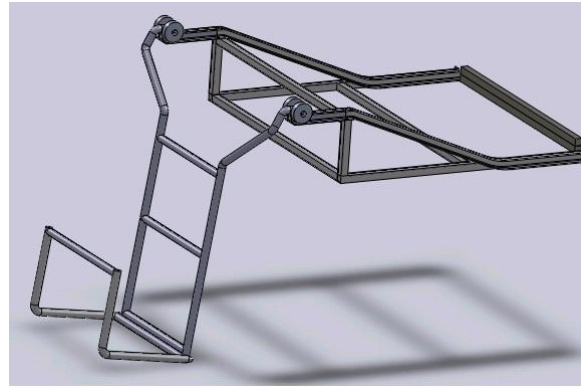


Fig. 20.22. Three dimensional model of the system.

made wider than the J-hook. Extendible arms were attached to extend out over the bumper to avoid any damage to the vehicle and its trunk. The length of the extendible arms was determined using the height of the trunk from the ground and the width of the bumper. These extendible arms are detachable so as to clear the trunk door when closed. It was determined that a moment would be created when the wheelchair is placed on the J-hook. Steel bars serving as counterweights were placed at the far end of the wedge to counteract this moment.

The final design was analyzed using hand calculations and FEA using SolidWorks software and found to be safe. FEA was also conducted on the locking hinge and the extendible arms to determine any major stresses or possible failure. Several parts were donated for this project. The actual total cost of all purchased parts was \$375 after donations. The machine shop of the Department of Mechanical, Industrial and Manufacturing Engineering at the University of Toledo helped cut the material to dimensioned sizes and Obars Machine and Tool Co. performed all the welding on the prototype.

The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address: <http://www.eng.utoledo.edu/mime/design/clinics/2010/Fall/2010-03-04/Main.html>.



# DEVICES TO ASSIST IN PAINTING AND SKETCHING

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## INTRODUCTION

Amy and Luis love to paint, but cannot utilize a classical easel due to developmental disabilities that limit their mobility. They have much different levels of mobility. The purpose of this project was to develop two devices that would mount to their wheelchairs and provide adjustable surfaces for the media upon which they would be painting. An articulating arm mount was developed for Luis who has low mobility and hand dexterity. The arm allows the media surface to pivot up and down and from side to side, to move towards and from the user, and to adjust in height. Figures 20.23 and 20.24 show two different pictures of Luis using the arm mount. Also, a wheelchair tray media mount was developed for Amy who has relatively high mobility. The unit is mounted to the tray on Amy's wheelchair allowing her to be seated comfortably in her wheelchair while painting. The media mount include links that allow positioning the painting surface at 60°, 45°, and 30°. Figures 20.25 and 20.26 show two different pictures of Amy using the media mount.

## SUMMARY OF IMPACT

The Sunshine Foundation serves individuals with developmental disabilities. They constantly strive to create a strong community in the activities they pursue and the interactions between the Aides and individuals spending their days there. The people being served are invited to take part in activities they greatly enjoy. Two individuals in particular, Amy and Luis, are active painters, but due to their disabilities, are unable to fully explore their hobby. The two painting aid devices that were developed through this project will allow them to further explore their interest in painting and fully exploit their creativity. The Aides, at the Sunshine Foundation who were at one time needed to hold the



Fig. 20.23. Luis using the articulating arm mount.



Fig. 20.24. Luis using the articulating arm mount.

media for these painters, will now be able to further interact with other individuals, which will directly correlate to more happiness within the facility.

## TECHNICAL DESCRIPTION

The purpose of this project was to provide two individuals, who experience different low levels of mobility due to developmental disabilities, assistance in painting and/or sketching. The assistive devices

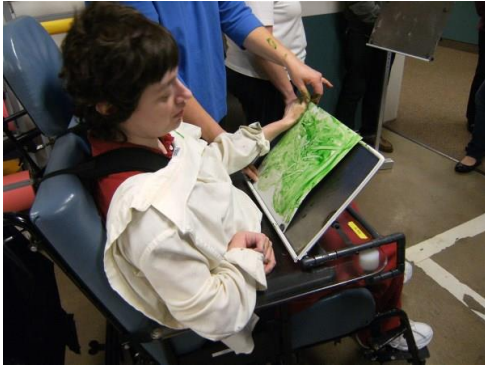


Fig. 20.25. Amy using the tray media mount.



Fig. 20.26. Amy using the tray media mount.

that were developed were designed to be lightweight, universal, and easy to use and to maintain. An articulating arm mount was developed for Luis who has low mobility, and a wheelchair media mount tray was developed for Amy who has relatively more mobility. Both designs were modeled using SolidWorks as illustrated in Figures 20.27 and 20.28, respectively. The articulating arm mount was developed to mount to the frame of Luis' wheelchair as shown in Figures 20.23 and 20.24. However, it can mount to any wheelchair whose frame tubes are up to 1.5 inches in diameter. The painting media surface of the construct has three means of adjustment such that it can pivot up and down and from side to side, it can move towards and from the individual; and its height can also be adjusted. The arms were made of 0.25" thick 6061 Aluminum plate. The painting surface was made from stainless steel and magnets were used to hold the paper to the painting surface. The upright was made of square 6063-T52 square aluminum 0.35" thick tubing. The frame of the media mount tray was made of PVC piping with a diameter

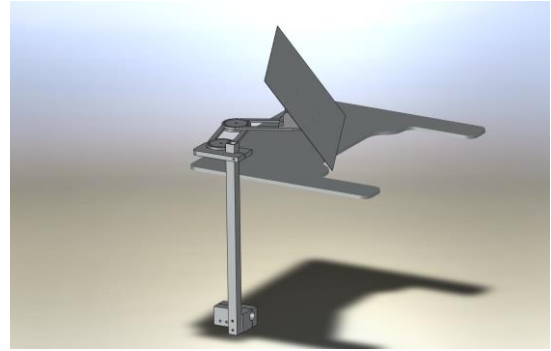


Fig. 20.27. Schematic of the articulating arm mount.

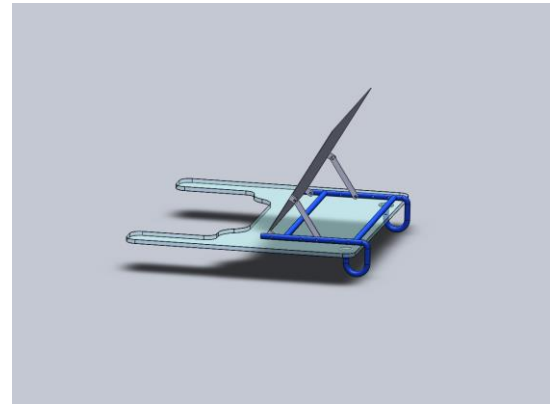


Fig. 20.28. Schematic of the wheelchair media mount.

of 0.5 inches. It was developed to fit the dimensions of Amy's wheelchair tray and to accommodate paintings up to 12 by 18 inches. The links were 3.2 inches long and were made of aluminum. The painting surface was also made from stainless steel and magnets were used to hold the paper to the painting surface. Pins were placed every 1.5 inches along the frame to connect with the link arms. The links allow positioning the painting surface at 60°, 45°, and 30°. The yield strength of the PVC was determined experimentally as 6540 psi.

FEA was conducted on both constructs which were found to be safe for a load of 25 lbs. placed normal to the painting surface. The total cost of the material for both constructs was about \$210. All machining and welding was conducted at the machine shop of the Department of Mechanical, Industrial and Manufacturing Engineering free of charge. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address: <http://www.eng.utoledo.edu/mime/design/clinics/2011/Spring/sites/2011-01-01/main.html>



# DEVELOPMENT OF A DEVICE TO ASSIST IN PACKING AND UNPACKING BAGS: HANGING BAG ASSISTANT

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## INTRODUCTION

The purpose of this project was to develop a device to assist an individual who lost control of most of the left side of her body with packing and unpacking various sized bags. With the use of only her right hand, the “client” struggles to keep a bag open in order to pack items into it. The developed device hangs from a door and holds various sized bags suspended off the ground, providing the client a simple way of holding the bags open while they are packed and unpacked. The device is lightweight and its frame was made of aluminum with one free standing upright and one adjustable upright. Two hooks attached to individual uprights were used to support the handles of the bag. The adjustable upright is controlled by a motorized aluminum wheel lined with a rubber O-ring that drives a threaded rod. The motor runs off a rechargeable battery pack. Two proximity sensors attached to the frame of the device were used to prevent the motor from expanding or contracting the uprights past its limits. This setup allows the client to vary the width of the uprights in order to accommodate small and large bags. A three-way toggle switch was used to operate the motor. The device is set-up and operated with one hand as illustrated in Figures 20.29 and 20.30.

## SUMMARY OF IMPACT

Tami Williams has lost much use of the left side of her body because of a stroke. Packing and unpacking a bag was difficult for her, since most bags required one hand to hold it open and one hand to load it. The developed “Hanging Bag Assistant” allows Tami to independently pack and unpack various sized bags with one hand. Tami was able to easily lift the



Fig. 20.29. Client setting up the Hanging Bag Assistant.



Fig. 20.30. Client using Hanging Bag Assistant.

prototype off a table and hang it on the back of a door as shown in Figure 20.29. Once hung, she could suspend multiple sized bags from the two hooks and operate the motor using the three-way toggle switch as shown in Figure 20.30. Once packed, Tami was able to remove the bag from the hooks and also remove the prototype from the door. Overall, she was very pleased with the prototype.

## TECHNICAL DESCRIPTION

The objective of the project was to develop a device to assist an individual who lost much use of the left side of her body in packing and unpacking various sized bags. Several factors were considered in the design including safety, ease of use and setup, weight, portability, cost and adjustability. Several design concepts were developed including using a tripod bag opener and a table top bag opener, both having multiple telescoping arms and legs and both controlled by linear actuators. However these designs were disregarded mostly because of cost and heavy weight.

The adopted design concept was modeled after a towel rack that hangs on the back of a door. The unit includes two steel hooks that hook over a door and attach to two vertical frame uprights. A plastic slider acquired from Spiratex Company and two small vertical uprights: one stationary and one adjustable were mounted on the vertical frame uprights. Hanging rods are attached to the two small vertical uprights for a bag to hang on for loading. The distance between the two small vertical uprights is controlled by a driving apparatus. The driving apparatus consists of square aluminum tubing (aluminum housing) with a hollowed out piece of UHMW plastic inserted inside the tubing. A threaded rod was placed inside the hollowed-out plastic insert and was attached to the adjustable upright. Mounted on the aluminum housing is a dc motor (rated at 15 rpm and produced 26.8 N-cm of torque at max efficiency) with an aluminum wheel attached. The aluminum wheel was outlined by a rubber O-ring and drives the threaded rod. Powering the motor was a rechargeable battery pack rated at 800 mAh and a toggle switch. The toggle switch allows for the polarity of the motor to be reversed in order to operate the motor in reverse. In order to limit the minimum and maximum distance of the adjustable upright, proximity sensors were installed. The sensors cut power to the motor when the

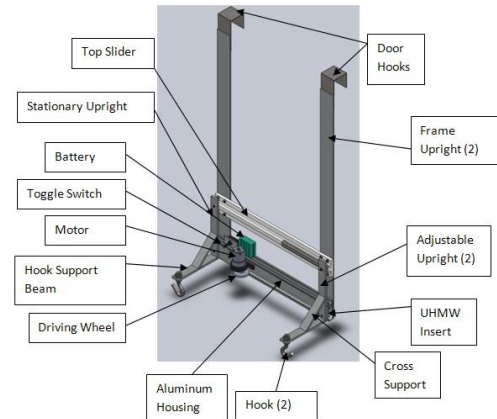


Fig. 20.31. 3-D model of the device.



Fig. 20.32. Close-up view of the unit.

maximum or minimum limits are met in order to prevent from over extension. Figure 20.31 shows a 3-D model of the device and Figure 20.32 depicts a close up view of the finished unit.

A structural analysis was conducted using SolidWorks and the unit was found to be safe. Several parts were obtained through donations. Machining was done free of charge. The incurred cost totaled \$140.00. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address:

<http://www.eng.utoledo.edu/mime/design/clinics/2011/Spring/sites/2011-01-02/main.html>



# CHAPTER 21

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# SUNRISE ALARM CLOCK FOR THE HEARING IMPAIRED

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## INTRODUCTION

For most people, the alarm clock is a device worthy of little concern, but this is not the case for individuals with a hearing impairment. For them, special design considerations are important. Presently, most of these designs involve bed vibrators, flashing LED's, or very loud audio alarms. Considering the current products available, the need to bring these concepts together into an effective and user friendly device was apparent. The result is the prototype of the Sunrise Alarm Clock pictured in Figure 21.1.

## SUMMARY OF IMPACT

To accommodate for the hearing impaired, three separate alarm systems were included in the device. Each of these systems was doubled, allowing for use by two individuals simultaneously. The visual alarm was designed to mimic the sunrise rather than utilizing harsh, flashing lights. This sunrise can be created using any lamp with an incandescent bulb. The user is granted the choice in the duration of the sunrise as well as the option for the light to flash when the designated alarm time is reached. By using these visual cues to wake the user, the device is more pleasant and effective for use by the hearing impaired.

## TECHNICAL DESCRIPTION

Along with the visual stimulus, a physical alarm in the form of a vibrating wristband is included with the device (see Figure 21.2). This design reflects the current use of bed vibrators but with some key advantages. First, the use of a vibrating wristband is more accommodating for individuals who share a bed. Rather than nondescriptly rousing both individuals, the wristband can be used to wake only the user. Also, where the bed vibrator may prove an overstimulation, the wristband produces vibrations strong enough to be effective yet not so intense as to



Fig. 21.1. The Sunrise Alarm Clock Prototype.



Fig. 21.2. Audio and physical alarms.

create discomfort. These advantages allow the device to be a step forward in the technology available to the hearing impaired.

The final stimulus provided by the device is an audio alarm. Again, current methodology utilized in specialty alarm clocks for the hearing impaired was mirrored in this device by incorporating an alarm system capable of producing high decibel sound.



Also, since certain frequency ranges are often easier for the hearing impaired to notice depending on the specific configuration of their hearing disability, two choices in pitch have been included in this prototype. With the audio alarm system operating in conjunction with the other alarm systems, this prototype is able to wake its user effectively, even if hearing impaired.

Space does not permit a full technical description of the project. Additional information is available by contacting the supervising professor. The project meets the following specifications and requirements:

- 120 VAC input
- Output from standard American wall outlet to attached lamps
- Useable with any standard incandescent bulb
- Alarm systems available for 2 users
- Volume less than 1 cubic foot
- Menu navigation through LCD screen
- Standard digital clock display with 4 seven-segment displays
- Time accurate to within 5 seconds per 24 hour period
- Sunrise durations from 5 to 60 minutes in 5 minute increments
- Choice of 2 audio alarm frequencies
- Flash lamps upon reaching maximum light output (optional to user)
- Three brightness levels provided by attached lamps
- Snooze functionality

# PORTABLE COLOR DETECTION DEVICE

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## INTRODUCTION

The purpose of designing and implementing this device was to enable colorblind individuals to determine the color of ordinary objects they may encounter. This system allows colorblind individuals to be independent and to alleviate the effects of being unable to distinguish certain colors. From power up, the device is designed to actively detect and determine the colors of objects, while continually reporting the results to the user through a Liquid Crystal Display (LCD) screen.

The final design packaging system for this device is a flashlight-like casing. This packaging system was chosen to provide the user with a familiar look and feel, while aiding the use of the device. The only actions required for the operation of this device are turning the power on and pointing and holding the device towards the desired object, for which color is to be detected. Once powered, the device will initialize all components and enter into a fully automated sequence. It optimizes the Red, Green, and Blue (RGB) sensor and detects, determines and displays the color. When the color of an object has been determined, the device will use an LCD screen to display the color, along with the RGB component.

## SUMMARY OF IMPACT

The final design for this project was successful in detecting and determining the color of objects. However, the results of this device were heavily dependent on the properties of the material from which the object was made. Objects with high opacity and lacking gloss tended to have very high color detection accuracy. As transparency and gloss is introduced, the efficiency at which the device can determine colors decreases. Overall, the device provides colorblind individuals with an ability to more accurately determine the color of objects that they may encounter in their daily lives.

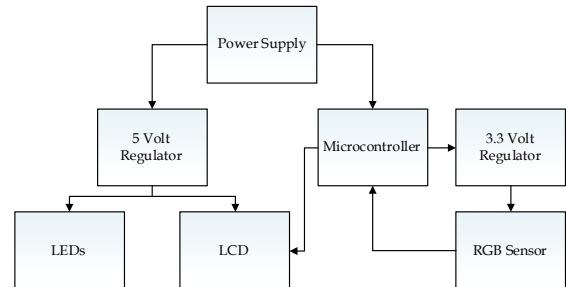


Fig. 21.3. Connection of device components.



Fig. 21.4. Completed device.

## TECHNICAL DESCRIPTION

In this design, the Arduino Duemilanove Microcontroller is responsible for controlling all operations. This microcontroller was chosen due to its ability to communicate with and control the ADJD-S371-Q999, RGB sensor.

These two devices talk to each other using the Two Wire Interface system. When power is applied, four LEDs will illuminate the object surface. The resulting

reflection of light, from the surface of the object, contains the information used to determine the color of the object. Using integrated light to digital converters, the RGB sensor measures the reflected light through three optical filters corresponding to red, green, and blue light. These measurements are used to create RGB components, one for each of the three colors of light and then are supplied into a color determination function. Once the color has been determined, the device will display the result using a standard 16x2, general input/output, LCD screen. The device continues to provide measurements and results until power is turned off. Figure 21.3 details the interconnection of components within the device.

Two Wire Interface (TWI). The Two Wire Interface is a serial communication system between devices. In this system, there are only two lines needed between devices - the data and clock lines. The TWI system uses a master and slave relationship between devices. In this application, the Duemilanove is the master, and the ADJD-S371-Q999 is the slave. The microcontroller is responsible for transmitting instructions and receiving data from the RGB sensor, while the RGB sensor must accept commands from the microcontroller. The design uses a BAUD rate of 9600 to communicate between the two devices.

Color Determination. The color of an object is determined by using the measured values that were generated once light passed through the filtered red,

green, and blue bands of the RGB sensor, and a custom color matrix. This design uses a 4x4x4 color matrix, providing for the detection of 64 possible colors. The design is similar to that of a 4x4 Rubik's cube. With the 4x4x4 design, each component of the RGB system can be split into quadrants, dividing the RGB range of 0 to 255 into fourths. When a measured value falls within one quadrant, the RGB value is reassigned the midpoint value of that quadrant. This measure ensures similar colors are determined to be the essentially the same color. For example, a measured value of 59 for red will be reassigned a value of 32 (0 to 63 is the first quadrant). Once all three colors have been assigned midpoint values, the RGB components will be compared to a predetermined lookup table that will determine the color at hand. The lookup table was created using the Custom Color function of Microsoft Word.

One of the most important lessons learned during the Senior Design process is to constantly evaluate each design. When a design is functional, it does not mean the design is the best way to meet the requirements for a given situation. If the right care and dedication is taken, designs can always be improved. Another very important lesson is to make the most of the available resources. No one carries expertise in all areas of a field. When information is lacking, seek out help from those individuals who have obtained expertise in the material at hand, and the final design to a project will greatly benefit.

# ASSISTIVE TECHNOLOGY FISHING DEVICE

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*Client Coordinator: Peter Pauwels*

*Supervising Professor: Mr. Scott Morton and Steven Barrett*

*Mechanical Engineering Department*

*College of Engineering and Applied Science*

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*University of Wyoming*

*Laramie, WY 82071*

## INTRODUCTION

This project is an Assistive Technology fishing device built for persons with physical disabilities. The primary specification of this design was to have a variable casting distance ranging from 30 feet to 80 feet and the ability to set the hook. A design was made that incorporated a linear spring and linear actuator. In this design, the linear actuator stretches the linear spring effectively storing energy in the spring. Once the energy has been stored, a solenoid releases the stored energy and rotates the fishing rod about a fixed point. Another solenoid is used to release the fishing line and lure. This system is controlled by a five input joystick interface that allows the user to control every aspect to maximize fishing enjoyment.

## SUMMARY OF IMPACT

Student engineers worked closely with Mr. Peter Pauwels to develop an assistive casting and take up system for use on a dock or within a raft. Mr. Pauwels provides accessible fishing opportunities for those in wheelchairs. The system is joystick controlled but can be adapted for use with other AT interfaces such as sip and puff inputs.

## TECHNICAL DESCRIPTION

**Mechanical:** This system is required to cast a 3/8 oz. lure a minimum of 30 feet and a maximum of 80 feet and is composed of multiple parts: a linear actuator, linear spring, reel and motor, a pull solenoid for the reel and a push solenoid for the linear actuator. The linear actuator is the driving force within the design. It was coupled with a quick release pin and solenoid that allows the linear actuator to load the spring to varying locations, which corresponds to different cast distances. When the linear actuator is connected to the moment arm and is pulled down there is a pivot movement of the linear actuator. To account for this movement, a hinge joint with a surrounding spring is



Fig. 21.5. Completed Device.

connected at the base of the linear actuator and allows for a 30 degree rotation about a fixed point. To ensure a connection on the linear actuator and the moment arm, a funnel connection guide provides for the uncertainty of the linear actuator motion. The reel is the component responsible for the reel in speed and ability to set the hook, and varies the reel motor speed from 2 ft/sec to 10 ft/sec. The reel is also designed with a solenoid that, when triggered, releases the line at a specific time. This solenoid ensured that the line is released with the forward motion of the rod. The handle of the fishing rod is clamped (via a hose clamp or zip tie) into the moment arm, which rotated around a single fixed axis. The frame is composed of

steel and is enclosed, to ensure safety and durability. The support is a dolly that allowed for easy transport.

Electrical: The electrical component of the design is a peripheral interface controlled (PIC) that received five inputs and responds with four outputs. The output response of the system is based on user control and programmed code. The casting mechanism and emergency shutoff outputs are binary on/off functions. The user controller is a five input joystick, based on five individual switches which correspond to the forward, backward, left, right and button motions of the joystick. The forward motion controls the upward motion of the linear actuator, which connects the linear actuator to the moment arm. The backward motion on the joystick controls the downward motion of the linear actuator, which in turn loads the spring. Both of these controls are based on the length of time the user holds the joystick in that position. When the forward and backward switches are on, the linear actuator move in accordance with the control. When the switches are off, the linear actuator stops moving, which allows for setting the variable distance of the cast. The right and left motion of the joystick control the reel and fishing line. Moving the joystick to the right, results in setting the hook of the fishing line; while the left motion on the joystick reels in the line at a constant slow speed. The button on the joystick controls the solenoid for linear actuator connection to the moment arm as well as the solenoid for the fishing line. When

the button is pressed, the linear actuator solenoid is released, followed by the release of the fishing line from the reel.

This particular system required the ability to reset in order to cast numerous times. The present scheme seems overly complicated and could likely be reduced into a simpler mechanical device in order to provide the cyclic action required. A simpler design would provide for a more reliable design and increased manufacturability.

A PIC does not provide a consistent voltage and current to saturate the transistors to activate the outputs. In order to successfully achieve saturation, additional voltage and alternative programming is necessary.

The main goals of this project were to achieve variable distances for the cast of the fishing line and achieve an ability to set the hook. Through design, analysis, mathematical models and testing, a device was created to achieve these goals. This marks the first time, with respect to accessible fishing, that a design has incorporated variable distance and an ability to set the hook. The mobility of the system, coupled with the frame design, yields the potential for this particular design to be scaled up or down to accommodate several different kinds of fishing and provides unique technology to assist persons with disabilities.



# WHEELCHAIR SENSORS AND ODOMETRY

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## INTRODUCTION

With the use of ultrasonic sensors around the wheelchair, this system is able to sense the objects around it and safely navigate. Rotary encoders on the wheels allow the system to determine how far the wheelchair is traveling and relay that information to the control algorithm hosted on a microcontroller. A keypad and liquid crystal display (LCD) screen is used to gather user input and view current system status.

## SUMMARY OF IMPACT

With these components, among a few others, the system will be able to autonomously control the movements of the wheelchair. This project aims to help give the wheelchair user the ability to move from place to place with the least possible physical effort to control the wheelchair. This project will directly contribute to the quality of life for people with disabilities, with special emphasis on independent living.

## TECHNICAL DESCRIPTION

The wheelchair model used for this project was the QUICKIE300. This wheelchair employs a joystick to control the motors on each of the rear wheels. A total of eight ultrasonic sensors were mounted around the wheelchair, with two sensors placed on each side. The analog sensor output is sent directly to eight 10-bit A/D channels on an Atmel ATMEGA1284p microcontroller via serial cables. The sensors are attached to the wheelchair on small PCBs that are used to connect the sensors to female serial adaptors. The sensors are able to detect obstructions from 20cm to 765 cm with a resolution of 1 cm.

The wheelchair was also equipped with two incremental rotary encoders on each rear wheel. A pulse train and its inverse (line driver output) went from the rotary encoders to a differential receiver package in order to filter out most of the noise in the

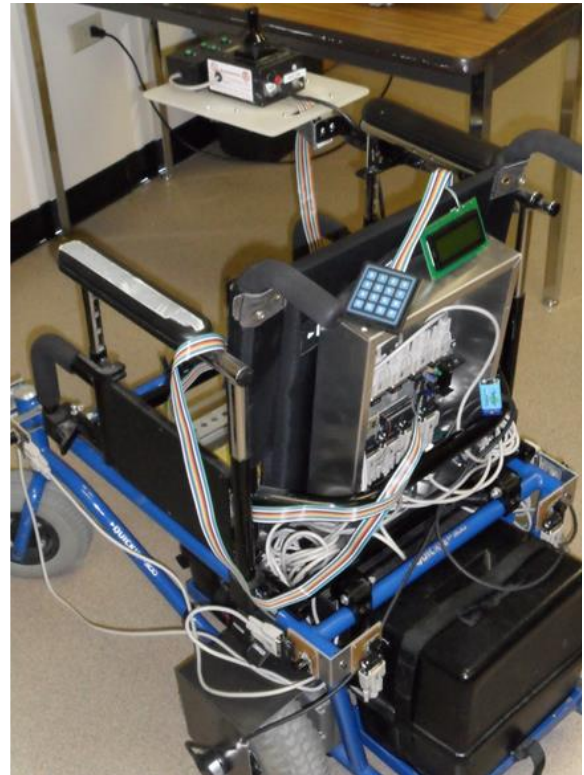


Fig. 21.6. Completed Device.

line. From the differential receiver, the signal then went to Timer Channel 0 and Timer Channel 1 on the Atmel microcontroller. These channels were able to count pulses using the TCNT0 and TCNT1 registers, while also using the two timer overflow registers to keep track of any time the TCNT registers overflowed. The rotary encoders provided 360 pulses per rotation. It was possible to keep track of the distance and direction the wheelchair traveled via the encoders.

All system components are powered from a 9V DC rechargeable battery that is routed to a 5V DC regulator.

The user can enter commands into a keypad that is interfaced to the main microcontroller. The user can also view current status information of the wheelchair with a liquid crystal display (LCD) that is attached to the microcontroller via a serial communication link.

A system was created by Dr. Steven Barrett that takes in four digital signals to control the wheelchair. This system is separate from the system described above in this report.

After initialization, the main code goes into an infinite polling loop. First, it determines which operational mode the user selected via the keypad. The modes that the code can run are an idle mode, a manual

mode, and a wall-following mode. The wheelchair does not move in the idle mode. The manual mode lets the user drive the wheelchair using a manual forward, left, right, or reverse. The sensors assist the user in avoiding objects by stopping the wheelchair if the user is too close to an obstruction. The wall-following mode allows the wheelchair to navigate through any environment by keeping the wheelchair a certain distance from the right wall and navigating around obstructions. This mode requires additional development.

The wheelchair has been equipped with eight ultrasonic transducers to detect obstacles and obstructions. Wheel encoders are used to measure wheelchair displacement and velocity.

# EFFORTS TOWARD AN AUTONOMOUS WHEELCHAIR

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*Supervising Professor: Dr. Steven Barrett*  
*Department of Electrical and Computer Engineering*  
*College of Engineering and Applied Science*  
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*University of Wyoming*  
*Laramie, WY 82071*

## INTRODUCTION

An autonomous wheelchair is in development to provide mobility to those with significant physical challenges. The overall goal of the project is to develop a wheelchair that is fully autonomous with the ability to navigate about an environment and negotiate obstacles. As a starting point for the project, we have reversed engineered the joystick control system of an off-the-shelf commercially available wheelchair. The joystick control has been replaced with a microcontroller based system. The microcontroller has the capability to interface with a number of subsystems currently under development including wheel odometers, obstacle avoidance sensors, and ultrasonic-based wall sensors. This paper will discuss the microcontroller based system and provide a detailed system description. Results of

this study may be adapted to commercial or military robot control.

## SUMMARY OF IMPACT

Researchers at the University of Wyoming are developing an autonomous wheelchair for those with severe challenges. The overall goal of the project is to develop a standalone control system that would easily interface to an existing powered wheelchair.

A block diagram of the control system is provided in Figure 21.7. This paper covers the development of the wheelchair controller designated as the current project (CP) in Figure 21.7. The function of the wheelchair controller is to bypass the existing joystick controller for the Sunrise Quickie P300 wheelchair used for the project. Instead an Atmel ATmega164 microcontroller will provide the necessary drive

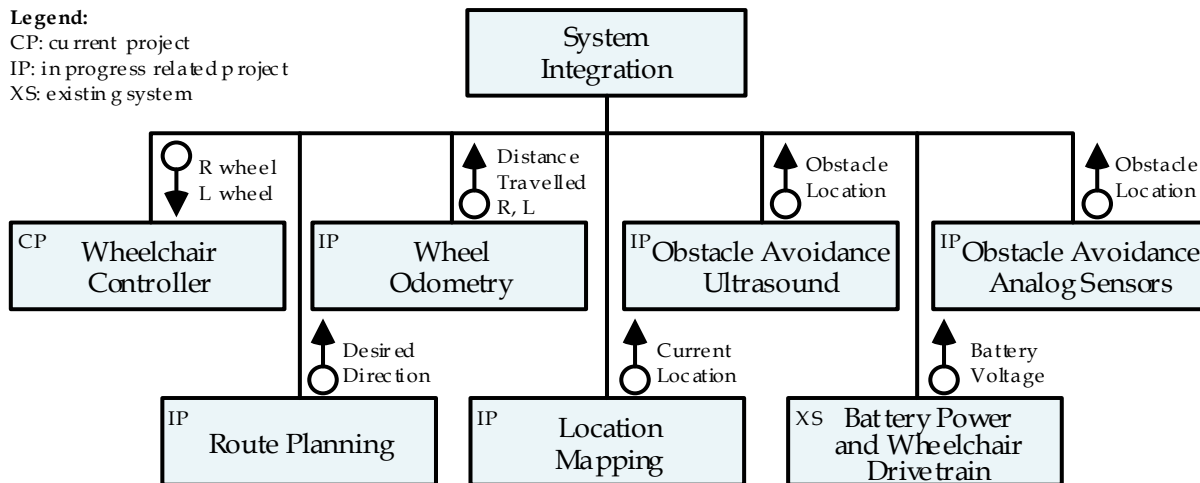


Fig. 21.7. Structure chart of the autonomous wheelchair control system.

signals to the existing wheelchair drive train (designated XS in Figure 21.7). Other related in progress subsystems are designated by an IP in Figure 21.7. Space does not permit a discussion of other diagrammed subsystems. All of the other subsystems are currently under development as part of the overall research effort.

The concept of a fully autonomous wheelchair is not a new concept. Simpson et al. provides a thorough review of related efforts and work ongoing at the University of Pittsburgh. At the University of Wyoming, Philips has performed an exhaustive study of other related efforts. Also, Hansen has completed a thorough study of related wheelchair guidance and control challenges.

## TECHNICAL DESCRIPTION

**Joystick signals.** To develop a microcontroller-based system to substitute for an existing joystick control, the signals issued to the wheelchair drive system by the joystick must be known for various joystick positions. Benson and Philips accomplished similar work. To determine the signal generated by the joystick for various positions, the voltage and current were monitored on the joystick's X (blue) and Y (white) channel outputs. Results are provided in Figure 21.8.

Several observations are in order relative to these measurements:

- In the neutral position the joystick provides approximately 6 VDC on the X and Y channel.
- The X and Y channels are independent of one another.
- The X channel increases by approximately 0.7 VDC in the forward direction and decreases by the same amount in the reverse direction. The Y channel varies in a similar manner when moved from right to left.
- The control system provides minimal current drain.
- The voltage levels required by the wheelchair drive train (+5.2 to +6.7 VDC) are not directly compatible with standard microcontroller levels (0 and 5 VDC) without interface.

**Block Diagram.** The block diagram for the wheelchair controller is provided in Figure 21.9. Directional input commands are provided to the controller via four (forward, right, left and reverse) momentary

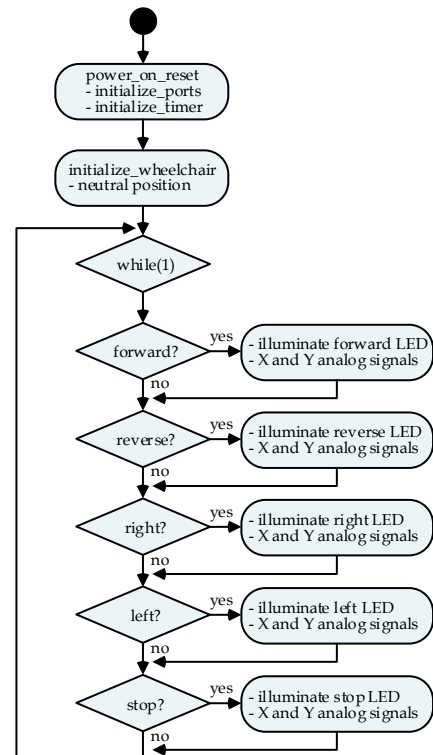


Fig. 21.10. Wheelchair controller UML activity diagram.

contact, debounced pushbutton switches. In response to a specific input command, the ATmega164 controller issues the proper analog output signals for the X and Y channels. As previously mentioned, the output voltages range from 5.2 to 6.7 VDC. To achieve these levels from a 5 VDC microcontroller, an analog signal from 0 to 2 VDC is provided via the Serial Peripheral Interface (SPI) fed TLC 5628 digital to analog converter (DAC). The DAC output voltage is summed with a 6 VDC (joystick neutral position voltage) reference and a negative 1.0 VDC bias. The overall result is an output voltage that ranges from 5.0 to 7.0 VDC as required by the joystick controller.

**UML Activity Diagram - Program Flow.** The microcontroller algorithm is provided in Figure 21.10. After initialization of the ports and timing system, the wheelchair is placed in a no movement neutral position. As different input switches are depressed, the control algorithm illuminates the proper light emitting diode to indicate movement and proper signals are sent out via the Serial Peripheral Interface (SPI) system to the TLC5628

DAC. The program continues to respond to different switch assertions.

Wheelchair interface. The wheelchair interface control is hosted on a 33.0 x 16.5 cm printed circuit board (PCB). The PCB is housed in an aluminum chassis that is under the wheelchair seat. Power for the interface control is provided by a four 9 VDC, 250 mAh Nickel Metal Hydride (NiMH) rechargeable batteries (Tenergy). The batteries are connected in series with the midway point between the batteries grounded to provide a +/- 18 VDC battery supply. The battery output is fed to a series of +/- 12 VDC and +/- 5 VDC regulators required by the analog circuitry and the DAC. The user interface containing the pushbutton switches and LED display are mounted within a small enclosure near the existing joystick. A ribbon cable connects the user interface to the PCB.

We have successfully completed the design of the wheelchair interface controller. The controller has been prototyped and operates correctly for all wheelchair directions. We are in the process of translating the circuit to a PCB design. The PCB design and fabrication is complete. PCB populating and testing is underway. The current drain for the +/- 18 VDC system is 55 mA and 25.6 mA respectively which provides an operational wheelchair time of slightly less than five hours between recharge events. We are investigating an improved battery technology.

This project is the first in a number of related projects toward a fully autonomous wheelchair. It should be emphasized that the pushbutton panel is currently a substitute for an integrated system level controller which will incorporate all other subsystems into a cohesive autonomous system.

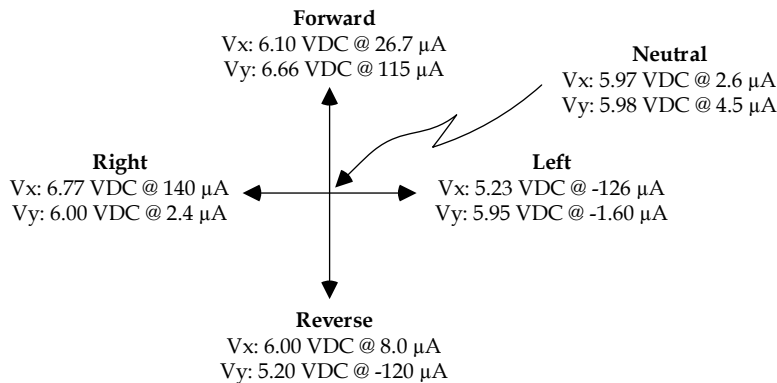


Fig. 21.8. Joystick X [blue] and Y [white] channel outputs.

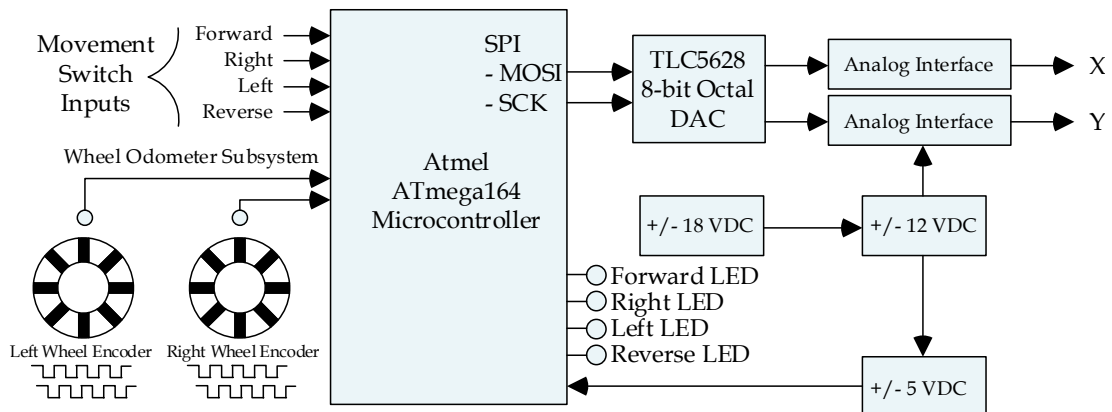


Fig. 21.9. Block diagram of wheelchair controller.



# CHAPTER 22

## WAYNE STATE UNIVERSITY

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# INDOOR WIRELESS WAYFINDING SYSTEM FOR WORKERS WITH COGNITIVE IMPAIRMENTS

## Part 1: Core System Design and Implementation

Designers: Arpit Mittal, Vimlesh Shukla, Cheng Ling, Muneer Al-Ali

## Part 2: Localization Algorithms and Evaluation

Designers: Arpit Mittal, Vimlesh Shukla, Prem Kumar Sivakumar, Liang Huang

Client Coordinator: Derek Finely, Supervisor, Jewish Vocational Services, Southfield, MI

Supervising Professor: Dr. Robert F. Erlandson, Santosh Kodimiyala

Electrical and Computer Engineering Department,

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## INTRODUCTION

Indoor wayfinding is a problem for many individuals with cognitive impairments. While there are many applications for indoor location and wayfinding systems, this project will target wayfinding as a work aid for individuals with cognitive impairments. Jewish Vocational Services (JVS) exemplifies an agency that can greatly benefit from this application. JVS is a CARF certified, NISH affiliated, non-profit organization that offers programs and services throughout Metropolitan Detroit. JVS supports individuals, challenged with disabilities, in the workplace and provides on-site, supervision and coaching at community-based employers through their janitorial operations. Job coaches have expressed interest in finding a way to remotely monitor their employees and provide task prompting.

The prototype system is a wireless sensor network (WSN) that uses ten reference nodes, one coordinator node, and a blind node. A reference node is a wireless transceiver at a fixed location. A blind node is a wireless transceiver which moves around an environment containing a collection of reference nodes. A star network infrastructure is used because of its network robustness. If one reference node is removed from the network, the others are not affected. The signal strength as recorded by the blind node is passed back to the PC via the coordinator; a wireless transceiver which connects to the PC through a USB port. A location finding algorithm within the PC calculates the position of the blind node with respect to the reference nodes thereby localizing the blind node in a facility.

The project actually spanned three semesters. The first semester's work was described in "Location

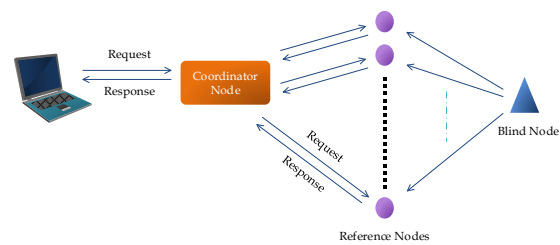


Fig. 22.1. Basic system configuration showing the blind node, reference nodes, coordinator and control PC.

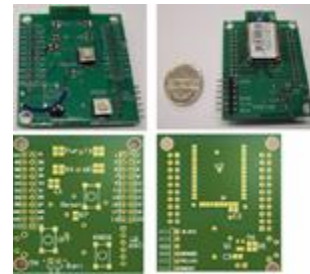


Fig. 22.2. Photo of the prototyped Jennic device both in a 3D model from.

Detection Engine - Part 2 Jennic: JN5139 and JN5148," published in the 2010 Edition of the NSF Projects to Aid Persons with Disabilities. That work designed and built generic transceiver units for the JN5139 and JN5148 and tested their functional capabilities. The resultant system demonstrated viability of the Jennic units to function in wayfinding applications.

In Part 1 of this project, ten new reference nodes were designed, built and tested and several location determination algorithms were implemented and evaluated. The major results from Part 1 indicated that: (1) the communications protocol between the

coordinator, the reference nodes and blind node needed to be modified; (2) an accelerometer needed to be added to the blind node so as to more accurately determine movement and the direction of movement, and (3) the current location algorithms were inadequate for the Jennic devices.

In Part 2, an accelerometer was added to the blind node and the communication protocol revised. Revision of the communications protocol required new code for all elements; the coordinator, the blind node and the reference units. A new location detection algorithm was written and tested in both the engineering laboratory and office space at JVS. The new system enables localization of the blind node to within 1 meter.

## SUMMARY OF IMPACT

The successful demonstration of the system's ability to localize the blind node to within 1 meter renders the system capable of being used to monitor JVS janitorial workers and thereby enables the supervisor or job coach to provide appropriate prompting and support to a worker via a wireless communication system. JVS's response has been very positive toward the system and they have expressed great interest in the improvements in the software. Our liaison from JVS, Derek Finely, stated, "This service is a great application for indoor wayfinding by providing our job coaches the flexibility of being able to remotely monitor the location of our workers in most facilities".

## TECHNICAL DESCRIPTION

All wireless modules, from circuit and schematic design, to printed circuit board (PCB) layout, were custom designed using Altium Designer. Figure 22.2 shows a photo of the prototyped Jennic device both in a 3D model and actual fabrication.

Reference node placement is a critical factor. The Jennic uses a Link Quality Indicator (LQI) signal, derived from the RSSI. As with the RSSI, the observed LQI measurements were inversely proportional to distance moved. The Jennic uses automatic gain control (AGC) which activates when the received signal strength between a reference node and blind node falls below a predetermined threshold, which corresponds to a separation of about 3 meters.

Experimentation clearly demonstrates the onset of the automatic gain feature hence reference nodes which are "far" (greater than 3 meters) from the blind node can be ignored in any location determination algorithm. Also, for separations less than 3 meters, the LQI value is a relatively good indicator of blind node reference separation. These results indicate, that for the given Jennic model, a blind node should always be within 3 meters of 3 reference nodes (3 reference nodes are needed for triangulation algorithms). This constraint should be acceptable for office spaces and the newer Smart Buildings that have high densities of ZigBee modules in the infrastructure.

The localization algorithm has evolved, from methods using signal strength measurements, to a more robust triangulation method. The blind node's onboard accelerometer provides information about its movement and trajectory direction. The algorithm executes in real-time on a MATLAB platform on the control PC.

Tests were conducted at the JVS facility in an office hallway with a length of 30 meters and width of 1.5 meters. The blind node was mounted on a janitorial cart at a height of 1 meter and 10 reference nodes were positioned in a zigzag pattern such that the blind node would always be within 3 meters of at least 3 reference nodes. To measure position accuracy, locations estimated from the algorithm were compared to predefined points on the map. The average estimated location, observed from the trials at the JVS facility, corresponded very well to results from trials performed in the Engineering Building.

The wayfinding system has been successfully demonstrated at the JVS facility. The system met our objectives for providing a solution that is low-cost, portable, easy to use, and robust. From the test results, we have been able to localize a janitorial cart to within 1 meter accuracy. The network can be setup in most office hallways with 3 meter spaced node placement. Total Jennic prototype boards cost about \$52/board (15 boards were made), this included the onetime PCB setup charges. The Jennic module alone costs about \$23 and an additional \$15 for components. The blind node is more expensive because it contains a \$20 accelerometer.

# DIGITAL HUMAN MODELING: FAB TO RAMSIS INTERFACE

*Designers: Muhannad Ghalib, Sam Prasanna Rajkumar James*

*Client Coordinator: Dr. Gerry Conti, OT, Active Reach and Manipulation (ARM) Clinic, Occupational Therapy Department, Wayne State University*

*Supervising Professor: Dr. Robert F. Erlandson, Biomedical Engineering Department, Wayne State University, Detroit, MI 48202*

## INTRODUCTION

The Active Reach and Manipulation (ARM) clinic was initiated in Spring 2011, provides sophisticated rehabilitation services to underserved people with stroke and significant movement limitations (SML). The ARM clinic will serve metro Detroit residents with no or limited health care insurance for rehabilitation following a stroke, spinal-cord injury or other neurological injury or disease. The ARM clinic is a collaboration between Occupational Therapy and Biomedical Engineering.

This project pairs the Michigan Rehabilitation Services (MRS) with a cross-disciplinary team of biomedical engineering students and occupational therapy students. They have demonstrated the effectiveness of using a digital human model to design an adjustable computer workstation for a quadriplegic MRS client who wanted to be able to access his computer. The major problem involved placement of a camera for eye-gaze control of the computer's cursor on the monitor. A "visual cone" and "eye-gaze" feature of the digital modeling package helped determine the camera and client placement requirements.

Virtual Ergonomic Assessments (VEA) offers the potential to increase return to work opportunities for adults with significant movement limitations (SML). VEA uses a digital human model (DHM) customized to the client's anthropometric and functional capabilities embedded in a virtual work environment performing job related tasks. The development of VEA will require the integration of computer-aided design, biomechanical movement simulation, and creation of virtual work environments.



Fig. 22.3. Required sensor placements for the FAB system.

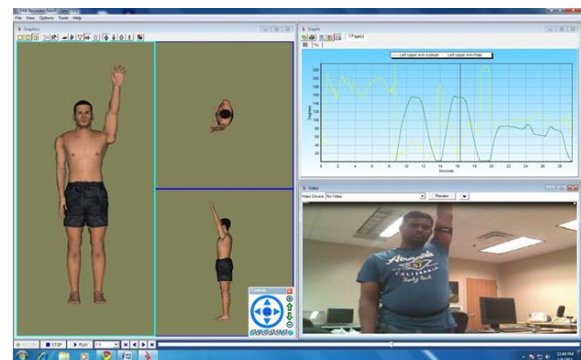


Fig.22.4. FAB display.

## SUMMARY OF IMPACT

Dr. Conti, from Occupational Therapy, is using the FAB system to rapidly and accurately measure movement patterns and capabilities of people with SML. The FAB System (Functional Assessment of Biomechanics) is a full body wireless motion capture

system based on inertial wireless sensor technology. FAB data is gathered as part of a typical intake procedure and then also to monitor and evaluate client performance. MRS placement specialists agree with our initial experiences that the ability to apply FAB collected data to a digital human model of a client would significantly enhance the VEA process and thereby facilitate the client's efforts to secure employment.

## TECHNICAL DESCRIPTION

The Enabling Technologies Laboratory (ETL) uses the Dassault Systems CAD packages CATIA/DELMIA for design and the RAMSIS package from Human Solutions to create digital human models. These packages have very sophisticated digital human modeling (DHM) capabilities which can be used to model individuals with disabilities and SML. The goal of this project was to gather human motion data from a person using the FAB system and then associate that data with a DHM of the same person within the RAMSIS software.

The FAB system uses a different reference coordinate scheme for representing human motion than does the RAMSIS system. There were two major technical challenges: 1) creating an algorithm for translating the FAB collected data into the RAMSIS reference scheme, and 2) associating the required FAB sensor placements on the real human with the representation of these corresponding body segments and joints on the DHM created in RAMSIS.

The real person shown is one of the design team students.

The project goal was satisfied in that data collected via the FAB system was transformed from the FAB reference scheme to the RAMSIS reference scheme

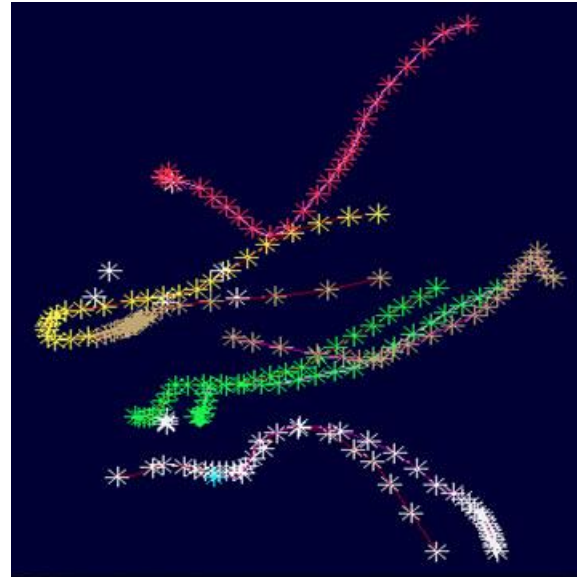


Fig. 22.5. Trajectories for the arm movements from the student in Fig. 22.4.

and the sensor placements of the FAB were placed on the corresponding DHM positions so as to observe the recorded movement patterns. Figure 22.5 shows five arm movement trajectories for the student shown in Figure 22.4.

The current implementation demonstrates the feasibility of the approach. However, the RAMSIS portion of the coordinate transformation algorithm is too slow for actual use in VEA / DHM workplace analysis for a real person's movement patterns. The next step is to gather the FAB data and associate it in "real" time with the RAMSIS DHM. Such a capability will enable utilization of VEA tools to facilitate workplace accommodations and the selection and evaluation of assistive technology needs for people with SML.



# ICF COMPLEX DATA VISUALIZATION

Designer: Bhagyesh Bhandar

Client Coordinator: Dr. Gerry Conti, OT, Active Reach and Manipulation (ARM) Clinic, Occupational Therapy Department, Wayne State University

Supervising Professor: Dr. Robert F. Erlandson, Electrical and Computer Engineering Department, Wayne State University  
Detroit, MI 48202

## INTRODUCTION

The Active Reach and Manipulation (ARM) clinic at Wayne State University provides sophisticated rehabilitation services to underserved people with stroke and significant movement limitations (SML). New therapeutic interventions must demonstrate efficacy before being covered by insurers. The ARM clinic is exploring the use of the World Health Organization's (WHO) International Classification of functioning and Disability (ICF) as a clinical tool for assessing therapeutic efficacy. The goal of this project was to explore the use of dynamic visual displays as exemplified by "Gapminder" to provide a more intuitive representation of ICF data and thereby demonstrate its utility in a clinical setting (<http://www.gapminder.org/>).

The ICF has four Major Components: Body Functions, Body Structures, Activities & Participation and the Environmental Factors represented by codes b, s, d and e respectively. These four major components are further divided into a broad classification of chapters which are a part of their respective components. All of these Chapters are represented by integer numbers starting from one up to the number of chapters these components possess. For example, b7 designates Neuromusculoskeletal and movement, b730 muscle power functions, b7301 power of muscles one limb.

Each element of the ICF also has an associated qualifier which provides a way to quantify the functional status of an individual. Qualifiers are used to capture the functional status of an individual at a specific point in time. The qualifiers are from a Likert scale: an impairment, limitation or restriction, is qualified from 1 to 4: 0 (0-4%: No problem), 1 (5-24%: Mild problem), 2 (25-49%: Moderate problem), 3 (50-95%: Severe problem) to 4 (96-100%: Complete problem). Quantification of the environmental factors is done in a negative and a positive scale which means to what extent the environmental factor

ICF Code	Categories	Description	PatientRatings	Date
b110	Consciousness Function	General mental functions of the state of awareness and alertness, including the clarity and continuity of the wakeful state.	1.11	12-31-2010 21:17:00
b114	Orientation functions	General mental functions of knowing and ascertaining one's relation to self, to others, to time and to one's surroundings.	2.51	12-31-2010 21:17:00
b167	Mental functions of language	Specific mental functions of recognizing and using signs, symbols and other components of a language.	0.94	12-31-2010 21:17:00
b730	Muscle power functions	Functions related to the force generated by the contraction of a muscle or muscle groups.	2.54	12-31-2010 21:17:00
s110	Structure of brain		0.74	12-31-2010 21:17:00
d330	Speaking	Producing words, phrases and longer passages in spoken messages with literal and implied meaning, such as expressing a fact or telling a story in oral language.	1.63	12-31-2010 21:17:00
d450	Walking	Moving along a surface on foot, step by step, so that one foot is always on the ground, such as when strolling, sauntering, walking forwards, backwards, or sideways.	4.00	12-31-2010 21:17:00

Fig.22.6. A portion of the brief core set for stroke.

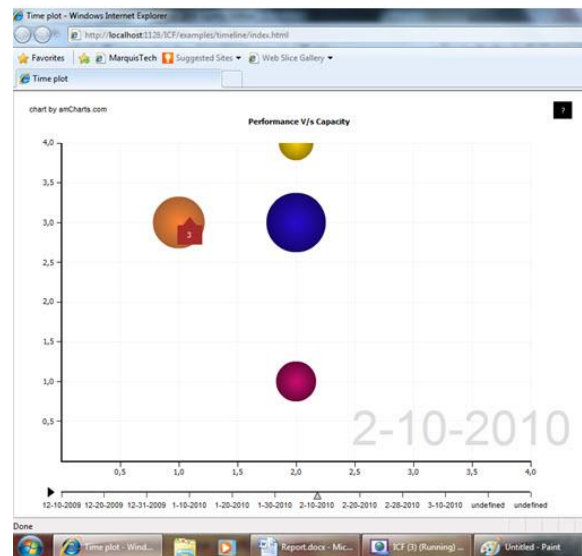


Fig. 22.7 Example of visual display.

is acting as a barrier or a facilitator. The ICF classification has more than 1,400 categories limiting its use in a clinical setting.

## SUMMARY OF IMPACT

The preliminary results demonstrated that one can provide dynamic visual displays of the complex ICF qualifier data as it changes over time. Furthermore, the environmental influences of therapy, assistive

technology, care-givers, etc. can be explicitly considered.

## TECHNICAL DESCRIPTION

Given the ARM clinic's interest in stroke rehabilitation and given the need to more narrowly define the problem, the Brief Core Set for Stroke was selected as the test vehicle. Practitioners are defining "core sets" which are a much smaller number of codes specific to a given condition. Figure 22.6 shows part of the Brief Core Set for Stroke which has 18 items; 6 body functions, 2 body structures, 7 activities and participation, and 3 from environmental factors. The slide bars shown to the right under "Patient Ratings" allows one to provide a fuzzy number value for the ICF qualifiers. This tool was used to create a clinically realistic database of ICF qualifier values collected over time.

Of particular concern were the items from "activity and participation." These items have two parts; capacity and performance. By "capacity," the ICF

means the intrinsic capacity to perform an action, as would be assessed in a standard clinical environment without aids or assistance; by "performance," the ICF means the actual performance of an activity in the person's current environment. Qualifier scores were provided using the data entry tool and variety of visualizations were explored.

The slider bar allows the practitioner to enter a qualifier value for an individual. This tool was used to create clinically reasonable data for testing various visualization displays.

Gapminder is a proprietary package for visualization of complex data over time. Google has purchased the rights to the Gapminder algorithms and provides a very simple capability within Google Doc's spreadsheet wherein one can insert a "gadget - motion chart" to see the data change over time. Google's Public Data Explorer provides examples of the visual displays. Figure 22.7 shows a simple example.

# COOKE SCHOOL SENSORY INTEGRATION TENT AND ACTIVITIES

*Designers: Andrew Aneese, Yazan Soofi, Tonya Whitehead, Jenna Batten, Shannon Hogan, Huda Kazak, Sarah Krug, Jillian Woodworth*

*Client Coordinator: Julie Rohroff, teacher at Cooke School*

*Supervising Professor: Dr. Robert F. Erlandson,  
Biomedical Engineering Department,  
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Detroit, MI 48202*

## INTRODUCTION

The goal of this project was to design and build a sensory integration tent for a classroom at Cooke School. A sensory integration tent is an enclosed space covered with a heavy light blocking material that is large enough to comfortably hold the student. The interior of the tent would allow the student to sit or lay down. Depending on the student's needs, the sensory tent environment can provide alerting or calming activities. Each set of activities requires different items within the sensory tent. The Cooke School students are all severely learning disabled and have cognitive impairments. Their ages range from 14 - 18 with a mental capacity of approximately 2 - 5 years. The tallest student is approximately 6 ft. Cooke is a special education school for children in Northville and surrounding communities. The mission of Cooke School is to prepare students for a productive and meaningful life by increasing communication, vocation, academic, and recreation life skills to be used in school, at home and in the community.

The rationale for the products we are suggesting for the sensory tent, all fall under Sensory Integration Theory. Jean Ayers, the founder of Sensory Integration Theory, defined sensory integration as "The neurological processes that organizes sensation from one's own body and from the environment and makes it possible to use the body effectively within the environment". The sensory tent is meant to improve a student's adaptive responses to sensory input; helping the student become more organized, helping increase attention to tasks, fostering independence, improving performance and decreasing self-stimulatory behavior.

The final design included an interior design plan utilizing the pipe & joint technology CREFORM as the frame or structural support material. The interior



Fig. 22.8. A selection of CREFORM components a pipe & joint agile system's technology.

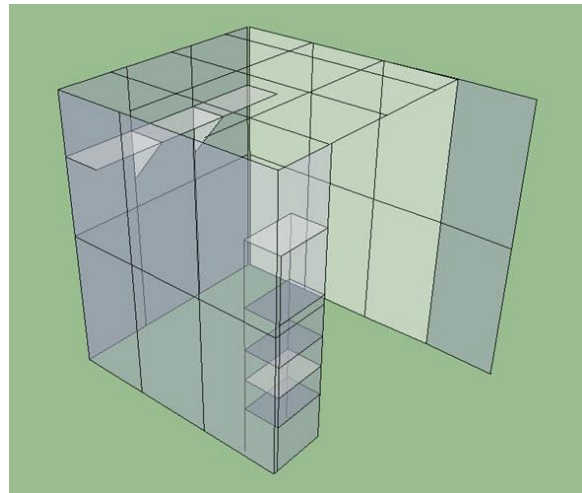


Fig. 22.9 A CAD rendering of the structural frame of the sensory tent. Shelves and storage space are shown in the interior.

design would also include storage layout and placement of power sources. Deliverables also include recommended items for each set of activities. For example, a Ball or Rice Tub is multi-sensory item that will calm or awaken the student's tactile system as well as provide vestibular and proprioceptive input to meet the student's sensory needs. Another example is a Bubble Tube which is visually stimulating and can have a therapeutic mesmerizing effect. Staff can place a mirror behind it for additional effects. Bubble tubes usually fall into two categories, passive (relaxing) and interactive (stimulating). Some tubes have plastic balls, beads and fish added to help develop tracking skills. Specifications for about 30 different activities along with the required materials were delivered to the teachers and staff. Parent volunteers are to sew and construct the covering for the sensory tent.

## SUMMARY OF IMPACT

The sensory CREFORM frame was assembled and delivered to the school. A temporary cover was placed over the frame and the tent was stocked with a variety of items. Teachers are using the tent and are pleased with its design. The students are responding to the tent much as the teachers had hoped. The final tent cover will be finished and installed by the start of the Fall semester.

## TECHNICAL DESCRIPTION

The frame material is a pipe & joint technology. Figure 22.8 shows a sample of the over 450 CREFORM components available for design and

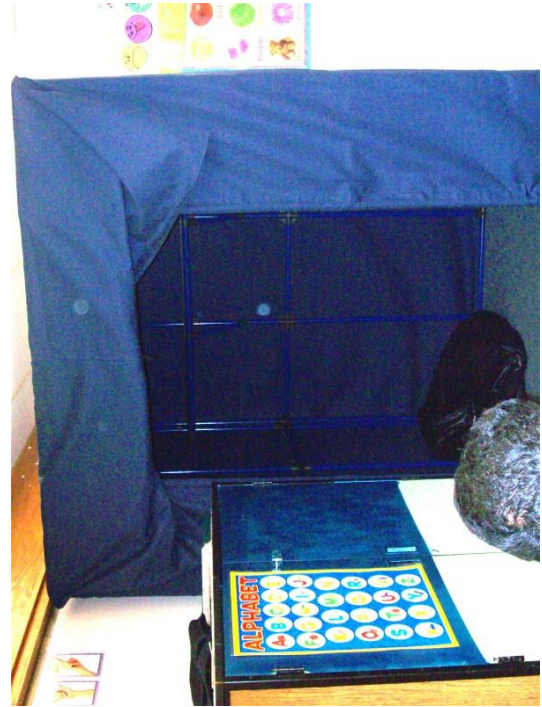


Fig. 22.10. The completed sensory tent with a temporary cover.

assembly. The components include plastic covered steel pipe in a variety of colors, metal and plastic joints, casters, and hinges. A pipe cutter, Allen wrench and ruler are all the tools needed for assembly. Figure 22.9 is CAD drawing of the tent's structure and Figure 22.10 shows the frame with the temporary cover.

# RFID TAG SYSTEM FOR PRACTICE DEBIT CARD PROCESS

*Designers: Angela Buckley, Prem Sivakumar, Samuel Gibson*  
*Client Coordinator: Dennis McElhone, Special Education Teacher, Visions Unlimited*  
*Supervising Professors: Dr. Robert F. Erlandson, Dr. Donna Case, Santosh Kodimiyala*  
*Electrical and Computer Engineering Department,*  
*Wayne State University*  
*Detroit, MI 48202*

## INTRODUCTION

Visions Unlimited is a post-secondary educational program operated by Farmington Public Schools serving 18 through 26-year-old young adults with developmental and physical disabilities. Emphasis is given to improving the students' life and work skills and, in particular, developing transitional skills required in moving from school to work. Visions Unlimited uses Positive Behavioral Support (PBS) principles to facilitate the educational process. The staff wanted to use a "debit" card like process that uses a point system rather than money, as the positive reward; while concurrently providing their students the opportunity to manage their points to "purchase" items from the school store.

The current system is replacing a previous system that was placed in service in 2008 and, due to computer upgrades and changes at the school, became inoperable in early 2010. Visions Unlimited staff learned a great deal from using the first system and had very specific ideas about the functionality of this new version.

## SUMMARY OF IMPACT

The new version has been installed and presented to Vision Unlimited teachers and staff. The introduction was very well received and teachers and staff were eager to have the redesigned system fully operational. The school has shifted to its summer schedule and the new system is receiving minimal use during the summer. Data regarding student

## The Architecture

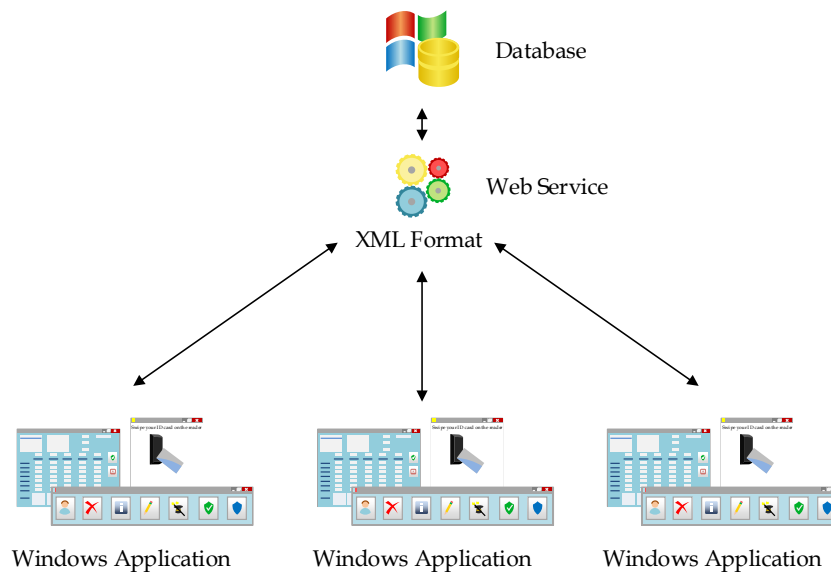


Fig. 22.11. Overview of the "debit" card system. There are seven RFID tag readers spread throughout the school.



points and “purchases” are being transferred from the old system to the system over the summer. A variety of reports can be generated by staff regarding student performance in relation to their respective Individualized Education Plan (IEP) objectives.

## TECHNICAL DESCRIPTION

The whole system is built on one SQL database with the option of being deployable even without an SQL database by using a single Microsoft Access file. Web service is a communication method between applications using XML. The communication can also be over a network. In this case, a database server is wrapped around by a web service. The web service acts as a broker between the database and applications running on PC's all over the school network and accessing the database. According to the database, web service is the only application that is accessing the data. Web service acts as a representative for all application entities as one entity.

The Database server is hosted in Microsoft's free hosting service for students through a program called Microsoft DreamSpark ([www.dreamspark.com](http://www.dreamspark.com)). The database consists of three tables:

1. Buddy Points: This table holds the points scored by the student.
2. Users: This table maintains the details of all the users, both students and teachers.
3. VisionsUnlimitedStore: This table maintains the history of students points usage (how they spend or on what they spend).

There are three applications used by the school to implement the whole system. They are:

1. User Management – This application is used to manage users in the system (Figure 22.12).



Fig. 22.12. The User Management interface screen.

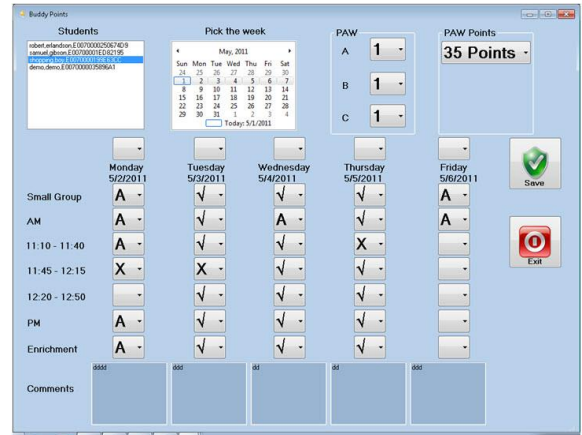


Fig. 22.13. The Buddy Points Management Screen.

2. Staff – This application is used by the teacher to award points to the students (Figure 22.13).

3. School Store – This application runs in the school store to which a card reader will be attached.

Each of the three applications has utilities that guide the user through the correct sequence of actions. Teachers and staff can print a variety of reports that summarize overall usage patterns or target specific behavior that is being monitored for an individual student's IEP.

Figure 22.13 shows the Buddy Points management system. The system defaults to all check marks. If a student is absent, staff enters an “A” and if the student does not in fact earn a check, an “X” is entered.



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