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ENGINEERING SENIOR DESIGN PROJECTS TO AID PERSONS WITH DISABILITIES

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Welcome to the twenty-first 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\(^1\) (BRAD) program of the Emerging Engineering Technologies Division of NSF\(^2\), 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.


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.

This book, funded by the NSF, describes and documents the NSF-supported senior design projects during the twenty-first year of this effort, 2008-2009. After the 5th 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 2008-2009. 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.\(^3\),\(^4\),\(^5\) Many call this the capstone course. Engineering design experiences are an integral part of the educational process. They provide students with the opportunity to apply their knowledge and skills in real-world settings, fostering teamwork, creativity, and problem-solving abilities. Design projects often involve working with individuals with disabilities, providing a unique and rewarding experience. This book offers insights into the creative processes and innovative solutions that students develop to address the needs of this population.
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:

- 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.
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
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. 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.

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conference, 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 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 person 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 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\(^7,8\). 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.\(^9,10,11\)

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,\(^12,13\) 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

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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 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.

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)\textsuperscript{14} 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.\textsuperscript{15}

"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

\textsuperscript{14} Accrediting Board for Engineering and Technology. Criteria for Accrediting Engineering Programs 2010-2011. ABET: Baltimore, MD.

\textsuperscript{15} 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.
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. 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 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).

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 2006-2007 Academic Year” (Criterion 3, Program Outcomes and Assessment)\(^\text{18}\)

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
(d) An ability to function on multi-disciplinary teams
(e) An ability to identify, formulate, and solve applied science 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 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 professional practice

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\textsuperscript{19}. 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.

\textsuperscript{19} 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

<table>
<thead>
<tr>
<th>Item evaluated</th>
<th>Score/ Possible Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Form and formatting</strong></td>
<td></td>
</tr>
<tr>
<td>Does not exceed two pages (unless authorized by instructor)</td>
<td>/2</td>
</tr>
<tr>
<td>10-point type size throughout the manuscript</td>
<td>/2</td>
</tr>
<tr>
<td>Margin settings: top =1&quot;, bottom=1&quot;, right=1&quot;, and left=1&quot;</td>
<td>/2</td>
</tr>
<tr>
<td>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)</td>
<td>/1</td>
</tr>
<tr>
<td>Text single spaced</td>
<td>/2</td>
</tr>
<tr>
<td>No indenting of paragraphs</td>
<td>/1</td>
</tr>
<tr>
<td>Blank line inserted between paragraphs</td>
<td>/1</td>
</tr>
<tr>
<td>Identifying information includes: project title, student name, name of client coordinator(s), supervising professor(s), university address</td>
<td>/2</td>
</tr>
<tr>
<td>Appropriate headings provided for Introduction, Summary of impact, and Technical description sections</td>
<td>/2</td>
</tr>
<tr>
<td><strong>Total points for form and formatting</strong></td>
<td>/15</td>
</tr>
<tr>
<td><strong>B. Images</strong></td>
<td></td>
</tr>
<tr>
<td>Photographs in black and white, not color</td>
<td>/1</td>
</tr>
<tr>
<td>Photographs are hard copies of photo prints, not digital</td>
<td>/1</td>
</tr>
<tr>
<td>Line art done with a laser printer or drawn professionally by pen with India (black) ink</td>
<td>/2</td>
</tr>
<tr>
<td>Images clearly complement the written report content</td>
<td>/2</td>
</tr>
<tr>
<td>Photographs or line art attached to report by paperclip</td>
<td>/1</td>
</tr>
<tr>
<td>Photographs or line art numbered on back to accompany report</td>
<td>/1</td>
</tr>
<tr>
<td>Figure headings inserted within the text with title capitalization, excluding words such as “drawing of” or “photograph of”</td>
<td>/2</td>
</tr>
<tr>
<td><strong>Total points for images</strong></td>
<td>/10</td>
</tr>
</tbody>
</table>
**Chapter 4: Using NSF-Sponsored Projects To Enrich Students’ Written Communication Skills**

### C. Grammar, spelling, punctuation, and style

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistent tenses throughout each section of the report</td>
<td>/2</td>
</tr>
<tr>
<td>Grammatical accuracy, including appropriate subject-verb agreement</td>
<td>/2</td>
</tr>
<tr>
<td>Spelling accuracy</td>
<td>/2</td>
</tr>
<tr>
<td>Appropriate punctuation</td>
<td>/2</td>
</tr>
<tr>
<td>Abbreviations and symbols used consistently throughout (For example, “” or in. throughout for “inch;” excludes apostrophe for plural on abbreviations, such as “BMEs” or “PCs”)</td>
<td>/2</td>
</tr>
<tr>
<td>Uses the word “or” rather than a slash (/) (For example, “He or she can do it without assistance.”)</td>
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</tr>
<tr>
<td>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)</td>
<td>/1</td>
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<tr>
<td>In lists, items numbered, with commas between them (For example: “The device was designed to be: 1) safe, 2) lightweight, and 3) reasonably priced.”)</td>
<td>/1</td>
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<tr>
<td>Consistent punctuation of enumerated and bulleted lists throughout the report</td>
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**Total points for grammar, spelling, punctuation, and style**

/15

### D. Overall content

<table>
<thead>
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<th>Requirement</th>
<th>Points</th>
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</thead>
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<tr>
<td>Excludes extensive tutorials on specific disabilities</td>
<td>/2</td>
</tr>
<tr>
<td>Demonstrates appropriate language regarding individuals with disabilities</td>
<td>/3</td>
</tr>
<tr>
<td>Avoids redundancy of content among sections</td>
<td>/3</td>
</tr>
<tr>
<td>Demonstrates clear and logical flow of ideas</td>
<td>/3</td>
</tr>
<tr>
<td>Excludes use of proper names of clients</td>
<td>/3</td>
</tr>
<tr>
<td>Citation and reference provided for any direct quote from published material</td>
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</tbody>
</table>

**Total points for overall content**

/15
<table>
<thead>
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<th>E. Section content</th>
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<tr>
<td><strong>Introduction</strong></td>
<td></td>
</tr>
<tr>
<td>Includes a brief description of the project in laypersons’ terms</td>
<td>/4</td>
</tr>
<tr>
<td>Includes problem addressed, approach taken, motivation for the approach, a summary of usual or existing solutions, and problems with these solutions</td>
<td>/4</td>
</tr>
<tr>
<td><strong>Summary of impact</strong></td>
<td></td>
</tr>
<tr>
<td>Includes a brief description of how this project has improved the quality of life of a person with a disability</td>
<td>/5</td>
</tr>
<tr>
<td>Includes a quoted statement from an educational or health care specialist who supervises the client, or from a significant other</td>
<td>/2</td>
</tr>
<tr>
<td>Includes a description of the project’s usefulness and overall design evaluation</td>
<td>/5</td>
</tr>
<tr>
<td><strong>Technical description</strong></td>
<td></td>
</tr>
<tr>
<td>Clear, concise technical description of the device or device modification such that others would be able to replicate the design</td>
<td>/10</td>
</tr>
<tr>
<td>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</td>
<td>/2</td>
</tr>
<tr>
<td>Text refers to circuit and/or mechanical drawing of the device</td>
<td>/3</td>
</tr>
<tr>
<td>Includes analysis of design effectiveness</td>
<td>/5</td>
</tr>
<tr>
<td>Concludes with approximate cost of the project, including parts and supplies (not just the NSF’s contribution) and excluding personnel costs</td>
<td>/5</td>
</tr>
<tr>
<td><strong>Total points for section content</strong></td>
<td>/45</td>
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Evaluation Summary

| A. Total points for form and formatting | /15 |
| B. Total points for images | /10 |
| C. Total points for grammar, spelling, punctuation, style | /15 |
| D. Total points for overall content | /15 |
| E. Total points for section content | /45 |
| **TOTAL POINTS** | /100 |
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.20 

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.21 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.”

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

Assistive Technology (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 (Vanderheiden, 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,
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://wwweng.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.

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.html

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 are excellent resources.

**Resources on Universal Design:**


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

**References**


CHAPTER 6
ARIZONA STATE UNIVERSITY

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INTRODUCTION
The term cerebral palsy refers to any one of a number of neurological disorders that appear in infancy or early childhood and permanently affect body movement and muscle coordination, but do not worsen over time. Even though cerebral palsy affects muscle movement, it is not caused by problems in the muscles or nerves. Rather, it is caused by abnormalities in parts of the brain that control muscle movements. The majority of children with cerebral palsy are born with it, although it may not be detected until months or years after birth. The early signs of cerebral palsy usually appear before a child reaches three years of age. Spastic hemiplegia is an acute case of cerebral palsy where a defect of one side of the brain causes substantial deficits in the opposite side of the body and may cause hemiparesis, which is the partial paralysis of one side of the body. It is generally caused by lesions of the corticospinal tract, which traces from the cortical neurons of the frontal lobe to the motor neurons of the spinal cord and is responsible for the movement of the muscles of the body. With the mentorship of Dr. Joe Peles, a student designer has proposed a device to provide therapeutic rehabilitation to children affected with Cerebral Palsy.

SUMMARY OF IMPACT
The design of the Customized Kick Scooter focuses on restoring strength through rehabilitation in the left upper limb of a child living in Zomba, Malawi, Africa. Although built for this individual customer, children of various ages and sizes suffering from upper limb physical disability due to early age cerebral palsy are able to use the scooter by adjusting the main frame of the device.

TECHNICAL DESCRIPTION
Utilizing the design process, the student designer, Soumendu Das, developed a scooter rehabilitation device for a boy living in Zomba, Malawi, Africa who suffers from an acute case of hemiparesis where the left side of his body is substantially weaker than the right side.

Apart from being weaker, he also lacks complete voluntary and motor control on his left side. Therefore, the most critical sub-problem is the strengthening of muscles on the weaker side of the body and the development of motor control. Keeping the child’s age in mind, the primary goal of the design project was to develop a device that provides the necessary therapy and also succeeds in holding the child’s attention for extended periods of time. Keeping these considerations in mind, it became imperative to design a device that would act dually to provide the necessary therapy and to be a general play device that the child would enjoy using. The design includes a basic kick scooter with a few custom changes. Instead of having usual brakes, the scooter has hand actuated brakes, or “dead man’s brakes” on the left side. As such, in order for the child to be able to move the scooter forward, he needs to operate the brakes instead of releasing them. This involves constant engagement of the child’s left hand in order to operate the scooter. Thus, the child operates the scooter by using...
his left hand to operate the brakes continuously while using his left leg to kick the scooter forward. In order to avoid muscle contracture, the handlebars are arranged in a thread cone design that fit perfectly in the child’s hands. The scooter also includes an air horn and plastic wires on the right side that encourage the child to reach across his midline to use it. In order for the scooter to serve the child for five years, the design also includes height adjusters and recliners for the handle bar to compensate for physical growth. This not only increases the durability of the device, but also helps improve the child’s posture. Using this design model, the student designer built a prototype of the scooter. In order to be able to implement the aspect of the design using hand actuated brakes, the brake calipers required special fabrication to be able to successfully install the cantilever center pull arrangement. As this costs approximately $1200.00, the design focuses on illustrating the functionality of the reverse brake system as a rehabilitation exercise tool. Upon finalization of the prototype, the student designer tested the device and found complete functionality using the custom brake system. As the user is required to continuously apply pressure to the brake system while riding the device, the left upper limb is significantly strengthened over repeated uses. As such, the design was considered sufficient for the customer’s needs. Given its slight risk of harm to the user, the device was identified as a Class I medical device. Overall, the scooter was designed to optimize two important aspects – provision of physical therapy and enhanced duration of use of the device by the patient. Physical disabilities caused due to cerebral palsy cannot be completely cured; however, it is the hope of the student designers that with extended use of the scooter, the Zomba boy will regain strength and functionality of his left arm.

Fig. 6.2. Final prototype of the Customized Scooter.
INTRODUCTION
Malawi is a small country in Southeastern Africa whose population suffers from a high incidence of AIDS and Polio. While the contagious disease of polio has not been an issue in the United States since the development of the polio vaccine, it remains a prevalent problem among children in developing countries, such as Malawi. Polio is a disease that enters through the mouth of an individual and it is spread through stool. The infectious virus resides in the intestinal tract for two weeks, which is then followed by approximately seven months of the disease. The care and health of the patient during those seven months are vital to complete recovery. Although polio is not a progressive disease, any damage that is not corrected within the seven months can become permanent afterwards. One such Malawian child named Naria contracted polio when she was one month old. Today, at the age of eleven years, Naria lives with secondary effects of polio in the form of a contracture of her elbow and wrist. Given that she is still a child, she has the potential for adaptability and could benefit from a rehabilitation assistive device. With the technical guidance of Dr. Jiping He, the student design team has designed a rehabilitation device that aids Naria in eliminating the contracture of the elbow and wrist and recuperates hand movement through muscle strengthening.

SUMMARY OF IMPACT
The design of the Elbow Wrist Orthotic device is intended to increase range of motion and rehabilitate the strength of the upper limbs in children that are contractured due to deformations caused by polio infection at a young age.

TECHNICAL DESCRIPTION
To address the contracture of Naria’s elbow and wrist, the student design team used the design process to develop a rehabilitation device that allows for greater range of motion and strengthening of the left arm muscles, tendons, and ligaments within the elbow and wrist. Following identification of the customer limitations in her daily life and her need for a corrective device, the design team determined a set of product specifications and accompanying metrics. Through early concept design generation, it was determined that the design goals would be best achieved through an elbow and wrist brace with active elements. Given that contractures are unique for every polio victim, the device design needed to be customized to meet the specific needs of the customer. With long distance communication to a mediator in Malawi, the design team was able to acquire Naria’s range of motion, sensitivity of her left arm, body weight, height, and pain levels when doing everyday activities. Using mathematical and technical models to assess the feasibility of the design, the team determined that the device would need to consist of an adjustable system to fix the affected arm in place, constricting elbow and wrist movement, while still allowing for normal shoulder and elbow rotation. To alleviate the contractures and allow the customer to regain muscle strength, the device uses a low-load prolonged stretch (LLPS) and total end range time (TERT), allowing for greater range of motion. The team then built a prototype to verify the device design and ensure the customer needs were met. The device prototype incorporates a wrist and elbow component into a complete rehabilitation unit for the left arm. The wrist component comprises a
modified golf glove with a Velcro interface on the top of the hand, which allows for the attachment of a linen elastic component to the elbow frame of the device. The elbow component is built around a steel frame and secured by four Velcro cuffs. Through discussions with a physician, it was determined that the customer would likely need to use the rehabilitation device for a period of two to three years. Therefore, the device is built to withstand daily usage for approximately this duration of time. Following assembly of several prototypes and through verification testing, it was determined that the device is safe to use, but that its ability to be fully functional for the intended rehabilitation purposes is not entirely known. As such, it is recommended by the design team that future research and development be conducted to increase the effectiveness of the device for the intended uses. Similar to existing braces and orthotic devices approved for use by the Center for Devices and Radiological Health, the Elbow Wrist Orthotic device is classified as a Class I medical device and is exempt from 510(k) and GMP regulations. The estimated cost of fabrication of the Elbow Wrist Orthotic is between $135.00 and $185.00. Given the difficulty in assessing the prototype functionality, the device has not yet been sent to Malawi, Africa. It is the hope of the design team that if future research yields an effective product that increases range of motion in upper limbs, an instruction manual should also be developed in order to allow multiple devices to be made for the people of Malawi.

Fig. 6.4. Final assembled prototype of the Elbow Wrist Orthotic device.
INTRODUCTION
Poliomyelitis (Polio) is a viral disease that can affect the central nervous system and lead to muscle weakness and paralysis, most often occurring in the legs. Although Polio has been virtually eradicated in the United States, it is a disease that remains a major healthcare problem in many developing countries today. Despite no known cure for Polio, several treatments exist including rehabilitation programs and devices that help aid motility of those with debilitating paralysis. For those with paralysis of one or both legs, hand cycles that are powered by rotating motion of the arms and typically exist in a tricycle form, can be used to aid in daily motility. Anthony, a man affected by Polio in Malawi, Africa is victim of Polio with severe paralysis of both of his legs. Supporting himself and his family as a woodcarver, Anthony’s work requires him to travel approximately 20 kilometers each day on rugged roads. Anthony presently uses a rudimentary and outdated hand cycle to complete his journey to work. With the technical guidance of Dr. James Abbas, the student design team has redesigned and developed a handcycle that satisfies Anthony’s daily travel requirements.

SUMMARY OF IMPACT
Through the design of hand cycle for a physically disabled person restricted in mobility in Malawi, Africa, the design team was able to provide a safe, efficient, and durable mode of transportation that is capable of traversing rough terrain and providing daily travel for the client. Upon receipt, the customer reported that the hand cycle was a significant improvement to his current transport and allowed for ease of travel to and from his work.

TECHNICAL DESCRIPTION
Working as a student team, designers Alex Sitek and Scott Kuhlman, completed the design process with a fully functional handcycle for their client, Anthony. Beginning the design process, initial customer needs were identified from a video interview with Anthony who discussed his physical disabilities, current mode of transportation, and limitations. Once the customer needs were identified, each was converted into a metric and built into a House of Quality, which organized all product specifications. Using competitor analysis of existing handcycles, design similarities were incorporated into the student designed handcycle to ensure that final product was state of the art and safe for customer use.

Given the limited resources and generally rough terrain in Malawi, Africa, the handcycle is designed to use materials and techniques that would increase the longevity and durability of the cycle in pre-developing and developing countries. The final product hand cycle was built of hand welded aluminum alloy metal with a 7 speed internally geared low maintenance system and a mechanical disk brake configuration. In order to improve comfort and functionality, the cycle design includes...
multiple seat positions, is light weight (less than 60 pounds), and has an attached storage compartment. Satisfying Anthony’s personal body size, the hand cycle measures 55 to 65 inches from axle to axle, has 26 inch wheels, seat depth of 14 inches, seat width of 16 inches, ground clearance of 20.5 inches, and weight capacity of 300 pounds. The rear wheels are attached to the axle using a feature that allows for quick release without removal of the entire axle, which allows for easy straightforward tire maintenance. Given the similarities to common wheelchairs, the hand cycle is classified as a Class I medical device according to the FDA Center for Devices and Radiological Health and requires only a 510(k) submission. Given the cost of components available in the United States, the cost to manufacture this hand cycle is approximately $500.00; however, the cost to ship the hand cycle, depending on the recipient location, can be quite expensive due to the overall size of the device. Using the determined customer needs and final design specifications, the hand cycle was assembled and tested to verify safety and efficiency. Once painted for aesthetics, the hand cycle was shipped to Sengay Bay, Africa where it was then transported to Anthony in Malawi.

Fig. 6.6. Anthony riding the hand cycle across a village road device following its arrival in Malawi, Africa.
HAND REHABILITATION DESIGN FOR STROKE AND OTHER HAND MOTOR PROBLEMS

Designers: Hiroko Austin  
Design Mentor: Dr. Jiping He  
Project Coordinator: Dr. Vincent Pizziconi  
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INTRODUCTION
In the United States, 300,000 people, or approximately half of annual stroke survivors, have chronic arm impairment and only ten percent of those impaired ever recover completely. Current rehabilitation therapy for stroke victims requires expensive one-on-one interactions with trained therapists, which makes it difficult for patients to receive long term rehabilitation therapy. Additionally, many stroke survivors receive less therapy than desired or needed as health insurance programs may stop payment of treatment once patient benefits have been detected. In this case, the patient’s condition is typically labeled as “chronic” and therefore future coverage of therapy is suspended. However, recent research proves that mild to moderately impaired stroke victims may be able to significantly improve their movement ability with therapy even years after the stroke occurs. One conventional therapy, called repetitive movement practice, has shown great improvement of movement rehabilitation in stroke victims and is the primary methodology chosen for a student-led design projects that focus on hand rehabilitation.

SUMMARY OF IMPACT
The Hand Rehabilitation Design is intended to improve the functional movement of the hand in patients suffering from a stroke. Despite available therapy modalities, this device is designed to allow users independent, long term rehabilitation therapy at an affordable cost.

TECHNICAL DESCRIPTION
The student designer, Hiroko Austin, completed the design process to bring the Hand Rehabilitation Device to market. Researching common rehabilitation modalities for stroke patients, the student designer identified the need for a low cost and long term hand therapy device that can be used independently by patients who are no longer receiving regimented therapy treatment sessions covered by their health insurance plans. Following identification of the customer needs, the designer generated multiple design concepts and tested each for feasibility and potential to provide the desired therapeutic effect. Choosing the best design concept with the goal of providing hand exercise through use of a hand held appliance and pneumatic system, the designer built a model of the proposed device using computer aided design software. The working prototype consists of a hand appliance, hand cover, and program for a control system. The main component of the prototype is a control box with a microcomputer, electronic parts, valves, a sensor, a micro-compressor, a tank, and tubes, which were
each selected using industry standards to ensure reliability. Specific electronic components of the control box include a voltage regulator, which allows for generation of approximately 5 Volts, transistors, resistors, capacitors, diodes, and a silicon pressure sensor. A program was then made for the hand appliance using Simulink to allow for repetitive opening and closing exercises of the hand. The hand appliance is made of PVC piping with end caps and consists of an inflatable bicycle tire tube covered with a washable cloth grip that fits into the patient’s hands with appropriate Velcro attachments and hardware. Inflation is controlled by the microcomputer to provide various exercise programs that are used to improve flexibility and mobility with ongoing use. This portion of the device was also made adjustable for up to three sizes to fit a variety of user hand shapes and sizes. The final component of the prototype was a remote controller with a power switch and three different colored buttons that activate different exercises. Once built to completion, the prototype was tested to determine if the pressure feedback worked successfully to control inflation and deflation to open and close the hand. Analysis of the input and output signals to the device was used to determine the error rate and The Failure Mode Effect Analysis was performed to establish the effect of possible failures, the probability of failures, and the potential hazard and danger associated with each failure. The result of the FMEA showed that the electrical components were of the greatest potential for failure, but that the probability of failure was low due to the high reliability of modern manufactured electrical system components. As over inflation could be problematic and perhaps even dangerous to the user, the maximum pressure of the hand application was designed with a maximum pressure that is unlikely to cause serious harm to the user. Future recommendations of the designer include addition of an emergency air release valve to enable emergency release of pressure from the system in case of over inflation. An additional result of FMEA was incorporation of an electrical interlock to help prevent injury to users misuse the device by opening the device housing where the AC line voltage is present. Given the relatively low potential for harm to the user, the device is classified as an exempt Class I medical device. Although one main customer need was that the device be of low cost to the user, the prototype device was estimated to cost $800.00 to manufacture. It is the hope of the student designer that future revisions to the model will utilize less costly components and provide a functional rehabilitation device that can be independently used by stroke patients.
INTRODUCTION
Although developed for some time, prosthetic devices for below-the-elbow amputees remain to have limitations that prevent total functionality in daily life. One specific difficulty with prosthetic limbs designed to replace the wrist and hand is the ability to grasp various objects used to perform food preparation. Despite advances in technology, prosthetic hooks continue to have difficulty grasping conventional kitchen knives, which are oftentimes a staple of home and professional cooking. Typically due to the non-specific grasping of common prosthetic hooks, kitchen knives tend to slip from the hook during food cutting, which can be both frustrating and dangerous for the user. Although prosthetic hooks have been modified in past designs to perform specific functions, such as holding the strings of a guitar for musicians, these design modifications are often permanent to the hook and are of high cost to the customer due to their custom design. Focusing on this issue with the guidance of Dr. Jiping He, a student designer proposed to develop a prosthetic hook adapter that can securely hold kitchen knives of varying sizes in place during cutting and food preparation.

SUMMARY OF IMPACT
The Knife Adapter for Prosthetic Hook is designed to relieve some of the strain of daily food preparation for below-the-elbow amputees by allowing them more specialized functionality with their prosthetic hook. For amputees that require assistance in food preparation, this device provides the opportunity for greater independence in at least one predominate daily activity.

TECHNICAL DESCRIPTION
Completing the design process, the designer Zachary Dodds, brought the Knife Adapter for Prosthetic Hook from concept to realization. Design and development planning were first conducted to manage the project and ensure that best industry practices were followed. By interviewing below-the-elbow amputees about the use of prosthetic hooks and their limitations for preparing food, the designer determined a set of design inputs.

Specifically, the customer needs required that the device be designed to be light weight, attach and detach from the prosthetic base quickly, withstand the force required to cut through common foods, hold multiple types of knives, prevent utensils from slipping, and be of low cost to the user. Coordinating the identified design inputs with design specifications, a House of Quality was created and multiple potential designs were considered. Following selection of a design concept where specialized grip components would be mounted on a fitted metal support, the student designer generated a computer simulated technical model of the device and assessed the feasibility for production. Using the design schematic, the designer built a prototype device using two rubber padded G7th Capos mounted on the underside of an angled aluminum frame that fit snugly into a standard prosthetic base. The rubber padded grips were chosen to mimic a hand grasping the handle of a common kitchen knife. Once attached to the
prosthetic base, the customer is able use their working hand to place a knife into the two capos and then close each capo individually. When secure, the user is able to cut food using the knife. Following preparation of food, the knife can be removed from the capos by pulling up on a black lever located on the outside of each of the capos. To verify the functionality of the device, the designer selected fifteen kitchen knives at random to test. First determining that all knives chosen would fit in the device’s grasp, each was used cut through a lemon. As each knife separated the lemon without slipping from the device, the prototype was given a 100% compatibility rating for knives with handles ranging from widths of 0.8cm – 2.5cm and heights of 1.5cm-3.0cm. Length of the handle was not found to significantly affect the grip of knife in the device. Secondly testing the average speed of knife attachment and detachment for ten trials with each utensil, the average time required to load a knife was found to be 4.5 seconds, and the average time to detach a knife was 1.1 seconds. The third test that was performed consisted of using the device to cut through hard objects such as carrots, apples, the thigh bone of a chicken, and ice cubes, for which the device held steady through the applied force without allowing any of the test knives to slip from the grips. To test the durability of the design, the device was dropped from a height of four feet onto a linoleum floor for ten trials. Although screws on the frame loosened and one grip was bent with the drop testing, there was no permanent damage to the device and repairs were made as needed. Given the limited risk to the user, the device is classified as a Class I medical device and must follow the 510(k) regulatory pathway. Additionally, to be marketable, the Knife Adapter for Prosthetic Hook requires approval from organizations that oversee the production of prosthetic devices, such as the American Orthotic and Prosthetic Association. The device costs $119.42 to manufacture. To reduce the cost to the customer, whether it be a company, non-profit organization, or other interested party, the designer intends to provide instructions for assembling the device from standard components, which would decrease the retail cost of the device incurred by production expenses. Although the market for the Knife Adapter for Prosthetic Hook is small, the device has the potential to alleviate the strain of daily cooking for many below-the-elbow amputees.

Fig. 6.10. Knife Adapter for Prosthetic Hook device used with four types of common kitchen utensils.
INTRODUCTION
In developing areas of the world, it is sometimes difficult to supply aid to those in need when no formal diagnosis has been made. Such is the case for one woman named Ida residing in Malawi, Africa. She is 22 years old and is confined to a wheelchair from what is believed to be a neurological degenerative disorder, although the root of her disability is unknown for certain. Having little insight into her disability, it is difficult to design a rehabilitation device that can directly improve the state of her condition. However, as her current mode of transportation for daily activities is little more than a plastic lawn chair fixed to a frame with wheels and a rigid foot rest, it is apparent that a newly designed custom wheelchair made to fit Ida is needed. With the mentorship of Dr. Ranu Jung, a student led design team has conducted the design process to develop Ida’s new wheelchair.

SUMMARY OF IMPACT
The Low Cost Customized Wheelchair was designed to aid the mobility and reduce the potential for pressure sores of a physically disabled person residing in Malawi, Africa. It is also intended to assist our client’s daily care provider by increasing functionality and ease of use of her main transport device. Given the limited resources of the country, the device was built using low cost materials and designed components producible by hand.

TECHNICAL DESCRIPTION
The student led design team began the design process by getting to know their customer through a video interview in her home town in Malawi, Africa. Although the design team had no knowledge of the cause of her physical disability from the interview, it was evident that Ida could not walk or manually operate her wheelchair without assistance. As such, Ida is aided by a caregiver, who pushes her wheelchair and assists in other daily life activities. Realizing the need for an improved design, the design team focused their efforts on improving the wheelchair for both the user and the caregiver. Through the video interview, the design team determined the customer needs to be a device that allows for daily mobility, can travel over rough terrain, is easy to use, can be replicated in Malawi, is comfortable, is easily maintained in the event of component failure, can allow for transport between the bed or the toilet, and is safe.

Using these identified customer needs, the designers researched currently available wheelchair designs that distribute pressure and exhibit ergonomic features as a basis for Ida’s new wheelchair. However, many of the designs found utilized leading edge technology in their production, and were therefore unrealistic to meet the requirements of a high quality, low cost wheelchair reproducible in a country with limited resources. With each team member focusing on unique aspects of the project, components for a custom wheelchair were designed and compiled using computer aided design software. The total design consists of a set of wheels, a seat and backrest unit, foot rests, arm rests, and a
stable frame. Hinging the seat and backrest together, the chair is designed to be able to recline up to 30 degrees. From these design plans, components were produced and assembled to make a prototype of the device. The metal frame consists of two matching sides, which are each bent to the specified shape by hand and connected via the wheel axle with welded brackets. Attached to the axle are two mountain bike tires and stabilized by two front caster wheels. Given the generally rough terrain of the Malawi landscape, both sets of wheels were chosen for durability and ruggedness. Stable arm rests are also incorporated into the frame and foot rests that easily rotate upward as needed and are fixed to the wheelchair frame. As a safety measure, anti-tipping bars are also attached to the axle facing the rear to prevent backward tipping of the wheelchair. To ensure that the user’s weight would be distributed evenly and therefore prevent sores from developing at the postural pressure points, a seat cushion is made of denim cloth, known for its low cost and durability, and pinto beans coated with a polycryllic spray. A sectioned cotton sack holding the beans against a lightweight central foam insert prevents accumulation of the beans in one area. In order to ease the use of the caretaker, a sliding transfer board is included to aid in transferring the user into and out of the chair. As each component was initially designed using SolidWorks software and then built to the specifications, the working prototype of the device directly matches the computer modeled design. Once fully assembled, the wheelchair was tested to determine if the design complied with the identified customer needs.

Foremost, the wheelchair was driven over several rough terrains and was found to provide adequate mobility. Feedback on the comfort level of the seat cushioning was also found to be very positive. Simulated using Cosmos, each side of the frame was found to withstand up to 500N of force. Total cost of manufacture is $342.15. Given similarly designed manual wheelchairs, the device is classified as a Class I medical device and is subject to general controls. As such, a 510(k) regulatory pathway is required. Upon completion, the Low Cost, Customized Wheelchair was sent to Malawi, Africa where it is currently being used by Ida.
INTRODUCTION
While public transportation is intended to help improve the mobility of people within a community, in developing countries’ public transportation systems, safety is compromised by less than ideal operating conditions. In such areas where medical treatment and disease prevention may be scarce, the transportation system becomes all the more difficult to use. For those with physical disabilities confined to wheelchairs, access to the overcrowded transportation system can become a daily struggle and source of much frustration. As such, the need for wheelchairs that is capable of folding, compacting, or being quickly disassembled for storage during transit is great. To address this issue, a student design team assisted by Dr. Larry Kammerzell focused on the design of a foldable wheelchair to improve the daily mobility and access to public transportation system for a physically disabled person living in Malawi, Africa.

SUMMARY OF IMPACT
The Malawi Foldable Wheelchair is designed to improve equality of access to the public transportation system by people with physical disabilities confined to wheelchairs in Malawi, Africa. The final product of this design is currently being used by persons otherwise restricted from access to public transportation in Malawi. It is the hope of the design team that students at the University of Malawi and non-profit organizations will be able to reproduce the prototype for donation to people with limited mobility due to physical disability.

TECHNICAL DESCRIPTION
Utilizing the engineering design process, a team of student designers, developed a foldable wheelchair to meet the needs of people in Malawi restricted from use of the public transportation system due to their physical disability. Given the generally rugged terrain and rough road conditions, the wheelchair is required to be of robust design and also to be made of durable materials accessible in developing countries.

Additionally, the wheelchair design is required to be safe, comfortable, and relatively easy to use for the rider. Once all relevant customer needs were determined, a House of Quality was developed to relate needs to product design specifications. Several design concepts were then generated and assessed using mathematical and technical models.

Using a light weight, but durable aluminum frame previously developed, components including caster wheels, hooks, foot rests, a locking system, and mountain bike tires are appended by hand welding according to the chosen design schematic. Given the custom design modifications, there is a fitting to mount the wheels, custom hand rails fixed to the outside of the wheels and a cloth seat added to the central frame structure. Foldability of the central frame bars is achieved through modifications of the frame and added components. When unfolded,
these bars cross at the midpoint to make an “X” shape, which supplies the greatest stability with applied force. When collapsed, the central bars fold to nearly parallel and the wheels shift inward to compress the overall size of the device. To verify that the customer design inputs were satisfied and the design requirements fulfilled, the design team conducted structural analysis, including force, stress, and displacement testing. Using various loads, the wheelchair successfully withstands up to 200 pounds of weight without displaying an indication of fatigue or stress. Given similarity to other wheelchairs that are currently commercially distributed and approved by the FDA, the Malawi Foldable Wheelchair is classified as a Class I medical device and follows the 510(k) regulatory pathway. Despite relatively inexpensive components, the device is estimated to cost $175.00 to manufacture due to the labor intensive hand fabrication. The final foldable wheelchair prototype is fully functional and meets the design criteria initially set forth by the intended customer. As such, the Malawi Foldable Wheelchair was shipped to Malawi, Africa where it is currently being used by a person with a permanent physical disability of the lower limbs to improve access to the public transportation system.

Fig. 6.14. Final assembled prototype of the Malawi Foldable Wheelchair.
INTRODUCTION
This design team developed a leg brace for their client Clement, a citizen of Malawi. Polio has affected his leg to the point that he is dependent on a crutch for mobility, which hinders his ability to perform his work as a gardener. For this reason, the design team chose to construct a brace that improves his mobility and thus helps him perform his job. With the help of their mentor, Dr. Ranu Jung, a durable and strong brace that remains affordable was designed. Since cost was a major limiting factor in the design, the team chose to use bicycle parts for the construction as they are both available in Malawi and relatively inexpensive. Specifically, the design includes spokes, wheel hub, and an outer wheel rim. They then found that by using these parts for construction they were able to build a brace that met all of Clement’s needs. In addition, a market and cost analysis determined that a similar design could be applied on a much larger scale.

SUMMARY OF IMPACT
The leg and knee brace device is intended to give support to those who are inflicted with combined leg and knee problems. It is designed to adjust to the correct functional degree at any given time in order to best suit the individual. In doing so, this brace will allow people who are affected by this kind of disability to be able to perform their daily activities with ease.

TECHNICAL DESCRIPTION
The design team proposed to develop a supporting leg and knee brace for Clement, a man in Malawi that has polio and does not have the full use of his leg. The primary customer need is a comfortable brace that is both reliable and affordable. The feasible product design consists of padded support material that fits to the leg with a hinge. The overall design consists of a support system that can be fitted to the user’s leg with a comfortable interface and has the ability to pivot at a central joint located at the knee. The supports are made of 1/8 inch flat stock steel, spokes and a rim, which was removed from a bicycle. The support system consists of a spoke threaded through the spoke hub and the rim with the flat stock steel adding side support. Fast Steel, a steel epoxy, is used to secure the supports together. The hinge, modified from a spoke hub, is pinned by two standard cotter pins. These pins are necessary to lock the brace at various angles that are required by the patient. The padding attached to the support system, to provide comfort to the user, is made of soccer shin guards and is riveted to the brace for lasting support and durability. With the client’s career as a gardener in mind, the brace is designed with a locking mechanism to lock the brace between the angles of 0 degrees and 90 degrees. Following completion of the device prototype, verification testing and standard risk analysis were performed. These tests are intended to determine the potential hazard of the support in terms of rotational and lateral strength, smoothness, and integrity. The finished brace passed all tests and is deemed functional and safe by the design team. As such, the brace is believed to be sufficient to meet Clement’s needs and allow him to bend and lock his knee at various angles that are comfortable to him while he is working. The brace is reliable, affordable, and offers a great deal of comfort. It also has the ability to adjust for growth and also to change out the padding for longer use. As reliability and affordability are other key design requirements, this brace provides reliability, availability, affordability and performance to all people that are affected with leg and knee problems, such as those affected by polio. The leg and knee brace provides superior performance in supporting the leg and knee to allow persons to perform day-to-day activities and thus will benefit those inflicted today and into the future.
Fig. 6.15. Finished prototype of the Malawi Leg brace.
INTRODUCTION
This Capstone Design project is based on the needs of our client, a young girl living in the developing country of Malawi. Our client has minimal movement in her left hand and arm. The purpose of this device is to encourage her to complete various movements with her left arm and hand by moving beads along various tracks. One primary objective is to instill interest in our client so she will complete the exercises. This is accomplished by making the device fun and interesting while improving motor function and range of movement in the left arm. In order to promote the desired arm movements, tracks are assembled to force various extensions and flexions of the arm. The beads are designed to give various resistances, making each progressive bead harder to push than the previous, in an effort to increase the strength in our client’s arm.

SUMMARY OF IMPACT
Physical disabilities are a problem that the people of Malawi face every day. These disabilities are primarily caused by polio, birth trauma, other diseases, or because of accidents involving fires. This project focuses on one specific Malawi girl with a disability in her left arm that has tightened her tendons forcing her wrist and elbow to be flexed. This disability prevents her from being able to complete daily tasks at school and home as well as playing with her friends. She is unable to pick up anything with her left arm or hand because she has very little strength due to the positioning of her wrist. Although the device designed in this project is custom designed for this specific individual, there is hope that it will also serve as a rehabilitation device for others based upon universal design considerations.

TECHNICAL DESCRIPTION
In order to address this problem, the design team first became familiar with the current abilities of the client by watching a video of the client performing simple tasks (such as picking up objects, going from sitting to standing, and walking). After considering a number of design concepts, the team choose a play device because the client is nine years old and thus would be more responsive to rehabilitative therapy in the form of a game or toy. The design is based upon a model of a bead rollercoaster that is similar to those in a doctor’s office waiting room. In operation, the beads at the top of the stack are the easiest to move to the other side, while the following beads have an increasing resistance that requires more strength to move. In order for the client to be forced to move the beads along the track, specific
hand, wrist and arm movements are used. She also has the ability to practice on the easier beads and move onto the higher resistance beads when she feels she is ready. The design students are confident that this product design provides both a rehabilitation device and a toy that the client enjoys playing with. Taking all of the customer needs and final specifications into consideration, an actual size prototype was developed and underwent testing to determine if it actually promoted the desired range of motions. The final prototype is composed of 2” x 2” pine boards that are assembled into a square of dimensions 22” x 22”. 1/8” diameter steel rods are bent into our desired shapes, and inserted into the tracks and secured by 1/8” shaft slips. Wooden beads are attached to these tracks. Springs provide resistance in order to illustrate how the device can be adapted into a strengthening tool. Upon completion, the prototype was validated for complete functionality and sent to the client in Malawi.

Fig. 6.17. Finished Multi-Pathway Rehab Device.
NEURO TRAINER: A NEUROREHABILITATION DEVICE FOR CHILDREN WITH CEREBRAL PALSY

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INTRODUCTION
Hemiplegia is partial paralysis of one side of the body and is a common disability in developing countries. One cause of hemiplegia is cerebral palsy, which in turn is caused by a number of conditions, including bacterial meningitis, lack of oxygen to the brain, childhood stroke, head injuries, as well as many unknown causes. These conditions cause a disruption of blood flow to the brain, resulting in long term damage or death to particular areas of the body. Hemiplegic patients typically tend to favor the opposite side of the body, which is completely functioning for all tasks and activities. This behavior generally referred to as ‘learned nonuse.’ While rehabilitation solutions exist for children with cerebral palsy in the United States, such opportunities are rarely available in Malawi. In addition, devices in Malawi are required to be cost-effective, resistant to harsh environmental conditions, built with materials that are available in the region, simple in design, and of minimal cost to operate and repair. With the technical guidance of Ed Koeneman, the design team created a prototype that models technology currently used in mainstream stroke rehabilitation therapy. Given that scientific studies in the field of neurogenesis demonstrate the potential of neurons to rebuild or recreate pathways in order to bypass damaged areas of the brain, it is the intent of The Neuro-Trainer to leverage this ability to regain lost functionality of the upper extremities. By recreating these pathways, many clinical studies have shown that a patient may regain partial or full functionality of the affected area, especially after years of ‘learned nonuse.’

SUMMARY OF IMPACT
The design of the Neuro-Trainer is intended to help patients suffering from hemiplegia to regain partial to full functionality of their attached limbs by aiding in routine rehabilitation exercises that build strength through resistance training. The Neuro-Trainer is currently being used by hemiplegic children in Malawi, Africa.

TECHNICAL DESCRIPTION
The Neuro-Trainer is specifically designed for two hemiplegic children that are approximately ten years old and reside in Ntchisi, Malawi, Africa. Using video interviews with the children, the designer determined that the primary customer need was to regain functionality of both the hand and the arm. Building on the design of current stroke patient rehabilitation devices, the product design specifications are composed of a set of metrics. With three iterations of concept generation, the final prototype consists of a dual pipe system, whereby one pipe with a smaller diameter is inserted and connected internally to an outer pipe with a larger diameter via an elastic band system. The elastic band system is intended to provide resistance to the patient and thereby strengthen their muscles with repeated use. Following this concept, the final prototype is composed of PVC piping, painted with specially formulated spray that is intended for adherence to plastics, connected internally using polyurethane bands. Attached to the larger pipe of the device, via industrial strength Velcro, is a Pedometer which counts the number of repetitions. Additionally, heavyweight...
polypropylene straps are attached to the device, with one strap placed across the patient’s shoulder and the other strap held by the weaker hand. Given that the Neuro-Trainer is designed for children, it measures nearly 24 inches and extends to a maximum of 48 inches. Construction of the device from raw material to finished product requires approximately 10 hours. Based on a substantially equivalent exercise device, the Neuro-Trainer is classified as a Class I medical device and is exempt from 510(k) submission. It is estimated that the device costs $9.00 to manufacture and is made from standard components available in Malawi and many other developing countries. Multiple full-sized, functional final prototypes of the Neuro-Trainer were constructed through the design phase and the final prototype version was shipped to Malawi, where it was given to the hemiplegic children originally interviewed as the primary customers.

Fig. 6.19. Final prototype of the Neuro-Trainer in the relaxed position.
INTRODUCTION
Currently there are no below-the-knee prosthetic devices designed specifically for dancers that are capable of rotating from the flat to the relevé positions of en Pointe dancing. For most ballerinas, dancing en Pointe is a thrilling experience culminating years of dedication and training. For those with a passion for dancing ballet or those who have made it their profession, it is oftentimes very difficult to maintain a lifestyle of dancing if faced with a lower limb amputation caused by infection or accident. Despite their limitations, many below the knee amputee dancers, or dancers with other lower limb disabilities, strive to continue their passion for dancing. As current prosthetic devices made for replacement of the ankle and foot tend to have limited rotational abilities, dancers with these prosthetics must forgo dancing en Pointe and restrict their movement to mainly flat positions. As such, with the mentorship of Jodie James, a student designer identified the need for a modified ankle and foot prosthetic device that would allow increased rotation about the ankle joint and thereby make en Pointe dance positions possible for lower limb amputee ballerinas.

SUMMARY OF IMPACT
The Pointe Prosthetic Ankle is intended to improve the abilities of dancers with lower limb amputations and disabilities to dance en Pointe without limitation. The prosthetic is designed to improve the lifestyle of those with lower limb disabilities who have a passion for dancing ballet.

TECHNICAL DESCRIPTION
Starting with identification of customer needs to determine design specifications, the designer investigated existing prosthetics for the ankle and foot and determined ways in which such devices could be modified and improved for en Pointe dancing. The specific needs of the device include the ability to support a person’s body weight without requiring assistance from an outside force, weighing under one pound, and the ability to absorb shock incurred from normal movements.

The closest existing prosthetic that matches these specifications is that of a diver or swimmer. However, as this device is intended to function free of outside assistance, the initial design concept focuses on incorporating an automatic mechanical component at the pivot between the ankle and foot. In order to rotate the foot about the ankle to rise from the flat position to the relevé position, the device requires the use of a small motor. Analyzing the rotation of the foot from the flat to relevé positions, a technical model was used to calculate the torque of the ankle at incremental angles throughout the movement, as well as the force required of a motor to perform the rotation. The design of the device also includes a switch that allows the dancer to choose when to relevé. Reaching the top of the relevé position, the motor locks into place and holds the position as long as the
user desires. Using a model dancer of 150 pounds and with a foot length of eight inches, the motor torque needed was found to be approximately 85 lb-in. The final device prototype consists of a motor, a battery, a foot attachment, an outer ankle piece, a worm and worm gear, a shaft and motor base connecting the motor to the outside ankle piece, a user switch, and limit switches. With this design, the motor of the device turns a worm and worm gear causing the ankle to relevé and lock into place when the foot attachment reaches the limit switch, which then stops the motor and prevents the gearing from rotating in the opposite position. When the switch is released, the device returns to the flat position and when sensed by another limit switch, will lock into place. The device is built of machined metal. In order to assess the potential for risk with the device, fatigue properties were tested with repeated rotation. The device is able to endure repetition with no visible deviation from the expected behavior. Similar to other prosthetics, the device is classified as a Class II medical device and requires the designer to submit a 510(k) premarket notification. Given the necessity for machine parts, the total cost of the device is $469.56. Although the market for the Pointe Prosthetic Ankle is relatively small, the designer hopes that future modifications allow the device to be used in other applications as well. Maintaining specificity towards sports related uses, it is the hope that the device will be used in the future to not only aid ballerinas, but also soccer players, gymnasts, and other athletes limited in their pursuits by physical disabilities.

Fig. 6.21. Final prototype of the Pointe Prosthetic Ankle demonstrating the rotation of the device from the flat to relevé positions.
SELECTIVE POWER ASSISTIVE DEVICE FOR
STANDARD WHEELCHAIRS

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INTRODUCTION
In order to assist physically disabled people using wheelchairs as their chief mode of travel, conventional wheelchairs have been adapted to incorporate motor systems into the frame that provide power for wheel rotation and movement. However, these assistive motors, which provide either full or part time power, typically add excessive weight to the chair and can make manual wheel rotation difficult for the user. In addition, a customer oftentimes pays large out of pocket costs as this type of device has no federal reimbursement code. As such, with the mentorship of Dr. Jiping He, a student led design team determined the need for a light-weight power assistive device that can be adaptable to and selectively drive standard wheelchairs. Different from fully powered wheelchairs that require no manual user propulsion, the device is able to selectively activate as a motor system incorporated into a push rim wheelchair to aid forward movement when assistance is deemed necessary by sensory components. Using this selectivity, it is the hope of the designers that the device will have greater longevity and practical appeal to wheelchair users.

SUMMARY OF IMPACT
The selective power assistive device for standard wheelchairs is designed to aid persons, with physical disabilities that use push rim wheelchairs, by powering motors that drive each wheel forward when the user is moving up an incline or is fatigued from operating the chair. Although current devices with similar applications currently exist, this device is intended to be more affordable, light weight, and adaptable to both collapsible and non-collapsible wheelchairs. This design is especially beneficial for persons with limited range of mobility and dexterity.

TECHNICAL DESCRIPTION
The design team developed and built a selective power assistive device for standard pushable wheelchairs to meet the need unfulfilled by current electrically powered wheelchair motors. To match current available technologies, the design includes a novel assistive motor, which provides either partial or consistent operating power to push rim wheelchairs. The motor is light weight, inexpensive, and adaptable; qualities that are important to wheelchair users. With the identified customer needs of the device, the design team generated a complementary list of design specifications to which their device would need to adhere and a House of Quality to relate each need with a corresponding specification. Analyzing several alternative design concepts, the team identified the concept that would most feasibly meet the determined specifications. The design utilizes sensors mounted on the wheelchair and is capable of determining when the customer needs power assistance, either via noticeable deceleration or change in angle of incline or decline from the horizontal. Sensing the need for
assistance, signals are routed to speed controllers on the hub-mounted motors to drive the wheels and propel the chair forward. The prototype is battery powered and adaptable as an accessory to standard push rim wheelchairs. The device consists of two direct current motors (one for each wheel), batteries as a voltage source, specialized brackets designed using computer-aided design software to mount the device, and a unique selective power assist control system. A BASIC Stamp microcontroller, which is popular for use in small robotics, is used based on its ease of connectivity and programmability. Additionally, an accelerometer capable of detecting forward velocity and working in tandem with an inclinometer sensor, which can measure the tilt angle of a wheelchair within ±1°, is incorporated into the device. When in motion, the velocity and tilt information calculated by each component are intended to be sent to the continuous loop feedback control system. Once assembled, the matching devices were mounted on the frame near each wheel of a collapsible, push rim wheelchair and tested to verify the safety of the device and its ability to satisfy the identified customer needs. Each component of the device was found to have minimal interference to the chair function and form. Despite initial wishes, the device was unable to be mounted on the wheel hub. This is suggested as a potential future revision to the design. Testing the device on several types of wheelchairs, the design team found that, because the motors and batteries are designed to adapt in a universal filament, the device can be used with both collapsible and non-collapsible chair models. While the device requires no user interface for control, recharging is necessary via long connectors and an electric wall outlet. As the wheelchair is required to stay relatively stationary while charging, the design team suggests that future revisions to the design should address this issue. Total manufacturing costs for the completed prototype are estimated to be approximately $687.00, with the motors and batteries being the most expensive components. Given minimal potential for hazard to the user, the device is anticipated to be classified as a Class II medical device and requires 510(k) submission. Pre-market approval is not necessary as the selective power assistive device builds on currently proven technology. Although the design team successfully developed a device that selectively powers standard wheelchairs and is light weight, the team hopes that future modifications to the design allow for a more cost effective design for widespread use.

Fig. 6.23. Finished prototype showing the selective power assistive device enclosed in black casing.
INTRODUCTION
There are many places in the world that do not have access to advanced healthcare systems. One such country is Malawi, located in the South Eastern region of Africa. Our client is a Ntchisi woman whose foot was severely burnt and permanently disabled by a house fire during her childhood. The unavailability of suitable medical care has left her with the inability to walk normally and even balance enough to stand up without assistance. The instability from her disabled foot has caused the misalignment of her shoulder, which leads to severe back pain. She experiences great difficulty in walking prolonged distances as is required by her daily activities. With the mentorship and technical guidance of Dr. Jiping He, a student design team determined the need for a rehabilitation balancing shoe device that is able to restore postural stability and provide the additional needed height for their client to walk normally and lead a more comfortable lifestyle.

SUMMARY OF IMPACT
The Balancing Shoe device is intended to aid the mobility of and provide stability for customers with a physical disability to one foot that prevents normal walking and unbalanced stance due to height differentials between the two sides of the body. With added support and leveling of the body’s posture, the device is also designed to reduce strain on the muscles of the back and thereby decrease pain associated with unbalanced posture.

TECHNICAL DESCRIPTION
Following the FDA Quality Systems Guidelines, the design inputs were first determined using a video interview with the client recorded in her home town in Malawi, Africa. From this video interview, the designers determined that the client predominantly requires a device that assists in daily movement to help perform routine activities and improves the declining alignment of her shoulders.

Other needs identified include that the device be lightweight, relatively easy to use, store when not in use, able to offset strain applied to the client, adjustable according to height, inexpensive to produce, provide general comfort for the customer during movement, and have a knee or foot rest. Although the video interview with the client provided identification of the individual needs, only a rough estimate of the physical dimensions of the client’s foot and shoulder-pelvis alignment were obtained. A set of corresponding design specifications were determined and a model of the device design was created. The design consists of a shoe-like device with an attached leg brace that could be comfortably worn by our client during her daily activities. The final prototypes utilize a quad base cane padded with a nylon mesh sleeve to aid in stability of the lower limb and provide a crutch...
support for the customer’s upper body weight. The leg brace portion of the device is modified with Velcro straps to hold the device in place during usage. A glycerin gel pad was originally considered for padding of the device, but the current design uses memory foam to compensate for the estimated anatomical measurements. The cost to manufacture the device is estimated to be $115.75. Once built, the prototype was tested for safety and verified against the previously identified customer needs. Different from conventional walkers, the Balancing Shoe device provides stability and mobility over most rough terrains. Given that the device is not invasive and presents minimal potential harm to the user, it is classified as a Class I medical device and is exempt from premarket notification requirements. Although the design of the Balancing Shoe centered primarily on one individual customer, the design is adaptable for other patients with varying disabilities.
"THE KICKER" CEREBRAL PALSY REHABILITATION DEVICE

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INTRODUCTION
Cerebral palsy is a disorder that encompasses a group of non-progressive and non-contagious conditions caused by damage to the motor control centers of the brain that result in physical disability. Cerebral palsy is 66% more common among children living in Southern Africa than it is among children living in the United States. The increased number of cases in Africa is attributed to poor prenatal care and the prevalence of meningitis and cerebral malaria which can both result in cerebral palsy. Although lower limb disability is common for children with cerebral palsy, no rehabilitation devices, aimed at increasing lower limb strength, are currently available in Malawi, Africa. Given that there are limited available resources in South Africa, design of a rehabilitation device must take these limitations into consideration and ultimately result in a sustainable device that can be easily reproduced by the people of Malawi. As such, with the mentorship of Dr. Joseph Peles, this project focuses on the design of a rehabilitation device for children in the pre-developing country of Malawi, Africa who suffer from cerebral palsy.

SUMMARY OF IMPACT
The Kicker rehabilitation device aims to improve the daily mobility and overall quality of life of children suffering from lower limb disability due to cerebral palsy. Given the relatively simple design and use of standard components, it is the intent that the device be reproduced in pre-developing and developing countries where little medical treatment for cerebral palsy is available.

TECHNICAL DESCRIPTION
Working as team, the student designers utilized the design process to address the need for an interactive rehabilitation device for children with cerebral palsy. Modeled after similar, current rehabilitation devices used in Malawi, Africa, that have been successful in using resistance to build upper body and arm strength in children with cerebral palsy, the designers determined several viable designs. Among five product design concepts, “The Kicker” concept, which allows cerebral palsy patients to literally kick their way to stronger leg muscles, was chosen based on safety properties, appropriateness for use by a child, ability to adjust resistance, ease of assembly and repair, and the availability of product materials in Malawi. By design, The Kicker provides rehabilitation for children’s lower extremities and is similar to a pogo stick that has been created from PVC piping and springs.

Using mathematical and technical models, the design was evaluated for feasibility and then constructed. The design uses two PVC pipes of slightly different diameter, where one pipe attached to a soccer ball is inserted into the other, and can move lengthwise with applied force. A resistance to motion is provided by an internal, adjustable spring system that supplies restoring force when depressed and brings the inner pipe back to the initial position. Given nearly instantaneous restoration, the device may be repeatedly kicked without delay. As consistent delivery of electricity is not yet available...
in most areas of Malawi, the device was manufactured using preformed, standard components that are accessible in either Malawi or other neighboring countries. In total, three standard springs, one dowel, two PVC pipes, one PVC cap, screws and bolts are used in the assembly of the final prototype. Although the device was built and mounted on a stable platform made of pressed wood, the device does not require a base to be functional. Rather, it can be placed against a firm support, such as a wall, and stabilized laterally by stakes. To ensure that The Kicker performs as intended and is safe for use, the final prototype was tested and verified by the designers. Additionally, five children were interviewed to determine the relative desire of children to use the device. All five children said that they liked The Kicker and would use it if available. The Kicker is classified as a Class I medical device as it poses little risk as a non-measuring exercise tool and is 510(k) exempt. Therefore, in order to market the device, only a Premarket Application is needed. Using the components incorporated into the final prototype, the cost to manufacture The Kicker is approximately $156.00. Although, not yet shipped to Malawi, Africa, the device is fully functional and ready for use by the children of Malawi. Using a detailed, color pictorial instruction manual provided with the final prototype, it is the hope of the designers that The Kicker will be reproducible by the people of Africa and help restore the mobility and quality of life of children afflicted with cerebral palsy.

Fig. 6.26. Finished prototype of the 'The Kicker' rehabilitation device mounted on a stable wood support with lateral supports.
INTRODUCTION
In conjunction with the Malawi Rehabilitation initiative, a student led design team addressed the need for a rehabilitation device to improve the daily quality of life of a woman suffering from post-polio leg deformations as well as double scoliosis. Polio, formally known as Poliomyelitis, is a viral infection that can cause debilitation through entry to the central nervous system and subsequent destruction of motor neurons. Muscle weakness and paralysis, such as is seen in our client, are common and can interfere with regular mobility. Scoliosis is a condition in which the spine is irregularly curved and can cause great pain to those affected. In combination, these medical conditions limit the mobility of our client Joyce, who resides in Lilogwe, Malawi, Africa. Although Joyce currently uses a wheelchair and crutches, she is frustrated with her inability to perform everyday tasks, such as sweeping and using the bathroom. With the guidance of Dr. James Abbas, it was determined that Joyce would greatly benefit from a device that would allow her to immobilize her injured leg while encouraging her to rehabilitate muscles in her unaffected leg through normal movement.

SUMMARY OF IMPACT
The design of the Knee Walker is intended to improve the daily mobility of a patient with a physical disability in one lower limb and ease the performance of chores and everyday activities.

TECHNICAL DESCRIPTION
To address Joyce’s needs and furnish her with a custom rehabilitation device, the student design team carried out the design process to develop a device similar to that of a common knee walker. With the goal of immobilizing Joyce’s injured leg while allowing unhindered movement of her unaffected leg in mind, the team determined a list of product design specifications through a video interview with the client.
In addition to improving mobility, the design encourages upright position during use in order to slow the worsening of the client’s scoliosis and allow her to rest against padded handle bars if the upright position becomes overly taxing on her back. Using measurements of the patient’s body dimensions, the design team considered product concepts that would be appropriate for her specific height and weight. The final design consists of a wheel mounted, padded seat with an elevated, padded handle bar system with braking and permanent lock capability. Using large wheels, the design intends to endure various terrains including asphalt, mud, and dirt. To allow for 360 degree rotation, the front caster wheels and forks are also designed to pivot. The prototype of the device includes one inch galvanized steel water piping and a handle bar set from a 10 speed bicycle. The handle bars are padded with foam polymer and bicycle hand breaks were affixed. Rubber plastic composite wheels are appended to the foam padded seat, which is made of a plastic cutting board fastened to the steel frame using Velcro. Additionally, the seat is encased in male swimming shorts to prevent entry of moisture from the environment. Verification testing of the device was conducted to affirm safety and comfort, as well as to ensure all of the user design requirements were met. From this testing, the tipping angle of the device (approximately 60 degrees from the horizontal) and the reaction of the device to various terrains were determined and found to comply with the design specifications. Based on similarly designed devices, the Knee Walker is classified as a Class I medical device and must proceed via the 510(k) regulatory pathway. The cost to manufacture the device is approximately $369.00. Although this device has not yet been shipped to Malawi for the client, the device is fully functional and will, upon arrival, improve her mobility and quality of life.

Fig. 6.28. Side view of the knee walker rehabilitation device showing handle bar system for support.
WEIGH SCALE FOR SEATED USERS

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INTRODUCTION
Currently there exists a need for an affordable and accurate seated weigh scale for routine weight assessments. Although many wheelchair accessible weight scales are available in clinical settings, such as hospitals, they are typically cumbersome in size, costly to purchase, and impractical for in-home patient use. As patients who are confined to wheelchairs or have difficulty standing may find it too strenuous, if not impossible, to use typical home weigh scales, they are unable to regularly determine their weight and must resort to the assistance of medical care facilities. For both medical and personal reasons, routine weight measurement is considered necessary for many people and as such there exists a notable market for a seated weigh scale. With the mentorship and technical guidance of Dr. Bruce Towe, a student design team focused on the design and development of a seated weigh scale, appropriately named the Sit-n-Weigh, for use by patients and clinicians in monitoring weight regularly.

SUMMARY OF IMPACT
The Sit-n-Weigh seated measurement device is designed to meet the need for routine weight determination for users that have difficulty standing for even short durations of time. It is intended to alleviate the inconvenience of repeated visits to medical care facilities by providing in home measurement for both patients and caretakers.

TECHNICAL DESCRIPTION
The student design team developed the Sit-n-Weigh for release to market with the specific intent to aid caretakers and patients with medical needs for which monitoring weight is a crucial indicator of health. Following the guidelines set forth in the Quality Systems Regulations, a set of customer needs was first determined and coupled with a respective set of design specifications. Foremost, the predominant need of the device is weight determination, accurate within one-fifth of a pound, and effective for users above 500 pounds. Additional needs for the device are to respond to applied weight within ten seconds, store and display weight readings in multiple formats, and supports for user balance and assistance while entering and exiting the device. Related through the development of a House of Quality, design metrics were determined from the identified customer needs and design specifications. The prototype is modeled after the design of a heavy duty seated commode. A measurement device is constructed using load cells, a microcontroller, instrumentation amplifiers, a 12 bit analog-to-digital converter, an LCD, and user-interface buttons. Additionally, rubber stoppers are added to each support of the seat in order to prevent unsafe movement across smooth surfaces. Using a known weight, as measured by a digital scale, a function relates voltage measurements to weight in pounds.

Once constructed, the device prototype was tested to verify the previously determined design specifications. By weighing several subjects, and comparing their known weights to that calculated...
by the Sit-n-Weigh, it was determined that the prototype is accurate to within one to two pounds, which deviates slightly from the desired specifications. Similar results were attained when the device was tested in multiple environments varying in temperature, humidity, and surface friction. The device requires grounding through the frame to prevent transfer of static electricity to the internal device electrical components, which can cause malfunctions and permanent damage to the LCD user interface. Otherwise, the device was deemed effective for the intended purpose and proof of the designer concept. As recommended by the design team, future versions of the Sit-n-Weigh should have the ability to store information for multiple users, be completely moisture resistant, have a larger display and user input panel, have a foot rest to ensure accurate weight measurements, and have a more professional and visually pleasing appearance. As the Sit-n-Weigh seated scale is similar in function to devices currently available through market, it is classified as a Class I medical device per the FDA requirements, and exempt from 510(k) regulations. Although the prototype costs about $430.00, the designers are confident that refined manufacturing processes and use of more cost-effective components could lower the cost to approximately $300.00. The Sit-n-Weigh seated weigh scale was not distributed to any clients and remains eligible for redesign and improvement by future engineering design students.
CHAPTER 7
CALIFORNIA POLYTECHNIC STATE UNIVERSITY

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THE UNIVERSAL PLAY FRAME ATTACHMENT: GOLF II

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INTRODUCTION
The Universal Play Frame Golf II attachment (Fig. 7.1) is intended to enable people with partial quadriplegia to play golf. The Universal Play Frame (UPF) is a wheelchair attachment that accepts various sports attachments so users can participate in a variety of athletic activities. A golf attachment, Golf I, already exists, but a new and improved device was desired by the sponsor and customers. The Golf II allows for putting as well as some pitching, two club angle settings, and left and right-handed use. To use the Golf II, an athlete turns a control wheel to lift the golf club to a desired height. Ratchets and pawls are used to keep the club in place. Springs and pulleys provide extra force to the swing. The control wheel is pulled back to release the club and allow it to swing.

SUMMARY OF IMPACT
Few devices exist in the field of golfing for people with quadriplegia. Many items are available to people who have paraplegia which typically help clients stand up, allowing them to swing the clubs in a typical motion. These kinds of devices are not practical for our clients who have quadriplegia. The UPF golf attachment is designed with this in mind to bring "pitch and putt" to people with quadriplegia in a device that is light, portable, and provides as much exercise as possible for the user. The UPF golf attachment is currently a staple of the San Luis Obispo County Special Olympics summer program. It is fairly compact and portable, and travels to multiple local programs servicing approximately 15 people on a fairly regular basis.

Fig. 7.1. Computer model of the Golf II attachment for the UPF.
Participants who use the UPF Golf Attachment are extremely satisfied. It gives people who usually don't get the chance to play sports an opportunity to play golf. This device was designed to give a joystick controlled wheelchair user as much control over the golf clubs as possible. Users turn a wheel to swing the club back, as much or as little as they decide is necessary, to make their shot. When the user is satisfied with the back swing, he or she then pulls back on the wheel to release the gear and swing the club. Turning the wheel repeatedly and pulling on it to play their stroke not only affords the user control of their shots, but also provides a degree of physical activity and requires thoughtful analysis and adjustments.
TECHNICAL DESCRIPTION

The Golf II attachment (Fig. 7.2) is a purely mechanical device. The attachment is placed on four of the six cylinders found on the UPF. This offset allows for both right and left-handed use. An assistant places the golf club in the U-bolt attachment and secures it using four easy-to-use wing nuts. The club can be easily positioned based on height and switched out if desired. The user rotates the control wheel to “crank up” the golf club. As this is done, the corresponding spring is stretched, creating a power source. A ratchet system placed between the control wheel and golf club keeps the club in place as it is raised. The user then pulls out the control wheel to release the pawl from the ratchet and swing the golf club. If the user wishes to switch from right to left-handed use, or vice versa, the assistant can simply loosen the rod in the pawl and ratchet subsystem to disengage the right-handed pawl, and engage the left-handed pawl. Once the corresponding pawl is set, the assistant then tightens the rod to secure it in place.

The Golf club holder (Fig. 7.3) is meant to allow for easy golf club attachment and detachment. The padded U-bolts are loose enough to allow room for the club to slip in, and then secured using four wing nuts (two per U-bolt). The quick-release pins are designed to enable two settings for putting and pitching. The pins are secured in the two outermost holes for putting, and the two inner holes for pitching. The angle between these two pin settings changes the corresponding angle at which the club is held. For putting, the angle is smaller and the club is more vertical, whereas, the angle is larger for pitching.

The rod held by the two slotted rectangular pieces is used to engage one pawl, and disengage the other. The assistant simply loosen the ends of the rod by turning one of the knurled knobs, and then repositions. In this case, there are two positions for the rod, one at the bottom of the C slot for right-handed use, and one at the top of the C slot for left-handed use. Once the assistant has set the correct pawl in place, the ends are tightened the ends to secure the rod in place. Once set, it does not need to be touched unless a user with a different hand preference starts to play.

Fig. 7.5 shows the Golf II pulley subsystem. When the control wheel is turned to lift the golf club to its desired height, the corresponding pulley and spring

(right- verses left-handed use) are used as well. The spring stretches relative to how high the club is rotated back. It acts as an extra energy source and provides the club with additional power when swung. As one spring is being stretched, the other remains loose. Once the user disengages the control wheel to swing the club, both springs return to their original neutral position.

Fig. 7.2. Two views of the Golf II attachment.
In order to make the UPF Golf II design as simple and user-friendly as possible, the hand wheel and release systems are combined into one. This is made possible by using the control wheel to engage and disengage the system shown in Fig. 7.6. When the user wishes to crank the golf club up, the square stock is engaged into the square tubing and the wheel turned until the club has reached the desired position. To release the club (i.e., to swing the club), the user then simply pulls the wheel towards the body. The control wheel is connected to a steel wire, which, is also connected to the pawls further down the top shaft. Once the user pulls the wheel, the wire shifts just enough to disengage the pawl, releasing the ratchet and enabling the shaft and club to rotate. The pawls do not disengage until the square stock is completely pulled out of the square tubing, ensuring that the wheel does not rotate with the club, thus protecting the athlete’s safety. The images in Fig 7.6 show the wheel in both its engaged and disengaged positions.

The cost to produce the prototype is $815.50.
THE UNIVERSAL PLAY FRAME MK. V

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INTRODUCTION

The Universal Play Frame (UPF) Mk. V is designed to be a fully adjustable and sturdy frame that can easily and quickly attach to any wheelchair. The UPF Mk. V connects to a user’s wheelchair and provides a foundation to which one of a variety of play attachments is connected, allowing clients to participate in activities such as disc golf, bowling, tee-ball, soccer and golf. The UPF Mk. V (Fig. 7.7) is the fifth in a series of UPF prototypes, each of which have an increase in functionality.

SUMMARY OF IMPACT

Perhaps the most important design feature of the UPF Mk. V is the achievement of universal wheelchair compatibility. Many of the latest motorized wheelchairs are taking on sleek designs that conceal the frame; this makes a universal attachment mechanism difficult to achieve. The UPF Mk. V uses a ratcheting ladder strap mechanism that can swivel to facilitate attachment to vertical or horizontal poles. The frame adjusts verticallly and horizontally for different sized chairs. The speed and ease of adjustment is significantly greater with the UPF Mk. V because of the circular tubing and quick release clamps, similar to those seen on bike seats. Quick release collars have the added advantage of being easy to replace in the event that they fail or are lost or damaged, a common problem with earlier prototypes. The chair attachment mechanism worked well with standard wheelchairs, but was limited in its use with newer power wheelchairs on which the frames are often covered by aesthetic paneling. Tests show that the Mk. V resolves the tendency of previous frames to lock up when changing directions.

The local community impact of the Mk. V. UPF has been enormous. Each Friday during the school year, athletes from San Luis Obispo Special Olympics come to Cal Poly to participate in a variety of sporting events (e.g., soccer, golf, T-ball, Frisbee golf) through a program called The Friday Club that is run by the Kinesiology Department. The UPF and its various attachments are highly sought after athletic equipment by the athletes who find them fun and beneficial to use. The UPF also travels to a variety of local programs and facilities throughout the year, particularly in the summer when the Cal Poly program is closed. The frame has six crossbar mounts for various attachments, making it compatible with the new Frisbee II and bowling devices, which are currently under development at Cal Poly. This design has enhanced the impact of the frame by providing a more stable base for a variety of attachments. Athletes in our community programs who use the UPF enjoy the increased durability of the UPF Mk. V, as well as the ease with which it can be adjusted, attached and set-up with their favorite attachments.

TECHNICAL DESCRIPTION

It is critical that the UPF be broken down for storage, but it is important that the number of separate pieces be minimized to ensure that components are not lost or damaged. To accomplish ease of storage without creating large numbers of removable components, past frames featured hinged folding supports that proved problematic, as they were unstable and prone to break.

Early prototypes adjusted by “click stop” buttons that quickly deteriorated and proved difficult to operate without pinching the operator’s fingers during adjustment. The chair attachment mechanism worked well with standard wheelchairs, but was limited in its use with newer power wheelchairs on which the frames are often covered by aesthetic paneling. Tests show that the Mk. V resolves the tendency of previous frames to lock up when changing directions.

The frame’s design and construction conform to established parameters that were derived to ensure...
that the frame could be attached to the maximal number of wheelchairs possible. The cost of production of four prototypes to facilitate more extensive testing is $1,759.59.

Fig. 7.7. The UPF Mk. V connected to a wheelchair and shown with Frisbee Launcher attachment.
INTRODUCTION
The Frisbee Mk. II (Fig. 7.8) is a specialty sports attachment designed for the Universal Play Frame (UPF). It represents a significant refinement of the first prototype (Frisbee Mk. I). When attached to the UPF, the Frisbee Launcher Mk. II is designed to allow people with partial quadriplegia to throw Frisbees and play disc golf. The Mk. II affords the user greater control over a Frisbee as it is launched and provides much higher levels of safety for both the user and their assistants.

SUMMARY OF IMPACT
The goal of Frisbee Mk. II is to improve upon the Frisbee Mk. I in the areas of safety, user controls and durability. The greatest of these improvements is safety. The ratcheted Frisbee arm and enclosure provide a level of safety for both the user and aid that was not attained by the Frisbee I. The durability of the system is also greatly improved by increasing component sizes. User controls are significantly improved - the hand wheel and large trigger user interfaces make the Mk. II much easier to use, hence increasing the number of potential participants.

The user controls and safety features of the Mk. II are major improvements over the previous prototype. The hand wheels provide a fun way for the athlete to control the disc direction, while simultaneously requiring a small amount of beneficial exercise.

The Frisbee Launcher Mk. II is one of the "marquee" attachments among the clients in our Special Olympics program, The Friday Club. The powerful spring loaded rotating arm, similar to commercially available skeet launchers, is inherently fun as it provides a degree of control rarely accomplished by the UPF's target population.

TECHNICAL DESCRIPTION
The launch mechanism is powered by a spring attached to a rotating arm similar to commercially available skeet launchers. An assistant stretches the spring and loads a Frisbee on the throwing arm. The distance the Frisbee launches is based on its placement on the rotating arm. A spring loaded pin attachment holds the arm in place until the user presses the trigger, which cannot be depressed until the safety cage is moved from the "load" position to the "launch" position. The hand wheels, designed to require less than five pounds of turning force, allow the user to change the flight trajectory of the Frisbee by adjusting a screw mechanism that controls the pitch and roll angles. The user can easily control the direction in which a Frisbee is launched by simply turning their wheelchair. The trigger mechanism is a large push lever that launches the Frisbee. These controls promote inclusion by giving the user a sufficient level of control to participate in a game of disc golf.

Safety was a major concern with the Mk. I, hence the Frisbee Launcher Mk. II includes a number of safety improvements. A ratcheting mechanism incorporated into the throwing arm prevents it from springing back as it is being loaded. The Mk. II includes a shatterproof polycarbonate shell that rotates between a "launch" position and a "load" position. With the shell in "load" position a ratchet mechanism is constantly engaged, preventing release of the Frisbee arm. A Frisbee can only be launched from the Mk. II once the shell is put in "launch" mode, at which point the protective shell prevents the Frisbee from exiting in any direction other than that intended by the user.

The manufacturing phase, which encompassed the second half of the project, included over two hundred hours of manufacturing and over eighty
custom machined parts. Although the testing phase was cut short due to increases in manufacturing time, it did show that the Mk. II met most specifications.

Several possible improvement areas for future iterations include: weight reduction, flexible transmission shaft resizing, and pitch control pin resizing.

The projected cost is $952.

Fig. 7.8. Computer generated model of the Frisbee Launcher attachment.
THE UNIVERSAL PLAY FRAME ATTACHMENT: ROCK N’ BOWLER

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Kinesiology student: Kellie Radosovich
Client Coordinator: Michael Lara, Special Olympics, San Luis Obispo, CA
Supervising Professor: Sarah Harding
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INTRODUCTION
The Rock n’ Bowler is a specialty sports attachment designed for the Universal Play Frame (UPF). The Rock n’ Bowler, designed primarily for someone who uses a motorized wheelchair, allows people with partial quadriplegia to bowl. This device is an attachment for the Universal Play Frame, giving the user a great deal of control over the spin and placement of the ball. The Rock n’ Bowler (Fig. 7.9) is designed to give the user a feeling of inclusiveness when participating in the sport of bowling.

SUMMARY OF IMPACT
The typical adaptation for someone unable to bowl through disability is a simple ramp down which the user rolls the ball. There are slightly more complex bowling adaptations that help the user increase the power of their bowl, but the Rock n’ Bowler takes bowling adaptations a step further by giving the user control over spin on the ball.

The degree of control afforded to the user is far beyond any other device currently available. Potential clients for this adaptation are extremely excited by the demonstrated functionality of the device. The Rock n’ Bowler is unique and ingenious. It controls the many aspects of bowling technique, requires skill and does not afford the user an inappropriate level of consistency, thus facilitating realistic recreational competition with non-disabled bowlers.

The user has multiple levels of control over the direction and spin of the ball. First, the athlete can determine how to approach the lane, or can choose to launch the ball from a stationary position. The user can determine the angle from which to launch the ball relative to the lane.
They can also decide on the height of the ramp, which will affect the speed of the ball, ranging from 12 ft/s to 13.8 ft/s. The direction of the spinning rails can also be controlled based on which way the user wants to “hook” the ball. Lastly, he or she can determine the speed of the spinning rails.

These options make the Rock n’ Bowler stimulating and challenging, giving the user ultimate control over the device and skill level.

**TECHNICAL DESCRIPTION**

Perhaps the most unique feature of the Rock n’ Bowler is the powered spinning rail system that can be used to add spin to the ball. As the ball rolls down the ramp, it comes in contact with two rails spinning in the same direction that “hook” the ball. An electric motor from a cordless power drill is used to drive the rails because it allows the user to easily control the speed and direction of the rails in order to change the “hook” on the ball. Either hand can be used to operate the controls. The user also has a spring assisted trigger mechanism that reduces the force required when the user chooses to release the ball. A safety mechanism prevents the ball from rolling down the ramp prematurely and a rail at the top prevents the ball from falling onto the user. Safety rails near the spinning rails also prevent the ball from jumping off the track.

The design uses a ramp to give the ball speed. Hook is achieved by imparting a spin on the ball transverse to the main rolling direction. This transverse spin is obtained by the ball rolling along a rotating rail after it travels down the ramp and before it enters the lane. The rotation of the rail is achieved through the use of battery powered electric motor. The control of the speed is set by the user.

The Rock n’ Bowler is designed to be practical and easy to transport. The base detaches from the main ramp and the two pieces fold together and interlock, making it compact and maneuverable similar to a dolly.

The total cost to produce the prototype is $865.33.
THE UNIVERSAL PLAY FRAME ATTACHMENT: BASEBALL

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INTRODUCTION
The goal of the Baseball project is to create an attachment for the Universal Play Frame (UPF Mk. V) that allows athletes with partial quadriplegia to play T-Ball. The athlete loads a spring on the UPF Slugger device (Fig. 7.10) by cranking a lever arm, and then activates the bat with a release mechanism on the end of the arm.

SUMMARY OF IMPACT
The "UPF Slugger" baseball attachment (Fig. 7.10) has been one of the most popular UPF attachments in the local Special Olympic programs. Participants like the fact that the Slugger uses a real baseball bat to provide a true batting experience. The design requires the user to be actively involved by using a ratcheting system to crank back the bat to a desired location before releasing it to hit the ball placed on the tee. The loaded spring provides a dynamic swing once released to send the ball approximately 90 feet (as determined during testing). The device provides the athlete with control over ball placement within a range of 180 degrees depending on how far back the bat is cranked. Participants can elect to bunt by not cranking the bat back for a full swing. Baseball is America’s game and is particularly exciting for those of our clients, who are baseball fans, but have never been able to swing a bat and then race down to first base. The slugger is used weekly throughout the school year by between 5 and 10 clients.

TECHNICAL DESCRIPTION
For the control and operation of the attachment, the most challenging engineering requirements are that the attachment must be operable with a minimum of 5 lb. hand force and within a 12 inch box of hand movement. These impact both the system which allows the athlete to load the device (via a ratcheting arm) and the release mechanism. Since the athlete’s ability to control the distance the ball travels requires the use a ratcheting arm, both requirements drive the design of the ratcheting arm’s length and
its constrained range of motion. The release mechanism is operable with minimal hand force while fitting into a compact area with the ratchet arm to meet the hand movement requirement. The selection of the spring, that bares the load of the ratcheting arm, is governed by the minimum and maximum travel distance specified in the requirements.

The main performance requirements are that the ball flight distance must span a range of 5 ft. to 60 ft. and that its angle must vary between +/- 30 degrees. Additionally, similar control inputs should result in consistent ball travel angles (+/- 10 degrees) and distances (+/- 20%). By using an independent tee separate from the attachment, the athlete is able to align his or her wheelchair with respect to the tee. This also provides an unconstrained ball travel angle. Fig. 7.12 shows the team conducting performance tests of the UPF Slugger.

Finally, the safety requirements, that no moving part of the T-Ball attachment (excluding controls) will be within 8 inches of the athlete’s body and that all parts (excluding the bat) must remain below the athlete’s neck level, are addressed in the design. The use of a long ratchet arm and a release mechanism with a connecting wire effectively distances the controls from the base of the attachment. This allows a sufficient gap to be maintained between the athlete and any moving parts.

The cost of materials and supplies to produce the UPF Slugger is $458.73.

Fig. 7.12. UPF Slugger baseball attachment.
THE UNIVERSAL PLAY FRAME ATTACHMENT: 
SOCcer

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INTRODUCTION
The soccer attachment for the UPF Mk. V allows users with partial quadriplegia to play soccer in the least restrictive environment. Athletes using this device are required to raise and lower a handle that is mechanically connected to a spring loaded bumper (Fig. 7.13) via a cable and ratchet wheel. The athlete aims the soccer ball in the desired direction and pulls a release lever to propel the bumper forward. The soccer attachment is designed to give the user control, exercise and the ability to play soccer from a wheelchair.

SUMMARY OF IMPACT
Soccer is the most popular game in the world and it is little surprise that Power Soccer is becoming increasingly popular amongst people with paraplegia. This indoor version of soccer retains many of the full game's elements in a form appropriate for people with paraplegia. As an attachment to the Universal Play Frame (UPF), which is intended for use by people with fairly extensive levels of quadriplegia, this modification facilitates participation in Power Soccer. Early soccer attachments for the UPF were basically just a lever arm, which greatly restricted the force with which people could strike the ball. With the new design, athletes must provide a small level of force to load up the springs. They can dribble the ball much easier due to the design of the carbon fiber bumper, and can shoot the ball straight or at 45 degree angles. When fully loaded, the springs return enough energy to easily shoot the ball 100 feet down the court.

TECHNICAL DESCRIPTION
The prototype includes a U-shaped bumper actuated with springs as seen in Fig. 7.14. The springs are loaded by the user who cranks the handle in a vertical motion. As the athlete continues to crank the handle, a ratcheting mechanism winds the cable that continually loads the springs. Once the user has loaded the springs to the desired level, the bumper can be unloaded by pushing the release lever away from the user. The soccer attachment connects to the UPF in six places; four attachments are at the top of the UPF under the ratchet and two more are on the legs of the UPF.

With this design the user grips the handle and cranks it approximately five times to fully load the springs. Then when the user is ready to “kick” the soccer ball, the release lever is pushed forward. These inputs require the use of multiple muscle groups making the workout for the athlete more complete. This design is durable, feasible, and fun for the user. All parts are designed conservatively to ensure that the attachment will not break. The safety of the user was held paramount in the development of this prototype.

The overall cost of the design is $983.68.
Fig. 7.14. Computer model of the soccer attachment for the UPF Mk. V.
RAPD POWER SOCCER

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INTRODUCTION
The RAPD Power Soccer attachment (Fig. 7.16) is designed for people who participate in the Special Olympics sport of Power Soccer. It is a highly adjustable wheelchair guard that attaches to power wheelchairs. The guard is used to push and steer the ball, as well as protect a player’s legs during collisions. In a five mile per hour collision, it is estimated that the guard will deflect less than three-quarters of an inch with no permanent damage to the guard. It can also be universally attached to any wheelchair with one inch diameter tubing.

SUMMARY OF IMPACT
The adjustability necessary to allow the device to be used on nearly all of the power wheelchairs utilized by the players of the San Luis Obispo County power soccer team is achieved in this design. The cost of this guard is much lower than all products currently on the market. In addition, the guard is aesthetically pleasing and offers the players of the power soccer team with the necessary strength and durability required to keep them safe during a collision.

Fig. 7.15. Computer model of the Power Soccer attachment.
TECHNICAL DESCRIPTION
The ability to minimize the weight on any product being designed to operate on a battery powered chair is extremely important. Other similar metal guards are very costly, ranging from $200 to $600. Key factors of this design include low cost, quick installation time and high range of adjustability. The final critical requirement for the project is user safety.

The prototype (Fig. 7.16) was tested using a hydraulic press. The Power Soccer guard was loaded evenly across its front with a piece of wood. A digital scale measured the load, in pounds-force, while a dial indicator measured the deflection at the front of the guard, in thousandths of an inch. An angle gauge was used to measure the twist in the mounts, if any. Multiple loading conditions were examined, including a worst case scenario of loading on the bottom bar only. Data were taken from the even load distribution condition up to 450lbf to get an approximate stiffness. These data were compared to the predicted stiffness and resulted in a 23% difference between the experimental and theoretical stiffness of the guard. The difference can be attributed to the fact that in the telescoping regions of the guard, there are two nested tubes, both of which are experiencing bending during testing. This is equivalent to having a tube with a greater wall thickness than accounted for in the calculations.

The material cost to produce the prototype is $138.33.

Fig. 7.16. The prototype Power Soccer attachment.
INTRODUCTION
The Adjustable Sit Ski project began when Jon Kreamelmeyer, Coach of the US Paralympic Ski Team (now called the US Adaptive Ski Team), contacted Dr. Brian Self (P.I.) about the possibility of developing a modular sit ski. A modular design would improve upon existing sit skis by helping athletes adjust the ski to their optimal body position for maximum power output as well as potentially increasing access to the sport by recreational skiers. The modular design ensures rental shops will have appropriate equipment on hand for those athletes desiring Nordic (cross country) sit skiing.

Cross Country skiing is a relatively new addition to the Winter Paralympic Games and not widely available as a recreational activity. People with complete or partial paraplegia are able to participate in the sport through the use of a sit ski (Fig. 1.17) similar to what was initially developed for use in downhill skiing. It is hypothesized that for cross-country sit skiing a kneeling position, as opposed to the usual sitting position, would improve the power output of some participants during poling.

Fig. 7.17. The Adjustable Sit Ski
SUMMARY OF IMPACT
The sit ski prototype implements a successful design that has the ability to adjust seat angle, seat height, seat width, and foot rest positions, thereby providing a broad range of positions for the skier. No current sit ski on the market has a comparable range of adjustment; hence the current design has significantly increased accessibility in the area of cross-country skiing. In January 2009, Jon Kreamelmeyer brought the Sit Ski to various venues to recruit more athletes into cross country skiing. Using Jon’s input and comments from the athletes, a second adjustable sit ski, which he can use on recruitment trips next season, is in development.

TECHNICAL DESCRIPTION
The main goal is to design a light, strong, durable, comfortable, functional sit ski that fits 5th percentile females up to 95th percentile males. The seat height, angle, and leg positions are all adjustable to an optimum position for the rider (Fig. 17.18).

Due to the fact that many sit skis are individually assembled for one specific athlete there is widespread variation in existing designs. The positioning of the rider is a critical consideration in cross-country sit skiing and there is great potential for optimization of both comfort and power through the ability to vary the position of the rider in the sit ski. With the goal of making cross-country skiing more accessible, the project team also aims to develop a sit ski that may be used globally at ski resorts.

Fig. 7.18. Side View of the Adjustable Sit Ski showing possible seating positions.

There are three main components to the design: a four pillar telescoping tubular aluminum 6063 frame, a split carbon fiber seat, and a four-bar tubular aluminum 6063 detachable front foot rest. Each component was structurally analyzed and all components meet conservative assessment calculations in the areas of stress, fatigue, and deflection.

The cost to produce the prototype is $1114.43 in materials.
INTRODUCTION
The Foam Wars (FW) project consists of designing and fabricating a durable and maneuverable play frame. The FW frame (Fig. 17.19) is intended to incorporate any kind of wheelchair – electric or manual, with an attached launching device capable of shooting foam balls at a moderate speed at non-human targets on top of an opposing frame. The game is monitored by RFID tagging for easy and accurate scoring, and an automated feedback system incorporates sounds and visuals for an exciting game-time environment. This project consists of the fabrication of two separate FW frames with the safety of the user as our main priority.

SUMMARY OF IMPACT
For people with disabilities, opportunities to participate in active games result in feelings of empowerment and independence. This is rarely accomplished in a team game where people with physical disabilities compete alongside people without physical disabilities. Foam Wars is a team game designed to be fully inclusive so that people with a wide range of physical disabilities can play and experience empowerment and independence. The first official game of "Foam Wars" was played at a wheelchair sports camp hosted by the University of California Santa Barbara in July 2009. The carts and the game were an enormous success, with the athletes cueing up to get into the carts. Based on the initial use of the equipment, the game itself is a resounding success. For people with quadriplegia there is simply no other game to rival the thrill of Foam Wars.

TECHNICAL DESCRIPTION
The bottom half of the FW frame is made of aluminum tubing (Fig. 17.20), while the top half is made from PVC tubing. The aluminum frame is TIG welded together and the top PVC piping is glued together with PVC glue and press-fitted onto six 3” aluminum stems. Welded onto the sides of the bottom aluminum frame are four lathed 2.5” long aluminum side stems that permit the side attachment to be slipped on and pinned into place with four 3/10” pins. The side attachment holds the ball launcher and the lead screw that controls the aiming angle of the launcher. At the bottom of the entire play frame, six 0.75” length aluminum stems, with 1” diameter, are welded on and threaded in order to attach six soft-rubber casters.

The bottom portion of the frame is covered with nylon mesh and the top portion is covered with nylon netting. This netting is attached all around the frame with elastic cords through manually made
grommets on the mesh, or through the netting in general. The target on top of the frame is called the Box of Joy and is made of 1” diameter PVC tubing. It contains fish weights that hang from metal chains. This helps stop any balls that land inside the target from rolling back out. Theme-colored felt surrounds the rectangular cube and aids in slowing down the ball once it enters. The bottom of the box is a plastic plate that slopes down towards the loading tube leading back to the play frame’s ball launcher.

The ball launcher is cut and modified to insert the one shot mechanism that was designed to permit only one ball to be launched with the push of the momentary switch on the universal controller. The universal controller consists of a momentary switch to activate the one shot mechanism, and a momentary toggle switch to activate the motor of the aimer and adjust the angle of the ball launcher.

All electrical components of the play frame are powered by a 12V battery that is housed at the bottom of the side aluminum attachment in an 8” x 3.5” x 3” aluminum bay. The electrical wiring from the battery runs through the aluminum tubing and connects to wiring of other electrical components via male and female quick connectors. The RFID scoring system consists of a Parallax RFID reader that is placed on the top of the loading tube, right under the Box of Joy, leading from the target to the ball launcher. Cyntag RFID tags are placed inside the Penn practice foam tennis balls. When the balls pass the RFID reader, the Bluetooth transceiver sends the signal to the laptop gaming program.

For aesthetic purposes, one cart is painted black with red flames and named “The Demon.” The second is painted blue with white stripes and named “The Saint.”

The total cost for the two foam war frames is $3,278.00.
SOLOQUAD KAYAK CONVERSION PROJECT

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INTRODUCTION
The SoloQuad Conversion Project (Fig. 7.21) is an ongoing project that has been significantly enhanced through inclusion in the RAPD grant. The SoloQuad Conversion Project started in 2003 with the award of a “Quality of Life Grant” from the Christopher and Dana Reeve Foundation and was the first collaboration between Kinesiology and Engineering to focus on student design projects to facilitate participation in recreation. The project goal is to give independent control over a kayak to someone with high-level quadriplegia. This is achieved by adding an electric motor to the kayak that provides control over the motor using a joystick to pilot the craft. It has since undergone a number of prototypes and design revisions on the stability, seating, and control subsystems. Ultimately the SoloQuad Conversion Project is utilized by the Cal Poly Adapted Paddling Program to provide kayaking opportunities for local community members with quadriplegia.

Fig. 7.21. The SoloQuad Kayak is controlled (forward and backward speed, left and right steering) by the kayaker using a sip-and-puff device.
SUMMARY OF IMPACT
A fundamental principle of adaptation for people with disabilities is to adapt for congruence, meaning the adaptation should blend in as much as possible with the original equipment. Additionally, the SoloQuad kayak is designed to be ability-appropriate, meaning that there are input devices (e.g., a joystick and a sip-n-puff controller) to match various levels of ability. On May 16, 2008, the SoloQuad Conversion Project completed its maiden voyage. The pilot (Fig. 7.22), a Cal Poly alumnus with high-level quadriplegia, was able to navigate the waters of Morro Bay for the first time in 25 years and described the experience as breathtaking.

TECHNICAL DESCRIPTION
The main focus of this stage of the SoloQuad Conversion Project is to redesign the subsystem that controls the motor and to provide multiple user input devices for people with different abilities.

The motor control system consists of an input device, an I/O board to monitor the device input, and a controller board that converts the device input to signals that are sent to the trolling motor. Infrared sensors are located on the motor shaft to provide feedback of the motor position to the controller board.

The project costs for the control subsystem are $425.

Fig. 7.22. The SoloQuad pilot, someone with high-level quadriplegia, kayaks around Morro Bay, California.
INTRODUCTION
Presently there are few opportunities for people with disabilities to participate in physical or recreational activities, especially in water sports. Previous attempts to create adapted water crafts, such as an adapted kayak for individuals with mobility impairment, failed because the control system on the kayak did not meet customer requirements for performance and durability. The scope of this project includes a major redesign of the motor control system for the SoloQuad Conversion project kayak.

SUMMARY OF IMPACT
The objective of this project is to improve performance and durability of the control system of the Solo-Quad Adaptive Kayak (Fig. 7.23). The control system is modularized, allowing an individual with limited technical knowledge the ability to maintain and replace parts. The system is more rugged, being able to withstand the conditions of a turbulent marine environment, such as salt water, wind, and varying weather conditions. The system is more accurate than previous versions by allowing users to have finer control in steering with various ability-specific control devices.

TECHNICAL DESCRIPTION
The main board is the center of the kayak control system (Fig. 7.24). It takes the control signals from the daughter board and uses them to set the direction and speed of the trolling motor. In addition, feedback of the motor from the motor control/feedback module is used to adjust motor speed and direction. This board is also responsible for power regulation and distribution to other functional modules. Inputs include the 12V power from the car battery, the motor feedback from the motor control/feedback module, the control signal from the daughter board, and the reset and power buttons. Outputs include 5V power to the daughter board and motor control/feedback modules, directional control and PWM output voltage to the motor, and status to the user.

The daughter board takes the signal from the assistive device (joystick, Sip ‘n’ Puff, or chin joystick) and converts it to the game port protocol used by the microcontroller on the main board. Its inputs are 5V power distributed from the main board and the assistive device signal. The output is the converted control signal from the assistive device to the main board via the universal controller port. There is a daughter board for each assistive device which doesn’t follow the protocol of the 15-pin game port. For example, the joystick can be connected directly to the main board while the Sip ‘n’ Puff device requires a daughter board.

The motor control/feedback module detects the current location of the motor shaft and speed of the motor, which it sends back to the main board. The motor is not part of the module, but rather the motor control/feedback module detects the direction of the motor. Speed and direction is adjusted by the direction control signal and PWM output voltage.
from the main board. The motor control/feedback module merely detects the position and speed of the motor and relays the information back to the main board. Input is 5V power from the main board and output is the feedback signal to the main board. The cost of materials and supplies is $986.37.

Fig. 7.24. The new printed circuit board (PCB) versions of the Motor Control and I/O Boards include some design modifications.
100 NSF 2009 Engineering Senior Design Projects to Aid Persons with Disabilities
CHAPTER 8
DUKE UNIVERSITY

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INTRODUCTION
Our client, a five-year old girl with Rett syndrome, cannot communicate verbally and has decreased motor coordination of her arms and limbs, resulting in limited interaction with her peers. To promote socialization, we developed a device that allows her to roll a ball to a classmate at the push of a button, as well as catch it when rolled back. A push-action solenoid in conjunction with a lever rolls the ball, while a ramp system catches the ball and holds it in place. With this device, our client can roll a ball back and forth with a classmate.

SUMMARY OF IMPACT
The device helps our client interact socially with her peers. She is currently mentally aware of her surroundings and the events around her, such as when a ball is rolled towards her, but because of her disability she is not able to respond. The Ball Roller and Catcher helps breach that barrier. As our supervisor remarks, “[she] will love playing with the device... [she] will benefit tremendously from playing with other students.”

TECHNICAL DESCRIPTION
The Ball Roller and Catcher (Fig. 8.1) case is made of ¼” thick acrylic. The side, rear and bottom panels attach to each other using acrylic cement. The front panel is hinged to a downward sloping ramp located inside the device and opens to double as the front ramp, which slopes in the opposite direction from the inner ramp.

Two sheets of acrylic are cemented to the inner ramp in the shape of the letter ‘V’, directing the ball into the correct position and then holding it in place in front of the rolling mechanism. The rolling mechanism consists of a push-action solenoid acting upon a lever to propel the ball out of the box. The lever is constructed from a 3” long, ½” diameter dowel rod. It is attached to the acrylic support structure, which is also cemented to the back ramp. The solenoid is suspended above one end of the lever and fastened to the rear panel. When the switch is pushed, the solenoid activates, pushes the lever, and propels the ball forward.

An infrared LED and matching phototransistor pair are mounted on the inner ramp, beneath where the ball rests when “caught”. When the ball rolls into this position, it activates a series of LEDs located on the V-shaped holder, illuminating the interior of the device.

A rechargeable 12V DC battery pack powers the circuitry. Both battery and recharger are located in compartments behind the V-shaped holder. The recharging cable plugs into a port on the rear of the device. The top panel of the Ball Roller and Catcher attaches with four screws, making it easy to remove to replace the battery.

Also located on the rear of the device are a power switch and a 1/8” jack for the actuating switch. A red LED next to the power switch indicates when the battery requires recharging, illuminating only when the battery voltage exceeds 10V. The total cost for parts for the device is approximately $400.
Fig. 8.1. Ball Roller and Catcher, with ball in “caught” position.

Fig. 8.2. Ball rolling into device.
INTRODUCTION
Our client is an independent, athletic woman who enjoys cycling. However, she is unable to ride a bicycle because of limited left knee flexion due to a car accident. The Pivoting Crank Arm allows her to cycle again. The device consists of a modified crank arm with a pivot joint. By allowing the pedal to drop to a lower height at the peak of the pedal motion, the pivot decreases the degree of knee flexion required for pedaling. The device was optimized for the individual client’s capabilities, but it can be adjusted for individuals with different degrees of knee flexion.

SUMMARY OF IMPACT
Prior to her accident, our client biked 25 to 35 miles every weekend. After the accident, she started swimming, but she “very much missed the physical activity in the open air that [she] got with cycling on country roads.” After using the device, she commented, “Thank you all very much for enabling me to bike again. I have been waiting for this moment for six years! It’s so exhilarating!”

TECHNICAL DESCRIPTION
The Pivoting Crank Arm (Fig. 8.3) is comprised of a shortened mountain bike crank arm, an aluminum bar used in an overlapping fashion as a pivot, and a shoulder screw with associated bearing.

The crank arm is cut at a location designed to maximize the client’s power generation with each pedal stroke while still adhering to her range of motion. The outer section of the crank arm, containing the pedal, is 78 mm long, while the inner section, attached to the axle, is 127 mm long. These dimensions were determined after testing an adjustable version of the device with the client to establish her maximum amount of flexion within a comfortable range of motion, while keeping the total length from axle to pedal at the standard 170mm.

The aluminum bar attaches to the outer crank arm portion with four ¼”-20 machine screws. The pivoting sections attach together with a shoulder screw, which rides in a sealed ball bearing in the aluminum bar to minimize rotational friction. After passing through the bearing, the shoulder screw threads into the inner portion of the crank arm. This threaded connection is secured with thread-lock compound as well as a set screw. A slight gap between the overlapping portions of the crank arm and aluminum bar accommodates a delrin washer to facilitate smooth rotation.

Figure 8.4 shows a picture of the client riding her modified bike. The replacement cost for the pivoting crank arm is about $90.
Fig. 8.4. Client using the Pivoting Crank Arm.
CAMERA SUPPORTS FOR A BOY WITH LIMITED REACH

Designers: Alex Li, Christal Choe and Irem Mertol
Supervising Professor: Larry Bohs
Department of Biomedical Engineering
Duke University
Durham, NC 27708

INTRODUCTION
Two camera supports were developed to allow our client, a ten year-old boy with TAR syndrome, to take pictures while using his powered wheelchair or ambulating. Since he has limited arm reach, the devices enable him to use a tripod and microphone boom system to easily position a camera both horizontally and vertically, while taking pictures with a remote. Both devices are unobtrusive and easily detachable so the client can take the devices wherever he goes.

SUMMARY OF IMPACT
The Camera Supports allow the client to take pictures easily and independently. The client’s mother commented, “This device gives him a sense of independence, which is fantastic.” About pictures he took at Disneyworld and the Duke Gardens, the client said, “I like being able to be like the adults who are taking pictures. It made me feel like I was a professional photographer. I think my pictures were better than some of the ones my parents and grandparents took.”

TECHNICAL DESCRIPTION
The camera wheelchair support (Fig. 8.5, left) includes a base made of ½” black high-density polyethylene (HDPE). Two knob screws firmly secure the base on top of the left armrest of the client’s wheelchair. A commercial microphone boom threads into the front, center portion of the base. A 3/8” threaded rod, bent at a 90° angle, attaches the end of the microphone boom. A ¼-20 threaded rod is threaded into the top of the 3/8” rod, providing the proper attachment for a commercial tripod head. The threaded rods are secured with thread lock compound.

A custom camera case provides a robust attachment for an aluminum lever, which the client uses to point the camera. This camera case, built for the Pentax T10 camera, consists of six pieces of 3/8” thick Delrin. The back of the camera case includes a rectangular cutout portion (3.5” x 1.75”) for the LCD display screen as well a cutout (0.375” x 0.5”) for two buttons to change the mode of the camera. The front of the camera case includes a 2” diameter circular cutout for the lens. The front piece also includes a 2.625” x 0.625” rectangular cut-out in the upper left corner for flash and remote sensor access. The bottom piece includes a ¼-20 Helicoil that threads onto the tripod head, and a cutout to allow easy access to the battery and memory card compartment. A 2.5” x 1” rectangular HDPE piece with a 0.5” hole in the center is screwed into the side of the camera case. The aluminum lever fits into the HDPE hole and is secured with a 10-32 thumbscrew. The lever is 15” long with black tennis grip and a racquetball on the end added for comfort. The inside of the camera case is lined with foam padding to hold the camera securely and reduce vibration.

The camera belt support (Fig. 8.5., right panel) is constructed from a back-support belt (McGuire-Nicholas), which fits the client comfortably. A sheath pocket (Fiskars) is used as a holder for the microphone boom. This pocket attaches to the support belt at any desired location using the clip on its rear side. The microphone boom is sewn tightly
into the Sheath Pocket. To provide additional support for the microphone boom, a rifle sling (Yukon) attaches to the vertical portion of the boom using a bike helmet buckle. This arrangement allows the neck strap to easily detach from the boom. A ¼" threaded rod is attached to the end of the microphone boom and bent 90° to screw into the bottom of the camera case.

Because the sensor for the remote is located on the front of the camera, while the client uses the remote from the rear, a mirror is attached to the camera case to reflect the signal. A string attached to the remote prevents the client from misplacing or dropping the remote. In addition, a pointer is affixed to the string to help the client press camera buttons. The Pentax T10 camera was chosen for its large touch-screen display and its ability to operate remotely. Cost of parts for the camera wheelchair support is approximately $325 and cost of parts for the camera belt support is approximately $300.

Fig. 8.6. Client using camera wheelchair support (left) and belt support (right).
MOBILE CLEANING STATION

Designers: Laura Angle, Rae Luan, and Sylvia Qu
Client Coordinator: Janet Hoele
Supervising Professor: Larry Bohs
Department of Biomedical Engineering
Duke University
Durham, NC 27708

INTRODUCTION
Our five-year-old client loves to clean the house, but this task is difficult because he has cerebral palsy and uses a walker to ambulate. We built the Mobile Cleaning Station to help him clean independently while standing upright. This wooden cart holds cleaning equipment and doubles as a stable anterior walker. It moves forward only when hand-brakes are released, giving the user full control over mobility. The Mobile Cleaning Station is durable, portable, and easy to store. Using the station, our client can clean around the house by himself, as well as strengthen his hips and mid-trunk through standing and walking.

SUMMARY OF IMPACT
The Mobile Cleaning Station allows our client to perform cleaning activities independently while in an upright position. The client’s mother noted, “This is the next developmental stage for [him]. You want him weight bearing and walking, not just standing. [The Mobile Cleaning Station] allows him to strengthen himself that way.” The client himself was extremely pleased with the device and described it as “very good.”

TECHNICAL DESCRIPTION
The Mobile Cleaning Station (Fig. 8.7) includes a wooden base with two 2” diameter swivel casters in front. The cart base is constructed from ¾” and ½” thick plywood secured using wood glue. The middle 5” diameter wheels are attached to the base using a threaded rod secured with three copper straps. Aluminum blocks in the back corners of the base anchor the attachments for the removable side support rails. These rails are made of ¾” galvanized steel conduit piping and add stability to the cart, preventing tipping forwards and backwards. Swivel casters are attached to the end of the side support rails. Each side support is attached to the main cart body by sliding over a vertical aluminum rod, which is secured in the aluminum block. Two spring plungers on each vertical rod fasten the side supports in place. The side supports can be easily installed and removed by depressing the spring plungers. The aluminum blocks also anchor the sides, back, and bottom of the base, which are bolted into the blocks.

Fig. 8.7. Mobile Cleaning Station.
The vertical supports for the handlebars are made of \( \frac{3}{4} \)" by 2\( \frac{1}{2} \)" hardwood, while the handlebar is a 22" long piece of 7/8" diameter aluminum tubing, with handgrips attached on either side. The handlebar is height-adjustable through a range of four inches. Each vertical support consists of two pieces of hardwood secured together by knob screws tightened into threaded inserts. Loosening the knob screws allows the handlebars to be raised or lowered.

The base accommodates a sweeper vacuum as well as a child-sized mop and broom. An upper wooden basket is made of ½" plywood and intended for storage of smaller items such as a duster. Three metal spring clamps along the front side of the basket hold the handles of the vacuum, mop, and broom in an organized fashion.

Brakes on the middle wheels allow the user to control the mobility of the cart. The brake parts are modified from walker brakes, and include a brake pad and spring. The brake pads are controlled by one brake lever on the left side of the handlebar. When the brake lever is not depressed, the brake pads are applied, making the cart difficult to push. Depressing the brake lever raises both brake pads, allowing the cart to move.

Padding on the back of the basket and handgrips on the side support rails increase user comfort. Corner bumpers on the front of the cart make the station safe for furniture. Red accents throughout the device – basket, middle wheels, and hand grips – make the Mobile Cleaning Station more attractive to young users. Fig. 8.8 shows the client using the sweeper vacuum. The cost of all components of the device is approximately $350.
WHEELCHAIR SHOPPING AID

Designers: Geoffrey Yih, Madison Li and Jason Kim
Supervising Professor: Larry Bohs
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INTRODUCTION
Individuals in manual wheelchairs often have trouble grocery shopping because they find it difficult to move a shopping cart while wheeling their chairs. The goal of this project was to develop an easily attachable shopping aid that provides a stable location for groceries. The shopping aid resembles a hand-held shopping basket that is stably fixed to the front of the wheelchair. The Wheelchair Shopping Aid quickly attaches to the wheelchair’s frame and the detachable grocery basket folds for compact storage. The device gives the shopper easy access to groceries while allowing them to simultaneously operate their wheelchair.

SUMMARY OF IMPACT
The Wheelchair Shopping Aid enables our client to shop freely and ergonomically. Since he is an active, independent individual, this device will give him a shopping method that allows him the same level of independence he has when completing other common tasks. The client says, “This shopping aid will allow me to shop much more efficiently, quickly and with less frustration than the typical shopping experience of a wheelchair user. This is a great step toward greater independence.”

TECHNICAL DESCRIPTION
The Wheelchair Shopping Aid (Fig. 8.9) includes a shopping basket, a basket tray, and two frame clamps. The collapsible basket is a commercially available product from Garnet Hill. It has a sturdy, lightweight aluminum frame and a rubber-cushioned handle that makes it ideal for grocery shopping. The basket material is durable polyester, which is held to the frame with Velcro straps. The Velcro straps also wrap around the handles of a commercial, wire-mesh shower tote (not shown), which allow the tote to attach inside the basket as a compartment to hold fruits and other delicate groceries. The collapsible basket folds flat for compact storage once the plastic side stabilizers are removed.

The rectangular basket tray is constructed from ½” thick high-density polyethylene. Five 0.8” diameter holes are drilled into the tray, which serve as receptacles for the plastic pegs on the bottom of the collapsible basket. The peg holes prevent the shopping basket from sliding off the surface. For added stability, two Velcro strips sewn to the bottom of the basket attach to mating strips on the tray to prevent the basket from tipping. Two steel T-hinges are attached to the bottom of the basket tray. Screwed onto the long arm of these hinges are ½” diameter aluminum support rods, which insert into frame clamps. The hinges allow the support rods to fold up for compact storage.

The aluminum frame clamps consist of two components that tighten around the wheelchair frame using two brass knob screws. Vertical holes in the clamps with diameters of ½” provide mounting
locations for the support rods. Figure 8.10 shows the client using the device. The replacement cost for the device is approximately $130.

Fig. 8.10. Client using the Wheelchair Shopping Aid.
INTRODUCTION
Our client, a 20-year old male with cerebral palsy, wanted to exercise his legs to gain strength as well as to enhance his cardiovascular fitness. Because no commercial devices met his needs, the Custom Workout Station was designed. The device sits on the floor in front of the client’s wheelchair, and has two pedals to which his feet attach. The resistance for each pedal can be adjusted independently by applying free weights of different values. The client exercises his quadriceps by pushing his legs downward, which lifts the weights vertically using tension cables and pulleys.

SUMMARY OF IMPACT
The Custom Workout Station helps promote quadriceps strength, improves cardiovascular fitness, and deters muscular atrophy. The device is currently being used regularly. According to our client’s mother, “the device does exactly what [our PT] and I wanted and envisioned; he is really working his quads which he could never do before.”

TECHNICAL DESCRIPTION
The Custom Workout Station (Fig. 8.11) is comprised of a base, two slider towers, two lever arms, two pulley platforms, two weight platforms, two cycling pedals and two tension cords and pulleys. The 18”x24” base is constructed of blue ½” thick Ultra High Molecular Weight Polyethylene (UHMW-PE) with routed edges. A rubber mat attached with Velcro to the bottom of the base prevents the device from slipping while in use. Two metal handles on the base allow for easy transport.

The two slider towers are made of white UHMW-PE blocks, 2”x1”x 18” long. Three white 4”-long support blocks help stabilize the towers: one block between the towers, and one on the front of each tower.
The aluminum weight platforms each hold a 6” long, 1” diameter aluminum post, onto which the weights are placed. Foam padding on the platforms reduces noise and vibration as the weights are raised and lowered. Figure 8.12 shows the client using the custom workout station. The cost of the components for the device is approximately $400.

![Client using the Custom Workout Station.]
CREATIVE PLAY STATION: ASSISTED IMAGINATIVE PLAY FOR CHILDREN WITH HYPOTONIA

Client Coordinators: Lynn Carswell, SLP  
Designers: Weixin Lin, Whitney Stewart, Lin Yang  
Supervising Professor: Kevin Caves and Richard Goldberg  
Department of Biomedical Engineering  
Duke University  
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INTRODUCTION
Our client is a bright two year old boy with an active imagination. He has an undiagnosed metabolic condition, leading to severe hypotonia. As a result, he lacks the ability to pick up or maneuver toys. He loves to pretend play with stuffed animals or other toy figures, but currently can only do this with the assistance of a parent or therapist.

The goal of our project is to develop a creative play station where the client can engage with animals or people in common daily activities. The device is designed for independent use and basic interaction. It is designed around a “puppy theme”, inspired by the strong relationship between our client and his pet beagle, Lulu. The play station offers our client three choices of activities with a stuffed animal dog that resembles Lulu: 1) feeding Lulu (a spoon moves up and down in front of a toy beagle’s mouth); 2) grooming Lulu (a yellow brush moves in circular motion to “groom” the toy beagle); and 3) Lulu watching a squirrel at play (a toy squirrel moves in a circular motion around a “tree” in front of the toy beagle). The device has bright colors and provides audio feedback to motivate active participation. Our client can use the device while seating in his “Kid Kart” chair. It is relatively small and lightweight so that an adult can easily put it away when it is not being used.

SUMMARY OF IMPACT
Once the client became comfortable with the Creative Play Station, he chose to engage with each of the three activities frequently. The play-station allows our client to think about and personally initiate the different scenarios provided by the device. This provides him with a fun and entertaining way to achieve important developmental milestones while providing more independence. Our clinical advisor, Lynn Carswell, SLP, told us “I believe many children with physical limitations, who presently have no opportunity to engage independently in imaginative play, would enjoy using this toy.” His mother added, “I think he loves this! I think it’s perfect!”

TECHNICAL DESCRIPTION
Motions of all three activities are controlled with the Lego Mindstorms NXT robotics kit, including a programmable controller, motors and gears. The client begins an activity by pressing one of the three commercial pushbuttons. This activates the corresponding motion from the Lego Mindstorms controller. In addition, the system starts playing an audio track, using a programmable uMP3 module (Rogue Robotics, Toronto ON). Each sound track consists of music and speech appropriate for the particular activity and it plays on two battery-
powered speakers. To further stimulate our client’s imagination, a free-standing acrylic trifold which features colorful outdoor and living room scenes is included in the device.

The device has three mono audio jacks, so that any commercial switches can be plugged in to activate the device. They are connected directly to the three input jacks on the Lego Mindstorms NXT controller. They are also connected directly to the uMP3 player to activate the corresponding songs. The controller outputs are connected directly to Lego servo motors, which operate the motions of each activity.

The software is written in LabView, using the LabView Toolkit for Lego Mindstorms, and stored in Flash memory in the Lego controller. The device is programmed so that a single press of the button starts the activity for a period of time. When that period is over, Josh must release and press the button again in order to restart the activity. The controller can run off a rechargeable battery or by an adapter connected wall power. The controller also powers the uMP3 player.

The play station is divided into an indoor section and an outdoor section which are partitioned using acrylic “walls”. The toy beagle, (elevated on a stand) surrounded by the feeding and the grooming stations, is located in the indoor section. The squirrel station is located in the outdoor section. The tree is made of a PVC pipe decorated with textured color paper. The play station is decorated with colored foam, textured paper and fabrics. The acrylic stand is collapsible for easy storage, and the pictures are laminated for durability. The mechanical and electronic components are located inside a large plastic enclosure to preserve them. The activities are mounted on top of the enclosure.

Total cost of the device is $685, including the full cost of the Lego Mindstorms robotics kit.

Fig. 8.14. The Lego gear mechanism is located inside an enclosure.
CUSTOM WORK TABLE

Client Coordinators: Angela Escalante  
Designers: Caitlin Fearing, Jordan Yoder, Aidan Burke  
Supervising Professor: Kevin Caves and Richard Goldberg  
Department of Biomedical Engineering  
Duke University  
Durham, NC 27708

INTRODUCTION
Our client is an adult male with quadriplegia. He spends most of his time in bed or in a manual wheelchair. Unless a nurse is present to assist him, he is not able to switch between activities he enjoys such as reading, watching TV, and using his computer. He does, however, have control of his head and neck and is skilled with both a mouth stick and sip-and-puff switch. We developed a custom worktable that can be placed in front of the client, and it enables him to switch between activities utilizing his mouthstick skills. We designed the table so that it is quick and easy to set up, as well as portable and height adjustable to allow for use when in bed or a chair. It uses a motorized lazy Susan to allow the client to independently switch between different activities. It is compact so that the client can reach everything with his mouthstick.

SUMMARY OF IMPACT
This custom work table will provide the client with increased independence. Through the use of this device he will be able to choose between reading a book, controlling the television remote, and using his computer at any time. The client commented, “It's really nice that I will always be able to reach my mouth stick and my sip-and-puff straw.”

TECHNICAL DESCRIPTION
The final design uses a donated hospital table as the base for the device. The table rolls on wheels and it is height adjustable so that it can be adjusted to fit the client’s bed or chair. Because the table is designed to roll up to a bed from the side, it includes a cantilever design with a support on one end. To prevent the table from bowing under the weight of the lazy-Susan, book, and computer, the table is reinforced with a solid wooden beam underneath.

For the lazy Susan, a 24” diameter circle of ¾” oak is mounted onto lazy-Susan bearings, which are mounted on top of the table. In addition, a 1.5” diameter hole is cut through the center of the oak and the table to allow wires from the computer to pass through. This also prevents tangling of the wires during rotation. The oak circle is stained to match the color of the hospital table.

The book stand consists of two wooden triangles that support the back of a commercial book holder and two wooden cubes that prevent the base from slipping forward without interfering with page
turning. The holder can be easily removed by simply leaning it forward and lifting up.

A commercial large-buttoned remote control is used to control the television, which can be accessed by the client with the use of his mouth stick. The remote control is Velcroed onto a raised stand on the table, in a location that is easy for our client to access.

The client accesses the different activities with a sip-and-puff straw and a mouth stick. A circular wooden tube holds the sip-and-puff straw. The tube has an adjustable screw that holds the straw in place. This is mounted onto the rotating lazy Susan. The mouth stick holder is made of a piece of PVC cut in half and capped at one end. The capped end is screwed to a flexible gooseneck device, which is reinforced with a second gooseneck for additional support. The goosenecks allow the mouth stick holder to always be available to the client. A button mount is fashioned around the lower half of the holder to allow the client easy access to the control buttons. These are mounted to the stationary part of the table so that they are always within reach.

A commercial motorized rotary tool is used to rotate the wheel. It is attached to a 4” diameter hard foam circle that pushes against the outer edge of the 24” lazy Susan. As the foam circle slowly rotates, it rotates the lazy Susan. The motor is attached to the back of the table along with the control circuit. The circuit consists of a voltage regulator and two relays. Power comes from a 12V DC wall transformer, which is fed to the regulator that drops the voltage to 1.86V. This is fed to the relay coils, which control the voltage polarity that goes to the rotary tool, allowing rotation in either direction. The circuit is controlled by two large, normally-open pushbuttons. When the user presses a button, it closes the corresponding relay, starting rotation of the table. Each button rotates the table in a different direction. The circuit also contains two normally-closed buttons that function as limit switches. They are positioned under the lazy Susan and when depressed by a wooden knob underneath the rotating oak circle, they become open circuits and stop rotation in one direction. This prevents the table from rotating more than 360 degrees in either direction, which would cause the wires to tangle.

Total cost of the device is $240.

Fig. 8.16. Client using his mouth-stick to rotate the lazy Susan.
SEW SIMPLE: THE “FOOT FREE” SEWING SOLUTION

Client Coordinators: Angela Escalante
Designers: Benjamin Barocas, Mary Ellen Koran, Mhoire Murphy
Supervising Professor: Kevin Caves and Richard Goldberg
Department of Biomedical Engineering
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INTRODUCTION:
Our client is a creative and intelligent ten-year-old girl with a desire to learn how to sew on a sewing machine. Due to a spinal cord injury, she has no mobility of her lower body and depends on her arms to balance and stabilize her upper body. As a result, she cannot use any standard sewing machines that are operated by a foot pedal. This project focuses on the design of an entire “sewing station”, complete with a hand-operated machine and modified craft table that will allow our client to sew independently. It has a table that allows for easy wheelchair access, and for sewing at an appropriate height while seated in her wheelchair. It permits her to maintain comfort and balance while using the sewing machine. It is height adjustable so that it can grow with her, and is also easy to store.

SUMMARY OF IMPACT:
Our client’s mother remarked, “I am so pleased with the conscientious design with its focus on growth and safety. I’m looking forward to [her] increased independence in operating the machine and accessing everything she needs for her ‘creations’.” When sitting at the workstation for the first time, our client had only three words for our design team: “This is great!”

TECHNICAL DESCRIPTION:
The final design is based around the Brother CS6100 sewing machine, which uses hand-controlled technology with buttons for power and speed control, rather than requiring the use of a foot pedal. The sewing action is controlled via a push button that is located directly above the needle, and a slider button to the right of the power button controls the speed of the needle which can range from very slow to very fast speeds. The machine is housed in a height adjustable sewing station complete with a hand crank mechanism to allow for multiple positions of the machine. The machine rests on a platform that can be moved up and down independently from the surrounding table. Auxiliary clip-on lighting, a detachable power strip, a bungee leg-securing system, Velcro pockets for storage, and free-standing sewing boxes for additional storage are included in the design.

For the height adjustability, the legs of a craft table are modified to decrease the height of the table from 28.5” to 26.5” by removing a two inch section from each leg. An insert is machined from solid, square aluminum bars that fit inside the tubes that make the legs of the table. ¼-20 screw holes are tapped into the block to allow for up to 2.25 inches of height to be added back in ¾ inch increments. This allows our client to fit perfectly under the table, thereby reducing fatigue in her arms, back, and neck. It is also the mechanism by which the table can be adjusted as she grows.

A custom Plexiglas template is fabricated from ¼ inch Plexiglas using a laser cutter. When placed...
around the machine in its lowered position, it provides a continuous workspace between the sewing machine work surface and the surrounding table, and it reduces the risk of dropping fabric or needles to the floor. Slim hexagonal screws are inserted periodically around the perimeter of the inset and provide ledges for stabilizing the insert while in use. The design also includes a laser etch of the client’s name.

The cost of the device is $325, excluding the cost of the sewing machine.

Fig. 8.18. The client working on her first sewing project
INTRODUCTION
Persons with spinal cord injuries and other disabilities are not able to play golf without the aid of a supportive device. Currently, commercial “single rider carts” are available, which provide support to the golfer. However, these are expensive and not always necessary for activities like practicing at a driving range. We developed a supportive golf chair that enables persons with disabilities to play golf at a driving range. The golfer sits on our chair, which provides additional support with belts at the waist and chest. The golfer can independently adjust the height of the chair using a hand-operated hydraulic pump. The device has attached wheels for mobility, and is stable.

SUMMARY OF IMPACT
In testing with several clients with a variety of disabilities, each of them felt the golf chair was safe and effective. One individual with two lower limb amputations stated, “It works great and I felt very comfortable in it.”

TECHNICAL DESCRIPTION
The basis for the design is a commercially available salon chair. Existing models of this type have a hydraulic pump which is normally controlled with a foot pedal. Since hand control is necessary for golfers who are amputees or don’t have full strength in their legs, the foot pedal is replaced with longer lever arms on both sides in this design. The lever arms have telescoping attachments, which are particularly helpful as the seat rises. The seat height adjusts between 25.5” and 32.5”, which meets the specifications given by the client coordinators. The hydraulic pump is rated to support individuals up to 350 pounds.

The base of the salon chair is raised by placing pressure treated wooden decking and other weather treated wood materials underneath it. The total height of the chair is raised 4.5 inches to bring the chair to a minimum height of 25.5”. Because rotation of the seat is not desired during a golf swing, custom metal poles are installed to impede rotation while still allowing the chair to move smoothly up and down.

The chair has waist and chest belts to support our clients during their golf swings. These seat belts were purchased from local auto parts dealers. They provide easily adjustable support and are quick to engage and disengage. The waist belts are secured tightly to metal brackets on the bottom of the chair. The back belts are secured tightly to the wooden decking that spans the rear of the chair.
The back of the seat slides horizontally to provide support for individuals with higher order spinal cord injuries who lack trunk support. The back adjusts up to eight inches forward. It is held in place with handles attached to threaded rods that screw into an imbedded T-nut. The chair has this locking mechanism and a track inside the wooden arms on both sides.

For portability, a hand truck is attached to the rear of the chair. The hand truck is secured tightly with four metal brackets to the base of the chair and with two metal brackets at seat height. An individual can move the chair by tilting it back and pulling or pushing it on its wheels.

Total cost of the device is $485.

Fig. 8.20. Client using the golf chair.
INTRODUCTION
Our client is a two year old boy who has limited trunk support and limited control of his limbs as a result of cerebral palsy. We developed a device that exercises and strengthens his trunk and limbs. Our final design is a chair that can bounce up-and-down as well as side-to-side. By kicking his legs, our client generates a gentle up-and-down bouncing motion. By twisting his body, he is rewarded with a side-to-side bouncing motion. Through continued use of the bouncer, the client will develop his leg and trunk muscles while performing an activity he enjoys.

SUMMARY OF IMPACT
Our client’s mother remarked, “The ‘Bouncer’ team created a dynamic, size-appropriate bouncer seat for our son to allow him to continue an activity that he loves - kicking! The final product is something that our son will be able to enjoy for years to come.”

TECHNICAL DESCRIPTION
The base of the device is made of furniture grade PVC pipe and serves to elevate the chair from the ground so that it can safely bounce without making contact with the floor. Furniture grade PVC was ordered in “Duke blue” colors to enhance its aesthetic appeal.

The seating system is a chair from commercially available stroller, with the legs cut off. Made of lightweight metal and plastic, the chair features a mechanism that allows for simple reclining of the chair’s back. A custom safety harness was fabricated from neoprene and secured with buckles.

The stroller chair is attached to the base by four springs, two in the back and one on each side. The springs can be swapped out for stronger ones as the client grows and gets stronger, and included with the device are springs of varying load strengths and spring constants.

The front of the chair has a Delrin attachment which is used to control the motion. To lock out side-to-side motion, the parent or therapist inserts a pin through the base and Delrin attachment, preventing the chair from moving sideways. To lock out up-and-down motion, a strap and buckle mechanism attached to the back of the chair and looped around the base can be tightened, negating the effects of the springs and preventing the chair from bouncing up-and-down.
Fig. 8.22. Client using the Bouncer Chair.
ASSISTIVE BOCCIA RAMP

Client Coordinators: Ashley Thomas, Bridge 2 Sports
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INTRODUCTION

Boccia is a variation of the game Bocce, enjoyed by individuals with varying degrees of disability. The object of boccia is to throw a ball closest to a target ball. Assistive devices such as ramps allow people with significant physical impairments to participate competitively. The Assistive Boccia Ramp was designed for an eleven-year old client with Thrombocytopenia with Absent Radius (TAR syndrome), a rare condition in which the individual is born without a radius bone, resulting in very short arms. He has limited hand strength, making gripping and throwing balls difficult. Additionally, our client has difficulty standing for prolonged periods of time as a result of surgeries in his legs.

SUMMARY OF IMPACT

Our client's mother stated: “With his physical limitations due to the TAR syndrome, there are few recreational sports [he] can master. This ramp will allow him to experience Boccia to the fullest of his capabilities because it was built with features that tailor specifically to him.”

TECHNICAL DESCRIPTION

The ramp consists of a chute with a custom base, handles and a release mechanism. To use the ramp, the player sets the angle and aims it for the shot. Then the player positions the ball behind one of the four “gates”, each at a different height, depending on how much momentum is desired. Finally, the player releases the ball.

The chute is made from a single piece of a 5” diameter PVC pipe, cut in half along its long axis, and it attaches to a curved PVC “elbow” which allows the ball to smoothly roll onto the floor. These parts are cemented together and provide a continuous surface over which the ball can roll without losing momentum.
bottom to the base with a similar knob that allows for adjustment of leg angle. At each connection site, there is a solid wood block which serves as a stable connector piece. These connector pieces also bear a majority of the weight and force exerted on the device. The bottom connector is reinforced with 4 L-brackets to ensure stability. We mounted trapezoidal stoppers to limit the adjustment range of both the ramp angle and leg angle. This mechanism ensures that the lower connector piece will not experience too much torque nor will the ramp tilt on the player or out of reach of the player’s arms.

The base incorporates a lazy Susan so that the ramp may be rotated easily to aim the shot. The base is 12” x 18” and can be separated from the legs for storage. There is adequate space on either side for the player to place his feet.

There are two handles at the top of the chute which allow the user to hold and maneuver the ramp. The cushion ensures that if the top of the chute is resting on the player’s chest, it will not cause discomfort.

The release mechanism, located on the top right side of the chute, has a small handle which can be rotated clockwise in order to open the four gates which block the chute. All gates are lifted simultaneously. The gates extend approximately 1.5 feet down the ramp, giving the player significant control over the potential energy of the ball.

The handle is easy to hold and turn. The player can place the ball directly behind the desired gate, or place it behind the top gate and briefly turn the release handle to let the ball fall down to the desired gate. At that point, he can then turn the release handle and let the ball roll down the chute.

Fig. 8.24. Client using the Boccia Ramp, with the ball resting on the top release gate.
CHAPTER 9
THE OHIO STATE UNIVERSITY

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DESIGN OF A MOBILE ARM SUPPORT FOR PATIENTS WITH PROXIMAL UPPER EXTREMITY WEAKNESS

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INTRODUCTION
The mobile arm support (MAS) is designed to restore the independence of persons with proximal upper extremity weakness. The MAS is a spring-loaded linkage that assists users in elevating their arms from either the elbow or the shoulder. To ease accessibility, the device is able to be mounted on a wheelchair. The ultimate goal of the MAS is to give the user the ability to perform daily tasks such as eating and bathing without the aid of others.

SUMMARY OF IMPACT
The need for a MAS was described by occupational therapists (OT) in a clinic at the Ohio State Dodd Hall Rehabilitation Hospital. Persons with proximal upper extremity weakness are often capable of moving their arms when they do not need to overcome gravity, but range of motion is often limited when they must overcome their own weight. The OT desired a device that could be attached to a client’s wheelchair and would allow the person to reach their head to perform the necessary tasks of daily living such as lifting their arm to eat or groom. The device is designed to work for a wide range of sizes of people. This device reduces the effort necessary for the user to elevate their arm. The MAS enables the person to perform daily tasks on their own, therefore providing them with more independence.

TECHNICAL DESCRIPTION
The MAS is constructed mostly from aluminum with some steel components. The use of aluminum is critical to keep the weight of the device as low as possible as extra weight can leave the user feeling tired after extended use. Steel parts are used where added weight has a minimal impact on the user and higher strength was a necessity. The parts of the MAS are joined with aluminum pins that allows for both quick attachment and removal. The device is clamped to the wheelchair prior to use.

The MAS mimics the motion of the arm through various linkages. A four-bar parallelogram linkage is next to the patient’s upper arm. One of the links of the four-bar copies the natural motion of the humerus. The nature of motion of the distal link of the four-bar creates a stable platform that separates shoulder motion from elbow motion. Two links at the elbow rotate in the horizontal plane. These links increase the range of motion when reaching across the body by eliminating a pinch point that would occur without them. Another pin joint at the elbow allows the client to flex their arm at the elbow. Finally, a cuff located near the user’s wrist rotates around its support on a bushing to allow the user to supinate or pronate the arm. Ball bearings or bronze bushings are used at every joint to minimize the effects of friction.
Passive assistance is provided at several positions in the MAS. Rubber bands connect diagonally across the four-bar to provide assistance when the user raises their arm from the shoulder. Rubber bands also provide assistance at the elbow for the user to flex their elbow. Rubber bands have several advantages over alternative materials in that they are cheap, and light weight. They also make adjusting the device to varying sizes easier. More rubber bands can be quickly added to support larger weight for heavier clients, and conversely removed for lighter clients. A torsion spring located at the cuff near the wrist assists the user in supinating their wrist from a mid-position.

The cost of parts and materials is $1200.

Fig. 9.2. Technical drawing of the Ohio State Mobile Arm Support.
DRESSING ASSISTANTS FOR WOMEN WITH THE USE OF ONE HAND

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INTRODUCTION
Our clients are women under the age of 65 with the use of only one hand due to stroke. Dressing can be difficult for this population, and many women will change clothing styles to save time and increase convenience. Changes of these types can sometimes result in lowered self-esteem and self-confidence, especially when striving to return to the workplace. Currently there are very few devices on the market specifically designed to help with one-handed dressing. Devices in this project are intended to help women put on a brassiere or a zip-up jacket with one hand.

SUMMARY OF IMPACT
Testing of the device involved the participation of neurologically unaffected subjects simulating one-sided paralysis, who attempted to don bras or zip up jackets with and without the devices. The devices did not always reduce the time it took for the unaffected subjects to dress, but many commented that it seemed much easier to dress using the devices. Most potential clients can take up to five minutes to fasten a bra unaided, and most often cannot zip a jacket unaided, so increased ease of dressing was an ideal outcome. An occupational therapist working post-stroke clients said, “These devices would be a very beneficial tool for a person with hemiplegia or hemiparesis to increase independence with dressing.” Particularly about the bra device the therapist commented “This device is the best I’ve seen for help with fastening a bra one-handed.”

TECHNICAL DESCRIPTION
Fig. 9.3 shows the two dressing aids designed in this project. The bra aid is shown on the left and the zipper aid on the right.

The bra aid consists of a curved, wide polyethylene waist band, a cloth arm cuff, two polyethylene inner clips, and two aluminum outer clips fastened to two polyethylene curved surfaces. The waist band is meant to wrap around the user’s torso just under the bust. Attached to this band at the apex of the curve is the cushioned arm belt meant to be secured around the user’s affected arm. This holds the device in place during use. Prior to placing the device on the body, the user inserts either the hook or eye side of the bra band into one of the outer clips, then threads the bra through the notch in the waist band and around the inside of the device. The bra is then secured in the opposite side’s inner clip to prevent the bra from slipping downward during use of the device. Once the bra is in the device in this manner (Fig. 9.4. left), the user puts her affected arm through the arm cuff with the outer-clipped side of the bra band facing out at the front of the body, reaches behind with the unaffected hand for the other side of the bra band, brings this side around, and fastens the two sides of the bra band in the front. This fastening is facilitated by the curved surface feature. When the eye side of the fasteners is
threaded along this curved surface, the eyes stick out tangent to the curve, which makes engaging the hooks much easier. The inner surface of the bra aid is lined with felt to increase comfort of the device for the user.

The zipper aid consists of a vertical support, two leg flaps, two stoppers, and two clips attached to a clipping surface. It is constructed entirely out of polyethylene, with the exception of the clips, which are cut from a plastic hanger, and the zinc-coated hinges connecting the leg flaps to the vertical support. The leg flaps fold in and out for easy storage of the device, with the stoppers preventing the unfolded leg flaps from extending past 90° from the vertical support. When the leg flaps are unfolded, they are meant to be secured underneath the user's legs with the vertical support extending up between the user's legs. The user orients the clipping surface so that the opening side of the clips is facing toward the user's body. This causes the clipping surface to be angled down and out, allowing the user an unobstructed view of the clips while providing a somewhat vertical initial orientation for zipping. The clips attached to the clipping surface are hanger-style clips with a metal component which can be pushed in to hold the clip closed or pushed out to allow the clip to open freely. Once the jacket is on and the zipper device in between the legs, the user begins the zipping process by securing the “box” side of the zipper in one of the clips. She then slides the zipper's pin through the slider and into the box. The user then secures the pin side of the zipper in the other clip, and can then use the pull-tab to advance the slider (Fig. 9.4 right).

The cost of these devices is approximately $10 for the bra aid and $4 for the zipper aid, assuming that the parts are bought in bulk.

Fig. 9.4. The devices in use (Left: The bra correctly oriented for left-handed fastening. Inset: Fastening the bra. Right: The jacket fully secured in the device).
ADAPTED CRUTCH TECHNOLOGY FOR PERSONS WITH CHRONIC DISABILITIES

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INTRODUCTION
There are approximately 566,000 people who use crutches in the United States. This number represents 8.32% of the 6.8 million people in America who currently use mobility assistive devices. While current crutches can support the body and enable locomotion, most long term users of crutches experience pain and discomfort in the wrists and shoulders due to improper positioning and high loads during standard crutch use. Some long term crutch users also suffer from carpal tunnel syndrome, due to the extreme wrist angles that are experienced during ambulation with crutches. Therefore, the purpose of this project is to design a device that supports the body and enables locomotion while reducing the harmful forces that are observed at the wrists and shoulders during ambulation with traditional crutches. Through research about current crutch technology and associated injuries, our team determined that the target population for the adapted crutches is patients who use a wheelchair for their primary means of locomotion and crutches as a secondary mean of locomotion. These include patients with disabilities such as cerebral palsy, spinal cord injuries, and post-polio syndrome. These users typically have limited lower extremity function but some functional movement in their upper extremities.

SUMMARY OF IMPACT
Motion analysis testing of healthy subjects and interviews with patients following spinal cord injuries suggests that the adapted crutch realizes its design goals. By using a force plate and Tekscan pressure sensors, our tests verify that our crutch does significantly reduce the time to peak loading reduction by a factor of approximately 13% of crutch-to-ground contact time. Through the use of motion capture, our tests verified that our crutch maintained the range of functional wrist angles of slight extension and slight ulnar deviation. Patients commented that the stability of our crutches was equal to that of standard crutches. Many patients felt that the crutches were aesthetically pleasing, that they would be happy using them once approved by a therapist, and mentioned that the “cool factor” of having a unique base for a crutch would add to the overall appeal of the device.
TECHNICAL DESCRIPTION

The body of the crutch is made from aluminum 2024-T3 tubing, and is adjustable from 28-36 inches from the ground to the handle. The forearm cuffs are made from ABS plastic, with nylon racks and pinions to allow for up to two inches of adjustability. The ground interface is made from type 2 titanium, for its high strength to weight ratio. The entire assembly is held together with standard sized nuts and bolts.

There are three different types of handles for the crutch. Each different type of handle has a different type of groove and contour to accommodate different user preferences and hand sizes. Each handle is made from ABS plastic with aluminum square tubing inserts to insure structural integrity. Some handles are coated in silicone rubber for added grip and comfort.

In order to reduce the impact loads seen during ambulation with standard crutches, the bottom of the adapted crutch compresses in a spring like fashion. The bottom of the device is bent into a “C” shape, with rubber padding attached to the bottom. This geometry creates both a spring like compression and a rolling action at the ground interface. The final “C” shape of the foot is based on extensive finite element analysis of different geometries and materials. These attributes of the foot of the crutch are what alleviate impact loading due to the rigid vault like action experienced during ambulation with standard crutches.

The cost of parts/material is about $2545.
ADAPTED TRICYCLE FOR CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY

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INTRODUCTION
Children diagnosed with hemiplegic cerebral palsy have difficulty with motor skills and upper and lower extremity strength on one side of the body. The purpose of the adaptive tricycle project is to design, build, and test a fun and safe option that offers valuable therapeutic benefits for these children. The adapted tricycle is designed to adjust for multiple users varying in size, age, and in upper and lower extremity strength. The tricycle also secures the rider, allows for steering, provides easy-to-grip handles, and is easy to use. Other similar tricycles currently exist on the market, but none are able to adjust the gear ratio to accommodate children with differences in strength. The proposed tricycle uses a belt-and-pulley drive system, which can be easily adjusted to four different gear settings.

SUMMARY OF IMPACT
Riding the tricycle offers a great therapeutic benefit to the user while providing a fun experience. When the children first see the tricycle, they are excited about it and want to ride it, which motivates them to participate in a fun and therapeutic activity. While riding the tricycle, the moving parts and fun colors motivate them even more to continue to push themselves, and get valuable exercise.

The adaptive tricycle provides an opportunity for children with hemiplegic cerebral palsy to receive therapeutic benefit and make progress with their physical abilities. By making the gear ratio for the tricycle adjustable, the parents or occupational therapists can continue to adjust the tricycle as the child progresses. This adjustment will make the child extend their affected limbs farther and farther from their body as they become more mobile through the tricycle’s use and ultimately result in substantial physical progress.
TECHNICAL DESCRIPTION
The tricycle is driven by two independent sets of pulleys and belts. One connects the front hand cranks to the front wheel, and the other connects the foot pedals to the rear wheel. Each set has four pulleys at each end, which allows for four different strength settings: 1) very easy, 2) easy, 3) standard, and 4) difficult. The pulleys are machined from UHMW plastic, and are used to drive the orange urethane belts. The belts are tight enough so that they can carry torque from the cranks to the wheels, yet they are stretchable so the therapist can move the belts from one pulley set to the other easily.

The tricycle frame is made from welded steel tubing, and the seat, foot pedals, hand cranks and other common tricycle parts are purchased from AmTryke LLC. The cost of parts/material is about $2000.

Fig. 9.10. Photo of completed adapted tricycle.
NSF 2009 Engineering Senior Design Projects to Aid Persons with Disabilities
CHAPTER 10
THE PENNSYLVANIA STATE UNIVERSITY

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THE BIONIC VEST

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INTRODUCTION
The purpose of this project is to develop a vest that improves the motion control of a person with cervical and upper thoracic spine injuries. These particular injuries often cause patients to lose the ability to control balance because of loss in functionality of abdominal and lower back muscles. The vest is designed to be used daily and provides the necessary support without sacrificing comfort. Creating a device that increases independent movement of the upper body and better the client’s quality of life are key foci incorporated in the design. The prototype vest is designed specifically for use by our client, Keith Parsons. The effects of his injury do not allow him to move his torso from the bent position to the upright position. The purpose of the vest is to replace the muscle functions that he lacks and restore movement to enable him to sit up straight after bending forward and to the sides of his wheelchair see (Fig. 10.1).

SUMMARY OF IMPACT
The final design for the bionic vest enables our client to achieve stability. This device is designed to let the user bend down in a wheelchair, pick an item up off of the ground, and then return to the upright sitting position without the use of the upper extremities. A second function of the vest allows the user to bend to the side as well as the front. The system is portable and convenient, and is functional even in the absence of a wheelchair. The materials chosen to construct the prototype ensure that it is also comfortable and lightweight.

TECHNICAL DESCRIPTION
The air bladder is attached to the abdominal region as shown in Fig. 10.2. The bladder also wraps around the sides of the vest to aid in side-to-side motion. The lower back and abdominal portions of the vest are a customized back/abdominal support brace comprised of Delrin slats as ribbing. The inner fabric of the vest is neoprene to provide support and breathability for the patient. The back portion of the vest does not contain air bladders, but contains the Delrin ribbing for support. The vest itself is less than 0.5” thick. The pump used is relatively inexpensive, rechargeable, and provides air at an adequate rate to inflate the vest. The bladder is shaped into a triangular wedge as shown in Fig. 10.4. The red portions in Fig. 10.4 represent the Delrin ribbing. The bladder and air pump are connected using 3/8” clear vinyl tubing. The air pump switch was extended three feet in order to allow the user easy access.

The cost of parts and materials is roughly $170.
Fig. 10.2. Vest Deflated.

Fig. 10.3. Vest Inflated.

Fig. 10.4. CAD drawing of final prototype design.
BIONIC GLOVE: DESIGN OF A GRASPING GLOVE FOR A PERSON WITH QUADRIPLEGIA

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INTRODUCTION
The bionic glove is designed to allow people with quadriplegia to use their fingers to pick up objects that they would not otherwise be able to grasp. This device consists mainly of two plates fastened to the hand by Velcro straps and rotated via actuators. The user slides their hand into the finger portion of the glove and uses the straps to then secure the glove to their hand (Fig. 10.5). Once secured, the user can then activate the glove to allow it to open and close as desired. The glove is designed for our client, Keith Pearsons and has also been reviewed by a board of doctors at Hershey Medical Center.

SUMMARY OF IMPACT
A person with partial quadriplegia suffers from different levels of mobility based on their particular spinal cord injury. Some people with partial quadriplegia, such as our client, have some mobility in their arms down to their wrist, but no movement or strength in their fingers and hands. This lack of mobility makes certain tasks very difficult if not impossible without assistance. This project focuses on designing a product that allows people with quadriplegia such as our client, to grasp and gain back independence in activities like weight lifting, fishing, and playing pool.

TECHNICAL DESCRIPTION
The project objective is to design and build a glove that allows the user to have partial control over the movement of their fingers. This design allows the user to grasp while maintaining wrist mobility. The design is based around a four bar mechanism on the back of the hand and fingers that uses two electric linear actuators to allow the fingers to sweep through 50 degrees of motion in a grasping manner. Airprene is used as the glove material because it is both comfortable and breathable. Rigid straps are sewn into the airprene glove to secure the mechanism firmly to the hand. The mitten design allows the client to easily slide their hand into the glove and secure it without assistance. Once the user put on the glove, a cylindrical object can be placed in the palm and the actuator activated to close on the object. The user then activates the actuators again to open the glove once the user is done using the grasped object (Fig. 10.6).

The device is capable of a holding strength of 70 pounds. At loads higher than this the actuators begin to back drive. Neither the actuators or any of the electrical components are damaged by the back drive. The glove gives a solid grip while transferring much of the load to the wrist. Due to its size, this glove is not suitable for objects that are less than one inch in diameter. Some recommendations are to create varying sizes of gloves to accommodate more individuals. It would also be beneficial to include customized actuators that have a longer stroke to allow for a larger sweep angle for the fingers to allow the user to grasp smaller objects. It
would also be useful to make the plates out of a lighter but strong material like titanium.

The cost of parts and material is about $800.

Fig. 10.6. Battery and Electronics Box.
INTRODUCTION

Spinal cord injuries can cause many physical problems such as chronic pain and muscle spasms that can severely affect the quality of life. Stretching the affected muscles has been proven to reduce or eliminate the patient’s spasticity but requires the assistance of a care provider. The goal of this project is to increase the level of independence of individuals affected by spinal cord injuries. This was accomplished through the development of a simple and lightweight mechanical apparatus that allows the patient to stretch the quadriceps independently. The final prototype is shown in Fig. 10.7.

SUMMARY OF IMPACT

Safety is of the utmost importance due to the fact that the user may not realize if the stretch is causing any harm to them if they lack feeling below their waist. For this reason, the device is constructed of materials that will not cut, scratch, or irritate the user’s legs. Stainless steels, aluminum, and plastics are the most viable options for fabrication. None of these materials rust nor cause any kind of allergic reaction, and keep the user’s leg from digging into the surface which prevents skin or knee damage. The device increases independence by containing design qualities that allow the user to put it on by themselves. It is also designed to be able to be worn through the night.

Fig.10.7. The leg stretcher consists of a brace and a ratchet mechanism.
TECHNICAL DESCRIPTION

The two main components of the manually powered quadriceps stretching device are the leg brace and the ratchet mechanism. These two devices are joined together by a sheathed steel cable. The leg braces consist of memory foam pads and fabric straps attached to an aluminum frame. The memory foam pads provide enhanced comfort by forming to fit each leg, while the lightweight aluminum frame provides the structural integrity and light weight requirements needed for an easily transportable device. The fabric straps keep the users leg in position and secure while the device is being used. These leg braces stretch the quadriceps approximately 120 degrees when sufficient tension in the cable provides a moment about the knee. Below is an image of the device in use.

The component that actually creates the tension in the cable is the ratchet mechanism. It is essentially a wooden box containing a ratchet and gears. For the prototype, oak was chosen for the box material due to its ease of manufacturing and accessibility. The ratchet mechanism consists of a handle attached to a sliding rack, which converts the users input force to a rotational torque by interacting with a ratchet. That ratchet in turn is connected to a small gear via a steel shaft. That small gear then transmits the torque to a larger gear which is attached to the cable via an aluminum spool. The gears and rack are made out of steel to prevent wear. A quick release feature is included for safety. In short, each seven pounds of linear input force from the user is converted to a rotational motion that coils the steel cable under 75 pounds of tension. By doing this multiple times, tension in the cable draws the bottom half of the leg-brace closer to the user’s midsection while the steel sheath prevents the cable from pulling at the entire leg brace. In total, the cost of parts and material used for manufacturing is approximately $300.

Fig.10.8. Client using the leg stretching device.
TRASC: WHEELCHAIR STAIR CLIMBER

Designers: Beth Dahm, Kyle Gilbreath, Christopher Rich, Brandon Shrader, Kyle Verrinder
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INTRODUCTION

The Tracked Stair Climber (TRASC) is designed to provide a means for manual wheelchair operators to climb up and down stairs. The user attaches their manual wheelchair to the TRASC device (see Fig. 10.9), and then powers the motor to turn the treads and carry the user up or down the stairs. This device allows for increased mobility for the user, allowing them to access areas that were not previously available. Our client is an individual with paraplegia who uses a wheelchair for transportation. The TRASC now allows our client to access areas where he was previously unable to go.

SUMMARY OF IMPACT

The design criteria for the TRASC are defined by the capabilities and the needs of our client, which were established during a meeting. As a result, the wheelchair stair climber device needs to be safe, independently operated, cost effective, and portable. The TRASC allows our client to climb stairs, allowing him to be more independent and access areas unavailable to him. Overall, it allows him to access even those areas that are not handicap accessible.
THE TECHNICAL DESCRIPTION

The overall structure of the frame is constructed using 2” x 1” rectangular aluminum tubing with a wall thickness of 1/8”. Aluminum is used for many reasons including the fact that it has an extremely low cost, high strength, is light weight, and easily machinable and weldable. Hollow tubing is chosen to achieve the lowest weight with the highest possible strength. This size was chosen not only for strength, but also to provide the ability to bolt other components to the frame without the stress concentrations becoming too high. Most of the frame is welded together with a few components fastened with bolts.

The manual wheelchair is locked onto the TRASC device. This is achieved by backing the wheelchair over the device and initiating the actuators. Two 2 inch actuators lift the wheelchair off the ground and one 6 inch actuator tilts the wheelchair back into a four bar locking mechanism. A 4 point safety belt is fastened to prevent the wheelchair and user from detaching from the device. This safety belt is essential in preventing any injury that may occur if the wheelchair were to detach from the device.

The device accomplishes climbing stairs by using an AISI 2060 double pitched hollow pin roller chain with an Aluminum tread fixed in between two of these roller chains. The roller chain is driven by a 650 lb-in, 10 RPM, 12 volt motor. The low speed of the motor allows the device to climb the stairs at a controlled speed. A one to one gearbox is used to allow one motor to power both tracks on the TRASC. As the tracks rotate the tread profile catches the edge of each stair, pulling the device upward.

The TRASC is operated by three three-position switches that are mounted on a rubber coated tube to prevent any chance of electrical shock. These thumb switches provide an easy way for an individual with paraplegia to operate the device. The three switches operate both in the forward and reverse positions, which allow the user to climb up and down the stairs, and raise and lower the actuators.

The cost of parts and materials is about $3000.
LIFT ASSIST: A DEVICE THAT LIFTS A CHILD WITH MULTIPLE HANDICAPS OUT OF THEIR WHEELCHAIR TO AID CAREGIVERS

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INTRODUCTION
The Lift Assist device is designed to raise a child in a wheelchair around 10 inches in the air to aid the caregiver lifting the child out of the chair (see Fig. 10.11). Currently, caregivers must bend down very low to pick children up from their wheelchairs, which creates many back problems for the caregiver. The Lift Assist device works by using a pulley system with three main components: the basket, pulley, and clutch. The basket sits inside the wheelchair seat and is connected with a rope. In normal operation the caregiver can push the wheelchair around as they would a regular manual wheelchair. When the caregiver wants to lift the child, a hand lever is pulled which engages the clutch. Then the caregiver pushes the wheelchair forward which raises the basket and the child. The wheelchair brake is activated to safely lift the child from the chair.

SUMMARY OF IMPACT
This device greatly improves the quality of life of caregivers that aid children confined to wheelchairs. By safely lifting the child just above the wheelchair armrests, the caregiver is able pick up the child from the side and does not have to bend down as far as they normally would without the Lift Assist device. The project client, Nancy Ehrlich, was thoroughly impressed and expressed that the Lift Assist device could help many of her colleagues.

TECHNICAL DESCRIPTION
A computer model of the device (see Fig. 10.12) displays the final design of the Lift Assist device. To accomplish the design goal of keeping the device lightweight, 3/4 inch aluminum tubing was used for the basket frame which is both light and strong.

Some features of the device that make it user friendly, are the detachable pulley and cam mounts. The cam mount holds the cam which presses against the clutch to engage it. The pulley mount is at the top of the wheelchair and holds the pulley in place. By making both mounts detachable, the wheelchair can be folded for easy storage and transportation. Due to careful design and material selection the final product is affordable and effective. The cost of parts and materials is about $325.
Fig. 10.12. The computer model of the Lift Assist device.
MEDICATION REMINDER TOOL: A SYSTEM TO REMIND MEDICAL STAFF OF MEDICATION ADMINISTRATION TIME

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INTRODUCTION
Skills of Central PA is a human services provider that supports patients with physical, developmental and emotional disabilities. The objective of this medication reminder system is to prompt the staff to administer the clients’ medication following the Five Rights of Medication Administration. The reminder system consists of a laptop interfaced to a TracFone (Fig. 10.13). A computer program, written in MATLAB, serves as the alarm system. At the time of medication administration, the computer screen displays a dialog box with the time and patient name. This dialog box has the capability to be “snoozed” for ten minute intervals up to an hour and a half to accommodate the busy schedule of the staff members but reduce the risk of medical omissions. The program also sends a text to the staff TracFone which emits a reminder that a client’s medication is due. Ultimately, the reminder system is designed to reduce medical omission errors, increase patient safety, and improve the quality of care at Skills of Central PA.

Fig. 10.13. The Computer and the TracFone with Alarm and Reminder Text Displayed.
SUMMARY OF IMPACT

The design criteria were compiled from several employees at Skills of Central PA including the Director of Quality Improvement and Training, the Medical Director, and the Residential Director. An on-site visit to a group home, where the team observed the staff administering medication to the patients with the current system, also aided in the investigation of client needs. The staff is often very busy, and at times needs a regularly scheduled reminder to administer medication at the appropriate time. In an effort to meet the needs of our client, the design includes an alarm that is inconspicuous to the patients of the facility, requires little input from the staff, and continuously alerts the staff until the medication is administered to the correct patient at the appropriate time.

The design part of our project focuses on coding several functions in MATLAB. An individual function is written that creates the alarm dialog box that displays the name of the patient that needs medication. The dialog box is coded to appear on the screen at the appropriate time with the correct patient name. The staff member can enter the patient name and medication time using a graphical user interface created in MATLAB. Finally a send-to-text function is produced in MATLAB that sends a text message to the cell phone carried by the staff at the same time that the dialog box appears on the screen (Fig. 10.14). These three scripts function simultaneously to create the system. The program creates a link between the computer alarm and the cell phone carried by the staff. Staff can easily run the alarm program and text function in MATLAB with the assistance of an instruction manual that contains detailed steps for initiating the program as well as troubleshooting tips.

TECHNICAL DESCRIPTION

To keep the design simple, dependable, precise, and low cost, several pre-manufactured products are used to aid in the assembly of the final product. These products include an ACER laptop computer, MATLAB programming CD, and a TracFone. With this strategy, the focus remains on the design of a customized computer program without the worry of making many modifications to the other components. Pre-purchasing components also allows the product to be easily produced in large quantities. The approximate cost of this system is $475.00 for a laptop, cell phone, and MATLAB program.
INTRODUCTION
The Diet Monitoring Device is a program targeted to assist newly diagnosed diabetes patients as an educational tool for understanding the effects of dietary habits and exercise on blood glucose levels. It is made for in-home use and operation. The user provides personal inputs (gender, age, height, weight, level of physical activity) to calculate the basal metabolic rate (BMR) and determine their daily caloric needs. From this, a dietary meal plan is given to the user which includes the necessary food groups: starch, fruit, skim milk, vegetable, lean meat, and fat. Throughout the day, the patient enters their blood glucose level to make sure they are making the correct dietary choices. Based on user inputs and a timestamp of when the inputs were entered, the program determines the patient’s next course of action.

SUMMARY OF IMPACT
Diabetes mellitus is a metabolic disease in which the body has difficulty producing or using the hormone, insulin. Diabetics need to monitor their blood glucose levels throughout the day by three methods: an insulin plan, dietary pattern, and physical activity program. For newly diagnosed diabetic patients, this involves a dramatic change in lifestyle. These changes include refraining from certain types of food, following a routine medication plan and engaging in more physical activity. Many of these tasks require more care and dedication to following a strict plan than they may have in the past. One of the major problems for newly diagnosed patients is this drastic change in lifestyle.

Fig. 10.15. Home Screen which provides access to all of the program’s features.
TECHNICAL DESCRIPTION
The maintenance of a steady blood glucose level is essential for diabetics. The traditional range of blood glucose levels in normal healthy adults is 90 – 130 mg/dl during the day. This program provides specific recommendations based on the blood glucose level input by the user and the time of day (before or after a meal). For calories, the user inputs their gender, height, weight, and age and the computer calculates their basal metabolic rate (BMR). The daily caloric needs are calculated by multiplying the activity factor by the BMR. In our program we chose an activity factor of 1.3 based on the fact that most Type II diabetics are overweight and less active.

There are many different types of dieting plans that diabetes patients use to help manage their glucose levels. The type of plan that is implemented by our program is a hybrid of traditional Carbohydrate Counting and a Diabetic Exchange diet. A carbohydrate counting plan is simply for the patient to count the grams of carbohydrates in the food that they are eating. The diabetic exchange diet is based on the different food groups. The user is given a meal plan based on a set amount of servings from each category that they should fulfill in a day. Any food selection can be made from each food group as long as they meet that category’s requirement. Our program serves both of these dieting functions (Fig. 10.16). The user of our device is told to eat a certain amount of carbohydrates from six food categories: starch, meat, non-starchy vegetables, fruits, milk, and fats. Any foods of the user’s choice can be eaten as long as they meet the specific carbohydrate requirements for each category for the day. The cost of the computer and software is about $750.

![Calorie and Carbohydrate Tracking](image-url)
WEIGHTED BODY GARMENT

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INTRODUCTION
In the United States, stroke is the leading cause of serious, long term disability. Much of this disability may include partial paralysis of arms, legs or both. This causes nearly 40 percent of stroke survivors to have balance problems that lead to falls each year. Most commonly, stroke survivors experience muscle weakness and atrophy. It is recommended that mild exercise be conducted each day to improve muscle function. These exercises can be as simple as walking or stretching using resistance bands. Currently, physicians and physical therapist work with weight training and resistance bands to help improve muscle movement and growth to improve the quality of life of stroke victims. Patients may struggle with such exercises due to balance difficulties. There are no current materials to help improve this aspect of a stroke patient’s recovery. A weighted garment that supports the muscles as it helps to build them is a revolutionary way to improve the lives of thousands of stroke patients each year.

SUMMARY OF IMPACT
A stroke can affect a person greatly and completely change their way of life. It can take months or even years to recover through muscle training and physical therapy if the patient is even able to recover completely. Dozens of exercises and rebuilding of muscle memory is involved in re-learning daily activities from walking to something as simple as holding a pencil. Many times stroke recovery patients suffer from a loss of balance. It takes much time and work in order to train the body to operate as it originally did. In addition to the standard physical therapy techniques, there is a need for a product that will allow for faster recovery. A weighted, thermo-regulating, fluid, form-fitting body garment can aid in the recovery of stroke patients to increase muscle mass and decrease recovery time. This project focuses on the design of a body garment that uses these characteristics and the idea of muscle compression and alignment in order to keep the muscles in place during exercises and recovery. Adding weight in particular areas can allow the user to complete simple exercises suggested by a physical therapist, allowing for faster recovery. Using this jacket for recovery after a stroke will provide balance to the patient, speed up recovery, and assist in physical therapy.

TECHNICAL DESCRIPTION
In the design of the garment, the main focus for the design specifications is the patient. The garment is designed with the specific patient in mind at all times. If the jacket is too light or too heavy, the patient will not benefit from its implementation or may even experience a delayed recovery or injury. With safety being the number one concern in every application, this jacket will not be designed until torque calculations are performed on the user. Problems are not expected to arise, as the additional weight due to the garment is very small, but it is still important to ensure the user’s safety in design calculations. To construct a jacket prototype, the following materials are needed: Maximus V gel, Polyethylene bags, heat sealer, 1.5-2mm neoprene, 2.5 yards black 80/20 polyester/spandex, 1 yard Teal 80/20 polyester/spandex, black thread, a 24 inch sports zipper, a 10 inch invisible zipper, a 10 inch sports zipper, a jacket pattern and a sewing machine capable of handling 4 mm of neoprene. The final design meets the patient needs and addresses the project’s objectives. The garment incorporates many different disciplines including kinesiology, rehabilitation, architecture, engineering, sales, and design that add to the credibility and marketability of the product. Having these different views and expertise allow us to ensure quality and efficiency of a much needed product.

The cost of parts/material is about $200.
Fig. 10.17. Weighted jacket for stroke patients.
DEVELOPMENT OF AN EMG-BASED MUSCLE SWITCH FOR COMMUNICATION VIA COMPUTER

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INTRODUCTION
For patients with degenerative neural diseases or those who have experienced trauma such as multiple sclerosis (MS) or stroke, conventional methods of communication can be difficult. One viable option for communication, for these individuals, involves the use of speech generating software programs through a human-computer interface (HCI). The objective of this project is to develop a low cost electromyography (EMG) muscle switch that uses only voluntary muscle signals to simulate left and right clicks of a mouse. These clicks will allow the user to communicate with family and friends via BLINK© software developed by the nonprofit organization, Volunteers for Medical Engineering, Inc. (VME) located in Baltimore, MD. Ultimately, this device provides a general solution to communication problems for patients with limited capabilities.

SUMMARY OF IMPACT
In order for the switch to be effective, it must accurately identify voluntary muscle movements from any noise or involuntary muscle spasms. Controlled by muscle movements alone, the device must also be adaptable so that two separate areas of the body can be used to simulate the two separate mouse clicks that will be input into the VME communication software. The system is most useful to the client, if it is able to be used for long periods of time and in the comfort of the user’s home. Therefore, the system must be easily applied, removed, and sanitized by non-technical individuals. Additionally, the device must require minimal upkeep. The device is limited to muscle control and can only simulate two mouse clicks, but this is effective for controlling the BLINK© software that allows for basic communication from the clients.

TECHNICAL DESCRIPTION
The overall conditioning of the EMG signal is dependent upon the initial signal characteristics from the human body. As distinguishing between voluntary and involuntary signals is one of the primary objectives of the device, several alterations to the input signal are required. The targeted area for left mouse clicking is the temple, where a click can be simulated by clenching the jaw and teeth or by pressing the tongue to the roof of the mouth. Right clicking is recorded on the bicep of the user, where tensing arm muscles successfully registers as a click. All conditioning circuitry is tailored to these characteristics.

The EMG signal is received by stainless-steel, pre-amplified surface EMG electrodes, which are both reusable and do not require the use of electrolytic gel. From the electrode, the signal first is conditioned by a non-inverting amplifier with a gain of 100. This high gain is necessary due to loss of signal magnitude during downstream conditioning. Due to the polarized nature of the EMG signal, fluctuations in both the positive and negative realm are theoretically able to trigger a mouse click. Therefore, the signal is further conditioned through a full-wave rectifier, which effectively takes the absolute value of the signal, resulting in an entirely positive output. The final characteristic that must be accounted for is the fluctuating nature of the signal.

To interface the EMG signal to the computer and activate mouse clicking for the BLINK© program, a simple USB mouse circuit board is connected to the EMG conditioning board. A mouse circuit operates by mechanically closing a given circuit which in turn sends a click to the computer. In the EMG conditioning circuit, a reed relay is used to mimic the closing of the mouse circuit. If the output signal from the averaging circuit reaches the triggering threshold of 1.4 Volts, a magnet is activated inside...
the relay which connects an open circuit. This circuit is then attached to the mouse circuit board, passing a mouse click when the EMG signal is greater than the threshold voltage of the relay. By combining the conditioning circuitry and relay trigger, EMG muscle signals are able to accurately replace the physical action of clicking a mouse. The cost of parts and materials is about $750.

Fig. 10.18. Completed EMG muscle switch device.
CHAPTER 11
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INTERACTIVE GAME FOR CHILD

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INTRODUCTION
The goal of this project is to create a custom handheld game for our client, a nine year old child with severe visual limitations as well as some motor limitations. The creation of a handheld game provides both educational and physical benefits to the client. A lower emphasis on visual cues helps to develop other senses such as touch and hearing. The ability for our client to participate in an activity, that other children his age enjoy, will also facilitate interaction with peers.

SUMMARY OF IMPACT
The design consists of a small handheld gaming device that provides three different games and tactile, audio and video cues to our client (Figs 11.1 and 11.2). The device is entirely unique from electronics to software to casing for the customer. The customer has been using the device for two months, as of the end of the academic year, and after subjecting it to numerous “drop tests”, his mother reported that it was still working and that he loved it.

TECHNICAL DESCRIPTION
The design of the handheld gaming device is grouped into three separate categories: hardware, software, and casing. Hardware design consists of microcontroller selection, audio and video output, power, tactile feedback, and printed circuit board (PCB) design. The microcontroller is capable of controlling elements of the hardware subsystems while also running the game software. It is also responsible for interfacing to an external display to provide graphic images to the user. This involves generating game graphics and appropriately sending them to the display device. The Parallax Propeller is used in this design due to its availability of open-source code for applications such as graphics and audio, its packaging simplicity (44 pin LQFP), the ability to generate NTSC and VGA video signals, and an available development board.

The customer receives feedback from the handheld device through audio, video, and tactile feedback. The audio subsystem consists of an all-in-one audio amplifier system (National Semiconductor LM436) and Kobitone 235-CE221-RO 8Ω, 1.1W speaker. For a display, a 4” LCD with a brightness of 220 nit is used. Tactile feedback is provided using two tactile feedback motors taken from an Xbox 360 controller, driven with separate fixed frequencies and variable duty cycle PWM signals that are fed to the gate of power MOSFETs. Each motor has independently controlled variable speed.

In order to integrate the electrical subsystems into a compact package, a custom PCB is included in the design. The PCB has a custom shape that allows for maximum layout area inside the enclosure while providing a cutout for the battery. In addition, the shape allows a single PCB to hold all of the subsystems including the user interface buttons. To avoid noise and EMI issues, the propeller, power and audio circuitry are all confined to different areas of the board. Large grounding planes are placed...
around and between these subsystems to provide additional shielding. The printed circuit board is shown in Fig. 11.3.

The system is powered by a 7.2V 700mAh NiMH battery back, which provides 1.5 hours of use between charges. In addition to the selection of a NiMH battery pack, DC/DC converters provide the required 12V to the LCD and 3.3V to all other subsystems. To increase the voltage to 12V, a MAX618 converter is used. To decrease the voltage 3.3V, a MAX1685 was used. Low drop out linear regulators are avoided in this design due to their inefficiencies and because a battery capacity of less than 12V was desired for weight reasons. The entire system is protected from faults by a 1.1A PTC placed on the PCB near the battery interface.

Three games are designed to provide entertainment for the customer: Simon, Avoidance, and Maze (Fig. 11.4 shows screenshots from Maze and Avoidance). Each game consists of varying levels of difficulty and focuses on audio and tactile cues. Many of the features of these games originate from prototype sessions with the client to observe his interests. The first prototype session introduced the customer to the vibration modules and ensured his comfort with the vibration feedback. The second and third sessions involved the client playing simplified versions of the games where his interactions were gauged and adjusted to fit his level of play. Game play is achieved by data transfer from a removable SD cartridge, one for each game.

The driving force behind the development of the Simon game is the desire to introduce our client to video games and the intended interface of the handheld. This game is a very simple and a common game for children, requiring the user to mimic a sequence of colors. After the first prototyping session, it was determined that an easier level needed to be provided to first familiarize the user with video games. Once the user adapted to the rules of the game, the level of difficulty would be increased.

The Avoidance game focuses on the player, represented by a triangle, avoiding a square that moves down the screen. To alert the player to move the triangle, the hand held vibrates. Another feature of the game is to retrieve bonus items. The bonus items are represented by circles that also move down the screen along with the square. When they are touched by the triangle, the score is increased and a sound is played. When the player hits the square a life is lost and when all the lives are gone, the game is over. A different sound effect is played to signify an obstacle being hit in order to show the user this is an undesired action.
The Maze game focuses on navigating through a series of pathways to reach an end target. This game utilizes the system of navigation known as “Hot vs. Cold”.

The player follows audio cues, rather than having to look at the screen, in order to navigate the map. The player listens for “Hot” sounds to indicate getting closer to the target and “Cold” sounds to indicate moving away from the target. This system allows the player to almost completely eliminate the visual aspect of the game pending appropriate level design.

One facet of the mechanical design that was closely coordinated with the electrical team is the dimensions of the PCB. Additionally, coordination is needed on the placement of the buttons on the PCB. This is important not only for the PCB layout itself, but also for the design and constraint of the mechanical buttons. The PCB is attached to the case using threads cut in the plastic.

The casing is made using a SLA process with DMX-SL-100 material, which has mechanical properties similar to ABS. The casing has a wall thickness of 3mm, approximately twice that of an Xbox controller. The LCD, the two halves of the case, and the screw for the battery cover, are mounted with M3-0.5 hexagonal electrical standoffs as screw bosses. In a production part, these would be molded in to the case, but with that option unavailable, the bosses are glued in place. While there is a possibility of the glue failing, the fix is simple enough to be done by the user if needed. It is a concern that if the plastic was taped instead of using the metal bosses that the plastic threads would have a limited number of uses before becoming too worn to function properly. A repair to these threads would be much more involved, even if they prove to be slightly more durable initially than the metal bosses. However, the plastic is taped for the PCB mounts, since it is mounted in a position that did not leave enough depth to insert a standoff. The PCB should not need to be removed unless a replacement is needed.

The components that do not have fixed mounting points are constrained by a variety of methods.
Molded pegs are used for the power switch and volume control knob. The parts are then permanently glued onto the pegs. The headphone jack is glued on three sides, and further limited by the protrusion of the jack itself. The vibration modules sit in grooves to prevent axial motion and limits radial motion as well. The speakers, lacking attachment points, are similarly constrained, but are also glued in place to limit axial motion.

The design of the mechanical buttons was accomplished with the collaboration of the industrial designers on the team, who modeled the exposed portions of the buttons. The basic shape of the buttons extends downward and flares out to prevent the button from falling out of the case. The extended section matches the extended guides that follow the holes in the top of the case. This prevents the buttons from wobbling in their holes. Finally, the buttons rest on their respective electrical buttons. The electrical buttons provide a surprisingly good “feel” to the button action, and the SLA buttons are light enough that they do not accidentally actuate the electrical switch.

The total cost of the project is $3,962.39.
UPPER EXTREMITY EXERCISER

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INTRODUCTION
Following a stroke, it is common for persons to lose significant amounts of functionality and range of motion in the upper extremities. Should some range of motion be restored, the arm may still feel heavy and difficult to move. Often times stroke patients will compensate with their upper body, specifically their upper extremities, in ways that may cause further damage to the muscles that are involved in upper limb control. The proper method for rehabilitation is to constrain the upper extremities to motion that is considered safe to perform, and to encourage the use of these particular motions as much as possible. The purpose of this project is to create a device that can be used by individuals in the rehabilitation of the muscles involved in upper limb control. A prototype and first generation device were created for this specific type of rehabilitation, but fail to sufficiently fulfill the primary needs of the project customer. As a result, it is this team’s principal objective to redesign or create a completely new device that more effectively meets the most critical needs of the client. In particular, the range of motion in extending and raising the arm must be increased, motion must be limited to the sagittal plane, and the device’s size and weight must be reduced.

SUMMARY OF IMPACT
The redesigned system met or exceeded the customer’s most critical needs. Figure 11.6 shows a comparison of (a.) the therapist prototype, (b.) the first-generation project, and (c.) the design created in this project. The range of motion at the shoulder is increased by 40° (120° shoulder extension), weight was reduced by 70% (5 lb.), and storage volume was decreased by 95% (24” x 10.5” x 6”). The elbow joint has a 168° range of motion and the amount of resistance and/or support provided by the system can range from 2 lb. to 9.5 lb., exceeding the customer requirement of 3 lb. to 8 lb. The device can be used on either the left or right side, although there is minor interference when the device is used on the left side of the body. The device is adjustable to accommodate 5th percentile females through 95th percentile males. Shrug-type motion is not well-constrained, but this is a lowest-priority customer need and does not negatively affect the rest of the system. Overall, the client was extremely pleased with the new design and plans to begin clinical use in the fall.

TECHNICAL DESCRIPTION
The design has three subsystems. The first subsystem is the shoulder subsystem (Fig. 11.7), which provides assistance/resistance for flexion and extension of the shoulder joint. The spring subsystem is composed of five individual components. The first is the torsion spring, which is removed from an EMPI Advance® Dynamic ROM elbow rehabilitation device. The spring is manually removed from the brace and implanted into the design as the source of assistive and resistive force for the patient’s arm. A pin is inserted into the spring to cap its range of motion at 120°, as indicated in the specifications. The second component is the upper arm shaft, fabricated from an aluminum rod and threaded at an end. The upper arm shaft’s function is to provide a track on which the upper arm will translate as it is raised and lowered. The third component is the torso shaft...
which, similar to the upper arm shaft, is fabricated from an aluminum rod and threaded at one end.

Several small holes are drilled into the torso shaft to provide vertical adjustability to accommodate numerous patient torso lengths. The fourth and fifth components are the spring arm bases which are fabricated from square aluminum bar stock. Each has a threaded hole for assembly of the upper and lower spring arms, and two non-threaded holes for spring attachment.

The second subsystem is the elbow subsystem (Fig. 11.8). The elbow subsystem is composed of three components. The first component is an EMPI® Advance Dynamic ROM. The function of this part is to assist the patient in achieving extension in their elbow. The second component is the upper arm cuff, fabricated from the moldable polymer Orthoplast. Its function is to join the shoulder and elbow subsystems and rigidly attach the arm subsystem to the patient. The third component is a linear ball bearing within a polymer pillow block. Its function is to provide smooth translation of the arm subsystem along the upper arm shaft during device operation.

The third subsystem is the torso subsystem (Fig. 11.9). The torso subsystem is composed of three different components. The first and second components are Valeo lumbar belts. These belts serve to rigidly anchor the spring subsystem to the patient’s body. The third component is the vertical adjustment sleeve, fabricated from a long hollow aluminum tube with two shorter aluminum tubes welded perpendicularly. This sleeve links the shoulder and torso subsystems, and provides for patient adjustability. The total cost of the project is approximately $2120 (includes $1300 worth of donated equipment).
MANUALLY OPERATED WHEELCHAIR FOR USE WITH ONE ARM

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INTRODUCTION
The goal of this project is the design and creation of a one-arm, manually powered wheelchair. The design is inspired by our client, a stroke patient with mobility of only one arm. Following a stroke, it is normal for patients to lose some or all of the functionality in one side of their body. As a result, it is inconvenient for them to use a normal, two-arm wheelchair. This wheelchair will provide the means for our client to propel himself with the use of only one arm in and around his home or at a long-term care facility.

SUMMARY OF IMPACT
The design chosen for this prototype is based on a push lever for propulsion of an existing wheelchair. The finished product meets nearly all of the initial specifications, and the client uses the wheelchair in many day-to-day activities and provides feedback to the team. He is comfortable moving the chair using the push lever and feels that the wheelchair is satisfactory for transportation on a daily basis. He expresses some concerns about performing sharper turns and controlling the brakes, but overall has provided very positive feedback.

TECHNICAL DESCRIPTION
The prototype is designed against existing wheelchair models that are used by individuals with the use of one arm. The two primary designs that exist are electric wheelchairs and wheelchairs with both push rims on one side of the chair. The electric chairs are significantly heavier than manual chairs, and often require the user’s car to be custom-outfitted for transportation. They also lack therapeutic benefits because propulsion is joystick-based. Designs with both rims on one side create problems when the user tries to grip both push-rims simultaneously. It is difficult to grab both rims with the same amount of force when attempting straight-line travel, which results in the wheelchair deviating from its intended path.

Based on all of this information, a push-lever design is implemented in this project. This new system requires the user to push forward on the lever to move forward and to use the right and left brakes on the lever to slow and stop the chair as well as to control turns. The rear axle is split, and a differential allows the two rear wheels to rotate independently for making turns.
Based on the client (50th percentile male), the design can achieve a 2 mph top speed without exceeding an acceptable amount of required grip or push force. Similar analysis ensures that the user is able to operate the hand brakes. Three lever pushes at 100 N, which is within the client’s ability, will accelerate the chair to 2 mph within three seconds. Four lever pushes at 60 N increases the time to four seconds, and still brings the chair to just under 2 mph. This means that even if the client is not able to push with 100 N of force, a significantly lower push force still allows him to reach cruising speed fairly quickly. Bicycle brakes, similar to the ones used in the wheelchair system, require approximately 30 kg to operate. Through dynamometer testing, it was determined that our client is able to achieve 25 kg in grip strength. Therefore, the brakes are adjusted to accommodate the client’s slightly lower grip strength to assist in stopping the wheelchair.

The three modifications made to the existing chair are (a.) the addition of the push lever for propulsion, (b.) the chain drive and the differential under the seat and on the rear axle, and (c.) the integration of the braking system into the rear wheel hubs (Fig. 11.11). The biggest challenges the team faced include maintaining chain tension and machining custom parts with close enough tolerances to off-the-shelf parts to eliminate poor fits. The chain does slip at full push forces, but limiting the force to approximately 60 N eliminates slip and delivers adequate propulsion. Shims are used to minimize mismatches in part sizes, which can be eliminated by custom made parts. Overall the system is fully functional and provides an alternate means of transportation for the customer.

The total cost of the project is $2,113.

Fig. 11.11. Key propulsion system components: (a) push lever and brake handles, (b) chain drive and differential, and (c) rear wheel hub and brakes.
CHAPTER 12
ROSE-HULMAN INSTITUTE OF TECHNOLOGY

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INTRODUCTION
This project focuses on the creation of a device that allows employees with disabilities, specifically visual impairments and tremors, to safely, accurately, and quickly trim the loose threads of a U.S. Military Gen III shirt to within their contractual requirement of 1/8". Prior to this device, only employees with milder disabilities were able to trim the threads manually, using sharp scissors, due to the inherent safety risk involved with the process. Previous attempts to solve this problem failed due to accumulation of cut threads in the device, difficulty or complexity of the device which increased the amount of time needed to cut the threads of a shirt, inaccurate thread cutting, and excessive device noise which required hearing protection.

In the design process, the team developed several alternate designs and ultimately decided to pursue the "Push Mower", shown in Figure 12.1. The Push Mower works on the same principle as a hand-powered reel lawn mower. As the operator pushes the device, a reel consisting of several bars rolls across the fabric pulling up the threads. The reel rotates on the inside of the drive wheels along a gearing system, which pulls up the thread. The reel then draws the thread across the blade, which is attached to the chassis behind the rotating assembly, and cuts the thread. The length of the cut thread is controlled by the angle of the device, which is constrained by the geometry of the chassis and body. The long body is the handle that the user will grip to use the device. The advantage of this design is that it is small and can be operated with one hand. Since the reel and cutting surface are approximately 2.625 inches wide, the client does not need to be meticulously accurate in finding threads. As currently designed, this device is powered purely by the user, which reduces both the size and the output of noise of the product. The loose thread falls back onto the garment to be picked up by a lint roller attached to the back of the handle which assists in managing the accumulation of the cut threads.

SUMMARY OF IMPACT
This small, compact device can be used by employees with tremors and visual impairments to quickly and accurately trim the threads to military contract specifications and to increase access to this job opportunity for employees with a variety of disabilities. To meet these design requirements, the Push Mower design is divided into four subsystems: reel, blade, chassis, and body.

TECHNICAL DESCRIPTION
Design requirements include the ability to safely, quickly, and quietly trim the threads to military contract specifications and to increase access to this job opportunity for employees with a variety of disabilities. To meet these design requirements, the Push Mower design is divided into four subsystems: reel, blade, chassis, and body.

The reel subsystem pulls the threads up from the fabric and directs them past the blade. The reel is made largely of laser-cut acrylic that is glued together, but also includes aluminum spacers to allow the reel to pass through the chassis. The
strength of this subsystem is that it operates on the simple and easily modeled principle of gears. The blade subsystem cuts the threads that are pulled into the device. The blade is held tightly in place by the chassis for accurate and precise cutting, as well as easy maintenance and replacement. The Push Mower uses a stock blade that can be purchased in bulk and at a low cost to minimize the difficulty of replacement, although two holes must be drilled through each blade to attach to the chassis. The cut threads fall from the blade back onto the garment where they are picked up by the body and thread storage subsystem. The body and thread storage are one piece, and they are connected to the chassis by two bolts. A standard lint roller is attached to the body to collect the cut threads. All of the subsystems are attached to the chassis via bolts. The chassis subsystem also includes a rapid prototyped cover that covers the reel to prevent harm to the user and the product.

The cost of parts and materials for the final design is approximately $250. 

Fig.12.2. Final Prototype of the “Push Mower” design for thread trimming.
ACCESSIBLE PAPER SHREDDING SYSTEM

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Client Coordinator: Darren Probst, Vigo County ARC
Supervising Professors: Dr. Renee Rogge and Dr. Glen Livesay
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Rose-Hulman Institute of Technology
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INTRODUCTION
The system created in this project is designed to assist our client, an individual with cerebral palsy, in performing paper shredding tasks at a local Recycling Center. Our client has little mobility in both of his arms and hands and is unable to firmly grasp objects with his hands. Due to limited range of motion, he requires assistance from a job coach to complete his work at the Recycling Center. The job coach arranges the paper for him on a table that is placed in front of a shredder. Paper is placed on rubber bands attached to the left side of the table. The rubber bands help him grasp and move the paper off the platform into the shredder using custom-made headgear.

The custom-made headgear our client currently uses has a single point of contact and the paper often rotates when it is fed into the shredder. The client also experiences difficulty pressing the on/off button. As this is a necessary activity for each piece of paper that is shredded, this aspect greatly hinders our client’s independence in using the device. Also, the job coach is only able to put a small stack of papers on the table at a time, thus requiring more frequent assistance.

SUMMARY OF IMPACT
The modifications to the client's headgear and shredding system provide our client with more independence in performing his job. Assistance from the job coach is currently only required at the beginning and end of his shift (or in special circumstances). The client is also able to turn the paper shredder on and off, which provides him more control over his working environment.

TECHNICAL DESCRIPTION
The client's headgear is modified with a two-pronged design to provide a more stable way to push paper into the shredder (Fig. 12.3). The two pronged modification prevents the papers from spinning which provides more control. The rubber material is threaded to fit Adam’s current headgear rod so that the tip can easily be removed if necessary. This also allows for a strong connection between the headgear rod and the tip.

The on/off switch is modified (Fig. 12.4) with a removable addition (no permanent changes to the shredder are allowed due to machine warranties). A large, contoured switch plate covers the original switch. The new switch provides a larger surface area for contact with the client's headgear. The client uses his headgear to easily push the switch into an on, off, or reverse position.

A spring box is designed to hold paper for shredding. The spring platform pushes the paper up to the side opening and allows for the job coach to fill the box full of paper at the beginning of a shift. The box is slightly larger than an 8.5” by 11” piece of paper so that the paper fits into the box only in one direction to ensure proper paper orientation.
A set of four springs is positioned at the bottom of the box and platform to move the paper up toward the shredding surface as necessary. Rollers are positioned at the top of the spring box to dispense paper from the box so it will not get stuck in the side opening. Because of the rollers, the client no longer has to pull paper out of the opening using his headgear. Instead, the paper is easy to reach as it glides out of the box opening. The rollers are driven by a motor that is controlled by a light sensor combined with a programmed microchip. To activate the rollers (and provide paper for shredding), the client moves his headgear in front of the light sensor.

Once paper is moved from the spring box to the rollers, it moves onto a guide way. The purpose of the guide way is to direct paper from the spring box into the shredder. The final spring box and guide way systems are shown in Fig. 12.5. The cost of parts/material for the final design is approximately $500.
CUTTING AND SEWING ASSISTANCE

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INTRODUCTION
Our client employs persons with disabilities to assist in the manufacturing of products under government contracts. One of the current products is a weapon carrier made of a waterproof material with two outer zippered pockets on the front. For this carrier, there are two manufacturing tasks that are difficult for persons with disabilities to complete. The first task is the cutting process for creating the correct shape for the pockets. Each pocket has four square corner cut-outs and a long darted cut down the center of the pocket (for insertion of the zipper). Currently, the pockets are marked and then cut using four different tools. In addition to being inefficient, the tools used also have very sharp exposed blades that only the supervisor can operate due to safety concerns. The second task is the sewing of the zipper into the pocket after it is cut. The tight government specifications placed on the stitching location and orientation limit the availability of employees who are able to perform this task. Our client desires to improve the accessibility of these tasks and make the job opportunities available to a wider population of employees.

SUMMARY OF IMPACT
The modifications made to the cutting station provide some additional opportunities for workers at the facility. However, the design requires further revision due to the high force requirements for cutting the material.

TECHNICAL DESCRIPTION
The cutting design (Fig. 12.6.) provides users with a variety of disabilities to safely and efficiently cut out the corners and the long slit in the middle of the pocket with a few easy steps. The design functions similarly to a metal stamp or punch with a user-applied force on the lever serving as the actuation mechanism. The custom-made blade (Fig. 12.7.) is contained in a polyethylene casing to protect the user. All the cuts are made with a single applied force (Fig. 12.8.).

The sewing design (Fig. 12.9) consists of two tracks, an upper and a lower track manufactured from polyethylene. The user folds the pocket material by hand and then places the folded pocket on top of the zipper in between the top and bottom tracks. By placing the pocket in-between the two layers, the pocket is held in position in relation to the zipper via a clamping force from aligned magnets in the top and bottom tracks. Additionally, prior to loading the pocket material, the user places small plastic clips around the edges of the folded zipper pocket edges. These clips hold the folded edge in place so that as the pocket is sewn, the user removes the clips as they progress around the edge of the pocket.
The total cost for the parts and materials associated with both the cutting and sewing designs is approximately $2000.

Fig. 12.8. Finished cut-outs for the pockets using the cutting design.

Fig. 12.9. Sewing design to minimize complexity of sewing the zippered pockets.
THE BUBBLE WALL

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INTRODUCTION

The Bubble Wall is a device used to aid persons with a visual disability in swimming laps in an Olympic sized pool. Persons with visual impairments have difficulty when attempting to swim in a lap pool due to an inability to sense lane dividers and the end walls. One existing solution to this problem is a floatation device that rests on the surface of the water. Parallel bars run the length of the pool and have cylinders positioned along the length of the bars that alert a swimmer of deviation from a straight path via a contact method. As the user reaches the end of the pool, an end bar alerts the swimmer that the solid wall is approaching. Swimmers reported that the contact method of notification was not optimal and interrupted normal swim patterns.

The device designed in this project uses an air pump to pump air into the water in a controlled manner. The air is pushed through tubes which are in a rectangular formation on the bottom of the pool. The rectangular formation is three feet narrower than a standard Olympic sized pool lane and 30 feet shorter than a standard Olympic sized pool lane. Holes in the rectangular formation allow bubbles to rise to the surface of the pool. The bubbles form a boundary within the pool lane within which the swimmer can stay by feeling when he or she is nearing the bubbles. When the swimmer crosses the bubbles at the end of the rectangular formation, they know that the end of the lane is only 15 feet away. The Bubble Wall is available for use by anyone who is visually impaired and wants to swim laps in an Olympic sized pool. The Bubble Wall allows visually impaired swimmers to maintain a course within a pool lane without impacting the lane lines or edges of the pool.

SUMMARY OF IMPACT

During testing, the Bubble Wall successfully indicated lane boundaries and provided swimmers with the necessary guidance to stay on course and

Fig. 12.10. Spacing of the holes along the Bubble Wall.

be aware of the end of the lane. Swimmers noted that the air bubbles were subtle enough to indicate location without disturbing swim patterns.

TECHNICAL DESCRIPTION

Flexible tubing comprises the piping system of the Bubble Wall. Holes are drilled every 12 inches down
the length of the pipe and every six inches across the width as shown in Fig. 12.10. Subject testing confirmed that the spacing created appropriate bubble notification to the swimmer. An air pump provides the air flow for the system due to its ability to supply a steady stream of air for a long period of time. The Bubble Wall rests in the middle of a pool lane; 15 feet from the walls at the end of the pool and two feet from the lane divider ropes. The final dimensions of the Bubble Wall are forty-five feet long and five feet wide (45’ x 5’). The PVC Stabilizers (Fig. 12.11) are composed of five foot long PVC sections filled with concrete which have T-fittings on their ends. These stabilizers slide over the flexible piping. Each of the ten PVC Stabilizers weighs approximately four kilograms, i.e. a total of 40 kg keeps the Bubble Wall secured on the bottom of the pool. The stabilizers can slide across the flexible tubing. A schematic of the Bubble Wall is provided in Fig. 12.12. The entire system is compact and portable for easy deployment in any standard pool, as shown in Fig. 12.13.

The total cost of the Bubble Wall is approximately $1000, including development costs.
INTRODUCTION
Our client has a disease called deuteranolomaly which results in the inability to see red and green pigments. Therefore, he also has problems distinguishing between shades of brown, gray, and pink. The ability to see these colors would be extremely beneficial in aiding him in activities such as shopping for clothes and home & gardening activities. Currently, a device to aid him in such activities does not exist on the market.

SUMMARY OF IMPACT
The prototype detects different colors but is not suitable for distinguishing between various shades of the same color. Further development and microcontroller programming is required before final delivery to the client.

TECHNICAL DESCRIPTION
The Color Detection Device makes use of a color sensor which contains an LED to shine light that is reflected off an object and back to the sensor. The sensor reads the wavelength reflected back through four color filters and sends the color data through its analog to digital converter to the microcontroller. Due to the extremely small size of the color sensor, it is soldered onto a small printed circuit board (with an area of four cm²) so that it can be mounted onto a bread board for preliminary development. A PIC18F4520 microcontroller analyzes the data received from the color sensor and sends the resultant color information to the LCD for viewing by the user. All of the components are powered by a 9V battery. The entire device can be seen in Fig. 12.14. A pre-made casing was used instead of a rapid-prototyped custom casing. The pre-made casing is machined to allow for LCD placement and reset-button accessibility. Two voltage regulators are included to drop the voltage from the 9V battery down to 3.3V and 5V for the color sensor and the LCD, respectively. Resistors are included as pick-up resistors for the color sensor and the PIC microcontroller.

The total cost of the Color Detection Tool is approximately $500, including research and development costs.
CHAPTER 13
SAN DIEGO STATE UNIVERSITY

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CABIN LIFT SYSTEM FOR RACING SAILBOAT

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INTRODUCTION

A lift system is needed for the Challenged America racing sailboat to allow cabin access for sailors with disabilities. Once completed, the cabin lift system carries a user from the cockpit down to the floor of the cabin. The design must fulfill an extensive list of requirements where the main goals are user safety and minimal weight added to the existing structure. A system was designed where guide tracks are mounted to the existing ladder, with a seat assembly raised or lowered by an electric winch. At the top position, the seat back can be lowered to allow a sailor to slide from the cockpit to the seat or vice-versa. This is the optimal design due to its ability to transfer the user safely between locations, the addition of a minimal amount of weight, and ease of interfacing with the existing structure.

The Challenged America sailing program is modifying a Nelson-Marek 43 racing sailboat to accommodate crew members with a wide range of physical and sensory disabilities. This program is located in San Diego and is dedicated to introducing sailing as a therapeutic and rehabilitative activity to individuals with disabilities, their loved ones, and professionals in healthcare and rehabilitation. The cabin lift system will be used by several of the regular crew members during recreational and competitive sailing.

SUMMARY OF IMPACT

The purpose of this project is to design a lift system to allow non-ambulatory crew members independent mobility from the cockpit of the Challenged America racing sailboat to the cabin below and back up again.

TECHNICAL DESCRIPTION

The design is comprised of a seat assembly which rides on marine-grade tracks attached to the handrails of the existing companionway ladder, actuated by a sealed ATV winch. It requires minimal modification to existing boat structures, and will allow normal use of the companionway ladder when the lift is not in operation.

The two guide rails are anodized aluminum extrusions which support recirculating ball-bearing cars; these are manufactured by Harken and typically used for travelers and other sail-management applications. The rails or tracks clamp to the vertical rails of the existing ladder and to brackets added to the top of the cabin. Two cars ride on each track and support the seat against lateral loads due to the pitching and rolling of the sailboat.

Fig. 13.1. Cabin lift system attached to mock-up of ladder.
A fully sealed ATV winch (Warn XT15) provides the power to lift the seat through a range of about five feet. This model is selected for its environmental resistance, reasonable power requirements and generous load capacity. The winch is placed under the top step of the ladder to minimize any interference with the normal function of the ladder. Two separate low-stretch synthetic lines run from the winch drum up to pulleys mounted at the top of the guide track, then back down to the seat assembly.

The seat has rigid bottom and back panels, with side gusset plates to support the applied loads in the vertical and fore/aft directions. The back panel is hinged to allow it to be dropped down to the level of the cockpit opening. This enables a user to make a sliding transfer from the cockpit to the seat, and then flip the seatback up for support during the ride down. The seat bottom panel is also hinged; the front portion flips downward to support the seat panel so that it can be used as a step when the lift is in the lowered position.

The operation of the system is controlled by the user with sealed momentary-contact pushbutton switches – one for up and one for down. An automotive relay switches the 12VDC power from the boat’s marine batteries, with limit switches to stop the vertical travel at top and bottom positions.

A wooden mock-up of the cabin and ladder was built for testing the system. The performance testing was successful, and integration onto the boat by Challenged America is planned for Summer 2009.

The cost of the lift system components is approximately $1900, with an additional $150 spent on the cabin mock-up.

Fig. 13.2. Use of the Cabin lift system demonstrated by a volunteer.
WINCHTOP GRINDER FOR SAILBOAT

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INTRODUCTION
A winch is a mechanism having a drum on which rope is coiled, and can be tightened with a crank or handle that allows easier adjusting or hoisting of sails. Traditional winches, ubiquitous on sailboats, rotate about a vertical axis and require significant arm, trunk and lower body strength to be used effectively. An ergonomically improved device would employ handles rotating about a horizontal axis using an opposing motion like a bicycle crank. Such systems, often referred to as pedestal grinders, are commonly used on large racing sailboats, allowing dedicated crew members to generate the higher forces needed to control large sails. If such a system could be adapted to smaller winches, it could allow crew members with limited lower body strength to work more effectively in the cockpit of a medium-sized sailboat.

The goal of this project is to design a mechanical adapter to an existing (traditional) winch, allowing a seated user to drive the winch with a bicycle-crank-like grinding motion. This winchtop grinder is designed for strength, light weight, ease of attachment/detachment, and corrosion resistance. The grinder is also needed to operate in both forward and reverse directions, in order to utilize the two- or three-speed gearing of the winches.

The project was sponsored by the Challenged America sailing program located in San Diego. This non-profit organization is dedicated to introducing sailing as a therapeutic and rehabilitative activity to individuals with disabilities, their loved ones, and professionals in healthcare and rehabilitation. Challenged America is modifying a high-performance Nelson-Marek 43 racing sailboat to accommodate crew members with a wide range of physical and sensory disabilities. Supportive seats with four-point harnesses allow crew members with disabilities including paraplegia to work effectively in the cockpit. The winchtop grinder adaptation will be used by several of the regular crew members during recreational and competitive sailing.

SUMMARY OF IMPACT
The winchtop grinder provides a portable device for crew members with limited lower body strength to comfortably and efficiently raise and adjust the sails of a boat.

TECHNICAL DESCRIPTION
The winch is a rotating drum with a star-shaped drive socket on top into which normally fits an L-shaped handle. This handle rotates in the horizontal plane and can easily be moved to different winches to adjust various sail control lines. The winchtop grinder replaces the conventional handle and converts an opposing vertical motion into a horizontal rotation that turns the winch.

The most critical element of this design is the right-angle drive between the crank handles and the output spline. Conventional right-angle gearboxes are typically designed for higher speed operation; in this case, the system must handle the full drive torque of at least 80 foot-pounds at very low speed. A standard bevel-gear unit with sufficient load ratings would have been prohibitively large and heavy. Consequently, the winchtop grinder is designed around a pair of commercial socket-drive universal joints. These were found to have sufficient torque capacity while being compact, inexpensive, durable, and easily replaced in the field if needed.
The rest of the winchtop grinder system consists of a tubular stainless steel crank shaft with a pair of rotating hand grips. A standard \( \frac{1}{2} \)" drive socket connection attaches this shaft to the universal joints. Another output shaft (a modified socket extension) applies torque to the machined square drive spline that fits into the top of the winch. Each of the two shafts rotates on a pair of sealed ball bearings, which are mounted in a two-piece aluminum housing.

The resulting system provides a novel and useful winch accessory, enabling an individual to apply powerful and ergonomically efficient torque to a winch from a seated position. It requires no modification to the winches, and is easily removed to load or unload lines (ropes) from the winch. Additional improvements to the design are, further reductions in weight and streamlining the design to avoid sharp edges. The winchtop grinder assists sailors with disabilities to compete with their able-bodied counterparts at any level.

The total cost for parts and materials is approximately $500.

Fig. 13.3. Winchtop grinder in use on racing sailboat.
CHAPTER 14
STATE UNIVERSITY OF NEW YORK AT BUFFALO

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RECLINING WHEELCHAIR WITH DETACHABLE CANOPY AND DESK

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INTRODUCTION

Traditional wheelchairs can be uncomfortable for any number of reasons such as thin unpadded seats, or backs that cannot be adjusted. They are also hand operated, which may deter users from using hand held accessories, such as an umbrella. In addition, wheelchair users are frequently without a suitable work surface. Standard wheelchairs do not have one, and not all facilities have tables that a wheelchair user is able to access comfortably.

This project addresses all previously mentioned issues. It has a sturdy design that allows safe reclining, while maintaining full balance. Also included is a detachable canopy top which provides users with shade from a range of weather conditions. This modification also includes a work surface that may be stowed temporarily on the wheelchair’s side, or removed all together.

SUMMARY OF IMPACT

This modification allows wheelchair users more comfort and convenience. The reclining feature allows users to relax while remaining in their chairs. Leg rests fold out with activation of the reclining mode, elevating users’ legs for additional comfort. When users need to perform any task which requires use of a desk, they have one readily available at their side. The canopy provides overhead and partial side cover which frees users’ hands allowing them to concentrate on mobility. It can also be easily detached if desired.

TECHNICAL DESCRIPTION

In order to recline, users push the seat’s back down using their arms and back. In a full recline, the chair back is approximately 45 degrees lower than in its original position. About an extra 15 degrees of recline may be gained by leaning back further.

To return to an upright position, users lean forward and pull on the chair’s armrests. This motion also moves leg rests back under the seat. Total stability is maintained in all reclined positions by adding extra support with the addition of small detachable wheels connected to the lower back of the chair’s frame.
The seat’s frame is made of plywood. A piece of Plexiglas is attached to the frame’s back to add extra support and comfort. Padding, 0.5” thick, is stapled onto the wooden frame and covered with black marine vinyl. The seat’s final dimensions are 14.25” x 21” x 25.25”.

The canopy top is made from nylon rip-stop fabric. Rip-stop fabric was selected for its versatility, tensile strength and lightweight characteristics.

This fabric is 1) waterproof, 2) fire resistant, and 3) has zero porosity. A 0.5” electrical conduit, bent at 90 degree angles, is used for the frame. For extra support, machined metal flat rods are attached to the top, back and sides of the conduit frame. Dimensions of the canopy top are 18.5” x 21” x 19.25”. Attachment of the canopy top to the wheelchair is simple and requires no tools or additional material. It is attached by sliding the canopy support bars into 0.75” conduit rods that have been attached to the wheelchair’s seat back.

The desk is adapted from a standard college class room flip desk. Its metal rods are cut and machined so that it can be easily attached to wheelchairs’ sides. When the desk is not in use, but is attached, it can be easily flipped up and tucked to the wheelchair’s side.

Total dimensions and weight of this modification without the canopy top attached are 40” x 29.75” x 35.75” and 75 lbs. respectively.

The total cost of these modifications is $85.
INTRODUCTION
During transport, medical staff members move a patient from one location to another; from a hospital bed to an X-Ray table for example. Currently, this process requires up to six or more medical staff to lift and move patients by their bed sheets. This process can be painful for patients, and troublesome for medical personnel.

The result of this project is a device which aids in transportation of immobile patients. By using this device, not only will fewer staff be required to conduct transfers, but patients will be more comfortable as well. As a result, this can help implement faster and more efficient health care.

SUMMARY OF IMPACT
This device minimizes stress on patients and staff members with its roller and self-supportive arm features. It is designed to be positioned between two locations of the same or different heights. This self-supporting device allows medical personnel to focus on patients, rather than equipment. No physical lifting of patients is involved during a transfer using this device. The roller feature enables patients to be rolled from side to side.

The target environment for use of this device is an emergency room setting. This target environment is selected because it is the most demanding of people and equipment. Therefore, if this device is able to perform here, it will perform in other environments with ease.

TECHNICAL DESCRIPTION
This device is designed to be set up between two separate locations to move a patient freely with the use of rollers inside an enclosed frame. The enclosed frame is constructed from wood. This reinforces the device’s structural integrity. Rollers are constructed from Poly Vinyl Chloride (PVC) tubing with a cap on both ends. A hole is drilled in the caps that allow rollers to be bolted to the frame, yet still spin freely. Around the outside surface of the rollers is a vinyl skirting which moves patients laterally from one location to another. This vinyl fabric is durable and easy to clean.

Four steel rotating locking support arms make the device completely self-supported. They also allow for different height locations to be accommodated. These arms are connected by pushbuttons to two aluminum pipes which run along the inside surface.
of the outer two PVC rollers, and protrude through the frame. When locked, the arms completely support patients’ weight. A C-shaped curl is bent into one end of the arms which allows them to attach to two locations of different thicknesses. Support arms are specifically designed so that patients can be transported from a higher location to a lower one, at a 15 degree angle. They are also designed to be positioned between two locations of equal height.

If this design were to be produced by a medical supplies manufacturer, steps could be taken to improve it. More angle choices for support arms could be added, and overall weight could be reduced by using lightweight medical grade materials.

A 1/3 scale prototype, weighing 16 pounds, was constructed. Patient weight limit for this prototype is 150 pounds. Full scale patient weight limit is 450 pounds.

The 1/3 scale prototype’s cost is $85.

Fig. 14.6. Demonstration of 1/3 Scale Prototype.
MANUALLY PULLEY RAISED PLATFORM FOR PET OWNERS WITH BACK PROBLEMS

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INTRODUCTION
It has been said that owning a pet can extend a person’s life. Also, pets can give a sense of much needed companionship to the elderly or people with disabilities. There are an estimated 68 million dog owners and 73 million cat owners in the U.S. alone. Feeding these pets often requires owners to bend down, but the elderly and people with disabilities may have difficulty performing this task. With this device, bending is no longer needed to feed pets.

SUMMARY OF IMPACT
This device allows pet owners to feed their pets without bending down. The platform of the device raises and lowers pet’s food bowls. Advantages of this device include 1) eliminating the need for bending; 2) accommodation for a range of pet sizes due to an adjustable platform; 3) portability; and 4) no power source is required.

TECHNICAL DESCRIPTION
Dimensions of this device are four feet high, two feet wide and sixteen inches deep. Technologies incorporated in this design are the use of a winch, and cabinet drawer sliders. To stabilize the platform, a winch is used to lock at every position. Sliders are used so the platform remains level while in motion.

A four foot long angle bracket installed along each side of the device guides the platform up and down, and prevents the drawer sliders from going off their tracks during use.

At its highest position, the platform is elevated approximately three feet above ground level. This position allows for pet’s food and water bowls to be filled without bending.

Fig. 14.7. Winch raised platform.

When pet owners want to lower food bowls, they simply rotate the winch’s arm, adjusting the platform to any desired height. At its lowest point, the platform is approximately four inches from ground level so even smaller pets may eat off the platform without straining. When pets are finished with their food or water, users can then pull the winch’s direction switch and rotate the arm in the other direction to lift the platform. A level position is maintained during motion allowing for water to be lowered without spillage. This design compensates for uneven weight distribution so the platform may
sustain unbalanced loads while overall stability remains. The advantage of using a winch is that cranking of the arm takes little to no effort, making it possible for the elderly to operate this device even with heavy loads.

This device is relatively heavy but can be easily pushed along the floor. Bolting to the floor or wall is not required by this design.

Dimensions of this device may also be manufactured to order. If a user wants a shorter or taller device, only drawer sliders and vertical wooden supports need to be changed.

This device need not be used exclusively for pet bowls. Options are endless. Although maximum weight has not been tested to failure, a safe approximate weight is 50 lbs.

Total cost for this device is $94.
RECLINING WHEELCHAIR

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INTRODUCTION
For those using a wheelchair, comfort is a big concern. This project’s goal is to make wheelchairs much more comfortable to sit in for prolonged periods of time. This goal is accomplished by modifying a wheelchair to have a reclining back.

SUMMARY OF IMPACT
This device decreases strain on user’s lower back. It also increases blood flow to the lower extremities, which is a major concern of people with limited mobility. A headrest attached to the chair’s top provides support for user’s head and neck, regardless of the angle of recline.

TECHNICAL DESCRIPTION
A prototype for this project includes modifications of an Invacare wheelchair frame. The original vertically fixed chair back support arms are removed from the frame and replaced with two pivoting arms. These allow the chair to recline back at various angles.

Each arm consists of custom fabricated and pre-made components including: 1) semi-circular base, 2) spring-loaded locking pin, 3) compression spring, 4) spring-pin housing, 5) square tubing, 6) bicycle brake lever, 7) control cable line, 8) two support plates that form a yoke, and 9) handle. The semi-circular base is attached to the frame by two bolts. Fabricated arms are attached to this base by side support plates which form a yoke. This yoke spans the semi-circular base and attaches with a shoulder bolt. Five holes are drilled at 20 degree intervals along the base’s circular perimeter. These holes act as receivers for the locking pin. Each hole corresponds to a different angle of recline.

A compression spring and the locking pin are housed in the spring-pin housing. The purpose of the housing is to give the spring a surface upon
which to compress. This makes engaging various holes along the semi-circular base’s perimeter easier.

The spring-pin housing is press fit and welded to square tubing. This square tubing houses control cable lines, as well as the majority of the pin.

Pins are connected to brake levers by control cable lines. Brake levers are mounted on top of the handle mechanism. When brake levers are depressed, pins are disengaged from a hole in the semi-circular base. This allows the chair back to recline to various positions in its range of motion. When brake levers are released, pins easily go into the next hole along the semi-circular base’s perimeter.

The headrest consists of EMT bent into an arch shape and backed by a piece of plywood. This is screwed to the wheelchair’s custom arms. The headrest moves, as a unit, with the chair back. Closed cell EPDM foam is used to cover the headrest and wooden backing in order to provide users with comfort.

The wheelchair’s back can be easily removed from the frame by removing the shoulder bolt from the semi-circular base and pulling upwards on the fabricated arms. This device is easy to transport, and compact.

This project’s total cost is $115.

Fig. 14.12. Demonstration of use of the Reclining Wheelchair.
MECHANICAL DIGIT PROSTHESIS

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INTRODUCTION

For many years cosmetic thumb and finger replacements have been available. However, there is a growing need for digit prosthetics that allow users to regain some level of articulation. This device makes steps towards meeting that need by providing users with lightweight digit prostheses that require no external source of power.

SUMMARY OF IMPACT

This digit prosthesis allows users who are missing a thumb or finger to regain some of their lost grasping abilities. The major advantage of this design is that it requires no external power source for its use. Motion of the prosthesis is implemented solely by motion of the user’s remaining digits and hand.

TECHNICAL DESCRIPTION

Wooden components were initially used for this prototype. However, if this device were to be produced by an orthopedic manufacturer, all of the components could easily be made of standard material used for prosthetic hands or fingers.

In order to fabricate the prototype, measurements of an adult hand were taken. Dimensions of the model hand are as follows: eight inches long; five inches wide; a palm size of four inches; and ring and middle finger lengths of approximately four inches. All components are manufactured according to these dimensions.

Control of the prosthetic thumb is accomplished through muscular movement and wire that connects fingers to the thumb.

To give the fingers natural bending motion, phalanges are connected on the palmar side to rectangular memory wire (NI-TI, 0.017 x 0.0225 inches). Hollow Teflon tubing is glued on the phalanges’ dorsal side and high tensile fishing line is run through it. Two pulley wheels are attached to the back of the hand through which fishing line is run and connected to the thumb. Tension is maintained throughout the connecting system so that as the middle and ring fingers close, the thumb will also close.
The total cost of the project is $60.

Fig.14.15. Finished Prototype and Wooden Hand Model Comparison.
INTRODUCTION
Great advances have been made in the design and technology of modern prosthetic limbs. However, certain activities, such as bicycling, may be made excessively difficult when trying to incorporate a prosthetic limb. This project’s goal is to create handlebars that transform a regular road bicycle into one that is comfortable to use for a person with a single arm.

SUMMARY OF IMPACT
This design allows a person with a single arm amputation to comfortably use a bicycle without having to support all of their weight on one arm, or attempting to force a prosthetic limb to grip the handlebars. By modifying a bicycle to fit a person’s physical condition, the experience of bicycling will be more comfortable and enjoyable.

TECHNICAL DESCRIPTION
For this design a set of “drop” style road bike handlebars are used. One half of the handlebars remain unchanged to be operated as usual. The other side is modified with an extension to fit a person’s body that has had an arm amputation.

For this prototype, the extension is made by modifying a standard crutch to be much shorter while retaining its length adjustment features. Installed at the crutch’s lower end, where a rubber pad is normally located, is an aluminum insert that had been milled to be press fit inside the leg. A ¼ inch hole is tapped into the insert’s center. Four indentations are made in the leg’s side above the insert to ensure that it is kept flush with the leg’s end.

The handlebars are severed on their left side where the straight and bent “drop” sections meet.
A plastic washer that is flat on one side and curved to match the handlebar’s radius on its other is inserted between the handlebar and extension. This washer allows better contact to be made between the handlebar and extension. Enough friction is maintained at this interface to prevent rotation of the extension to its lower position when a rider is not leaning on its pad.

Once complete, these handlebars may be installed on any regular bicycle. This design allows rotation of its extension, and, is accommodating for a variety of rider sizes and positions.

The only cost of this design is a used set of handlebars, totaling $5. The crutch is an extra from a previous project. If this product were to be made from brand new products, a conservative estimate of the cost is approximately $75.
BASEBALL KICKING GAME

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INTRODUCTION
This project’s objective is to provide children with disabilities an entertaining method of exercise. It can be used by both standing children and those sitting in a wheelchair.

A baseball theme is used to create a fun activity for which children can participate. A “batter” kicks a target to release a ball which rolls down a surface with several holes. Points are determined by which hole the balls fall into. An opening on the unit’s side allows balls to be retrieved. This game may be separated into two pieces for more convenient storage.

SUMMARY OF IMPACT
During a trip to a local school for children with disabilities, importance of activities was stressed. This game is designed to give children an activity that offers them leg exercise, while having fun. Storage space and mobility are also taken into account by this design.

TECHNICAL DESCRIPTION
This game has two main components, a track connected to a target; and a base. Its track and target skeleton are constructed from Poly Vinyl Chloride (PVC) pipe. The target is made from clear polycarbonate. Protruding from the base is a straight, upright piece of PVC pipe, followed by another piece which is angled 45 degrees to the game’s back.

The next section is a short, upright piece of PVC pipe that connects to a horizontal section. This horizontal section acts as a housing for an axle connected to the target’s top. This axle acts as a center point for the target’s turning radius.

A friction fit is used to hold the PVC section and base together. This allows the track and target portion to be separated, decreasing the unit’s size for storage.

This friction fit also allows the track to be rotated. Doing so creates more variability when a ball rolls. A kicking height of up to two feet from ground level is accommodated by the target. This allows for use by both standing users and those in wheelchairs. The ball track is constructed from two PVC pipes attached parallel to the 45 degree angled section. Balls are held back by a PVC piece attached to the target’s top. Kicking the target raises this PVC piece.
and releases balls. After rolling down the track, balls roll onto the base’s top surface.

The base is made from wood with several holes drilled in its surface. When balls fall into a hole, they hit a lower surface. This surface is angled so balls roll to one side of the base. A hole on the base’s side allows users to retrieve balls. Lockable casters mounted to the base allow it to be easily moved. The total cost of the project is $113.
INTRODUCTION
This project is intended to assist people who use wheelchairs by offering them more control when travelling down inclined surfaces.

The brake system is similar to those featured on mountain bikes, but requires only one handle for brake actuation of both wheels.

SUMMARY OF IMPACT
This modification will be particularly useful to those wheelchair users traveling down inclines regularly. Additionally, users who have difficulty using traditional hand rail brakes, or those who simply desire a more reliable braking system will also benefit greatly from the single lever braking.

Versatility is the leading advantage of this brake system. It allows for placement of its lever almost anywhere on a wheelchair’s frame and attachment of the wheels to almost any existing wheelchair. As a finished product, the brake system consists of pairs of brakes with a single activation lever to eliminate the need for users to balance out braking force on each wheel separately.

TECHNICAL DESCRIPTION
This modification includes: 1) two wheels, 2) two rotors, 3) two calipers, 4) one lever, and 5) appropriate cables.

The disc brake modification consists solely of existing technology already available on the bicycling market. However, this technology has not previously been applied to wheelchairs.

When applied to a wheelchair, this modification will have little to no impact on upper portions of the wheelchair, offering users identical mobility as before. The wheels themselves consist of standard mountain bike wheels equipped with a disc brake compatible hub to allow mounting of the rotor.

Essentially any appropriate bicycle tire could be used to allow for optimal performance. Twenty-six inch diameter wheels are used so that if desired, a standard type handrail could be attached. Greater rolling capabilities could be offered by attaching a disc brake compatible road bike wheel. A six inch diameter rotor, made by Avid Brakes, is used for this modification. Attachment of this rotor to its hub is accomplished using six Allen bolts.
To eliminate mixing and matching of parts, a rotor from Avid Brakes was chosen because it includes a set of universal mounting holes that allow it to be mounted to any disc brake compatible bicycle hub rotor. Replacement brake pads are also included.

An integral adjustment knob allows for the distance between brake pads to be adjusted, giving users further control over their braking. This knob may also be used to lock pads on the rotor, doubling as a parking brake. This allows for modified wheelchairs to be left unattended without fear of rolling.

Calipers are cable activated using a standard bicycle braking cable to squeeze pads together. The brake lever is similar to those typically found on mountain bikes. A C-shaped clamp allows for easy and convenient mounting on nearly any straight section of frame tubing that is similar in dimension to a handlebar.

The user is able to choose the location of the lever as only a single one is required in this design.

In order to operate a two wheeled system with only one lever, a single cable from the lever is attached to a three-way cable coupling and the other two ports are connected to each of the brake calipers. This design allows for equal braking force to be distributed to the two brake calipers from a single lever.

Total budget for this project is approximately $175.
THE ADAPTA-BOARD

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INTRODUCTION

The Snowboard for persons with disabilities, or Adapta-Board, is a snowboard attachment designed to accommodate people who have impairments below the waist.

This device not only allows people with disabilities to try snowboarding for their first time, but also allows someone who had been a snowboarder, prior to a disability, to continue their hobby with a minimum purchase of new equipment. It is used with a standard snowboard deck and does not require any modification.

SUMMARY OF IMPACT

Devices which allow people with disabilities to ski and snowboard do currently exist. However, these designs all have individuals facing downhill, which is not optimal position for traditional snowboarding. This design provides a truer snowboarding experience by seating the user sideways on the board.

TECHNICAL DESCRIPTION

A prototype is constructed which consisted of 1) two support towers, 2) a snowboard deck, 3) control handles, 4) a seat frame, and 5) two T style bars. Aluminum is used for metal structures to minimize weight. The two support towers are welded to a plate which is bolted to the snowboard deck’s binding holes. Slotted plates are welded at the top of the support towers to secure the chair/frame that holds the user.

Also attached to the binding plates are handle devices. These are constructed from two walking assist handles, modified to fit the Adapta-Board. Strong outer sleeves are welded to the binding plates and reinforced with triangular gussets. Handles are cut to size, inserted into sleeves, and welded in place.

The frame/seat is constructed from 1 ½" Polyvinyl Chloride (PVC) pipe to minimize cost and weight. Standard PVC joints are used to construct this frame.
T bars are manufactured to fit the PVC frame and provide an interface between the frame and seat plates. A PVC pipe is fit into the bar; bolts are run through the bar’s vertical piece, and the PVC pipe. T bars are slotted in such a way that they can be bolted to the upper plates in different positions. This allows users to change both the angle at which they sit and the location of their center of gravity.

For a final model, material similar to that used in construction of the snowboard itself would be used for all components.

This project’s total cost is $203.

Fig. 14.27. Use of Adapta-Board.
INTRODUCTION
This project’s goal is to help people with disabilities pick up small objects that would normally be out of their reach. The device designed consists of a grabbing mechanism mounted to the end of a beam which is controlled by the power of the user’s hand.

SUMMARY OF IMPACT
This device allows users with difficulty bending and reaching a way to regain a measure of these abilities. By extending a user’s grasp, this device allows them to perform tasks including, but not limited to, retrieving objects from the ground without bending or those on a high shelf without using a step ladder.

Allowing users to perform such tasks reduces their dependence on other individuals and affords them greater freedom.

TECHNICAL DESCRIPTION
The prototype consists of: 1) a stabilizer arm which secures the device to users, 2) gripping mechanisms, 3) triggers that control gripping mechanisms, 4) a handle, 5) A two foot long beam which extends the user’s reach, 6) Teflon line to connect triggers and gripping mechanisms, and 7) guide pins which direct Teflon line.

The main body consists of a one foot long, one inch diameter, 1/16 inch thick aluminum pipe welded to a five inch long pipe of equal diameter and thickness at a 60 degree angle. The handle is made from another five inch long pipe of equal diameter and thickness. This is welded to a pair of two foot long 1/2 x 1/16 inch channels, also at a 60 degree angle.

This project’s cost is $118
Fig. 14.29. Operation of Prototype.

Fig. 14.30. Operation of Prototype.
HELPING HANDS REHABILITATION LIFTING CHAIR

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INTRODUCTION
Using a standard chair can be quite challenging for people with decreased mobility or muscle strength. The purpose of the Helping Hands Rehabilitation Lifting Chair is twofold. The first is to increase the amount of time spent supported by a chair during sitting or standing. The second is the bending of the hip of the user. There are similar products currently available that utilize an electro-mechanical or pneumatic system for seat rising. This project focuses on a completely mechanical system to eliminate the need for an external power source, thereby allowing a greater range of use.

SUMMARY OF IMPACT
This device allows anyone with limited mobility and strength to navigate easily from a sitting to a standing position by removing the need for their body to bend to a 90 degree angle as required by a standard chair. This device may be utilized both in professional and private settings.

The one major technical aspect of this design that distinguishes it from similar products available is that it is a completely mechanical system that does not require a power source.

TECHNICAL DESCRIPTION
This prototype is constructed from 1) 1 ¼ inch PVC pipe; 2) ¾ inch plywood; 3) 1 ¼ inch pulleys; and 4) 3/16 inch cable. Plywood surfaces are covered with a synthetic vinyl material for aesthetic purposes.

This device’s lifting mechanism consists of four parts: 1) a tilting seat; 2) cable and pulley system; 3) rotating footpad; and 4) adjustable height legs.

Fig.14.31. Lifting Chair Prototype.

Pipe clamps that allow for rotation are used to connect the seat and forward cross bar of the frame as well as the footpad with the rear crossbar.
Bolts are replaced when the second set of holes has been lined up and are then secured using wing nuts. Cable clamps beneath the footpad are repositionable using a 5/16 inch wrench and utilizing the marks on the cable which indicate clamp positions for various heights.

To operate, users first stand on the footpad with their back to the chair. As users sit down and transfer weight from the footpad to the seat, it slowly lowers.

Cables are run from the chair’s arms, around pulleys, and back through the arms down to the footpad. Spare cable is included in the footpad so that its length may be adjusted to accommodate the chair’s highest setting.

Leg height adjustments must be made when the chair is not in use, and will typically require two people. To adjust leg height, the four bolts and wing nuts need to be removed, and the 1 ¼ inch PVC frame and one inch PVC base must be separated.

The foot pad in this position will be raised and can be used as a foot rest. To stand up, users lean forward and put pressure on the footpad which will raise the seat approximately six inches. The footpad remains in its lowered position when not in use so as not to be a trip hazard for users.

Total cost of this prototype is $72.
QUICK FOLDING WHEELCHAIR DESK ATTACHMENT

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INTRODUCTION
This device is geared towards a professional and student based clientele who frequently change locations and require easy access to a functional workspace. This device’s intended purpose is to offer users a desktop that is always accessible, yet never in their way.

The Quick-folding Wheelchair Desk attachment is a flat surface, suitable for working, which attaches directly to a standard wheelchair, and may be stowed out of a user’s way when not needed.

SUMMARY OF IMPACT
While numerous wheelchair-compatible desk designs are currently available, most suffer from any combination of the following disadvantages: 1) they are large, floor-mounted units that offer no form of portability or mobility; 2) they require modification of wheelchairs and are therefore difficult to install and remove; and 3) they offer no portable storage solution when not needed. This device resolves these issues by providing a drop-in desktop that is mobile, quick and easy to store and retrieve, and is unobtrusive when in its stored position.

TECHNICAL DESCRIPTION
This design’s principle idea is that a set of folding arms, mounted to a wheelchair’s frame, allow a desktop to be attached. This desktop may be extended in front of users, and retracted overhead for convenient storage.

This device is comprised of four main components: 1) desk and arm assembly, 2) mounting frame for item one, 3) A front cross-beam which supports the desk when in use, and 4) A set of rear support hooks which hold the desk in its storage position.
The desk and arm assembly is comprised of: 1) two jointed aluminum arms (welded with a cross-beam at one end to form a U-shaped frame), 2) a desk component (constructed from wood) which slides on these arms, and 3) an aluminum support beam which keeps the assembly propped up when in use.

Coupling of the desk and arm assembly with a wheelchair is done by the mounting frame. Arms pivot about this component over a set of bearings. This component connects to a wheelchair by way of four vice screws, allowing the frame to be clamped on without tools or chair modifications. Having no requirement for tools allows the product’s bulk to be quickly removed when not needed.

Four screws are used to connect the front cross-beam to the front of the wheelchair. This provides a mounting point for the support beam. Rear support hooks attach to the rear handles of the wheelchair with four screws.

This project’s material cost is approximately $100, excluding the wheelchair, which was donated.

Fig. 14.36. Use of the modified wheelchair.
INTRODUCTION
This project’s objective is to prevent and treat idiopathic toe walking (ITW) as aesthetically as possible. Current braces available to prevent ITW are very bulky. Therefore, it is desired to prevent and treat ITW with an insert that could fit into a child sized shoe.

SUMMARY OF IMPACT
This design is based on discussions with a physical therapist that deals with ITW and is also a certified prosthetist and orthotist.

Since current ankle-foot orthotics (AFO) for ITW are out dated and a simple insert type design was not currently available, this prototype was designed based on input from the aforementioned professionals.

This design’s concealed nature allows any child to be worry free about appearance thus encouraging longer wear times than previous braces. This insert deviates heavily from braces currently available in its size, geometry, and methods used to inhibit ITW.

TECHNICAL DESCRIPTION
To minimize material usage and weight, two struts are positioned on top of the foot and in front of the ankle and shin rather than below and behind the foot and calf.

Due to the opposing nature of this brace when compared with existing AFOs, it is necessary to deviate from use of a standard tamarack joint as well. A combination of a stop and Chicago screw is used, as seen in Figure 14.37. This mechanism is simple, functional, and very slender with respect to a tamarack joint.
When a child tries to plantar flex, this motion calls for the foot splint to rotate clockwise, looking from the right. This motion is inhibited once the foot splint’s arm reaches the anterior strut arm’s 90 degree bend. This mechanism is shown in Figure 14.40.

A child is still able to walk with a normal gait that includes dorsiflexion. As a child dorsiflexes, flexing their foot back in taking a step forward, the anterior strut rocks forward and the foot splint rotates counter clockwise from the right. This is why the anterior strut arm’s bend tapers up, to allow natural rolling of toes toward the shin.

To fabricate early prototypes, a material called Aquaplast was used. General forms for the two components were cut and placed in hot water. Once pliable, forms were removed, molded over a foot and held under pressure until solidified. The anterior strut was formed second due to its geometric dependence on the foot strut.

After testing, it was discovered that a material with more rigidity was required. Polypropylene, a stiffer thermoplastic polymer, was selected. Using this new process, a plaster cast of a foot is made and sent to a fabrication shop where polypropylene is formed to the foot’s shape. Chicago screws are used for joints and a non-elastic Velcro is used for straps. A final fit is performed once excess polypropylene is removed. The final product fits into a shoe and is able to prevent a toe-toe gait and only allows a normal gait.

Through generous donations, this project’s cost is $0.
INTRODUCTION
For persons using wheelchairs, going up slopes may often present a challenge. Standard wheelchairs are propelled forward by directly rotating their wheels by hand. This movement requires users to move their hands back and forth, temporarily releasing wheels. If on a slope, this temporary release may cause users to roll backward.

This difficulty is overcome using this device. It consists of a set of hand cranks, mounted to a wheelchair’s frame, which are used to rotate the chair’s wheels. By rotating wheels in this fashion, users may continuously apply power instead of in bursts as before. Two separate cranks are used to allow users to easily maneuver their chairs.

SUMMARY OF IMPACT
By powering wheelchairs with cranks as opposed to the standard method, users are able to move their chairs in a smoother, more continuous fashion. This makes travelling uphill significantly easier. Also, introducing a gear ratio between handles and wheels reduces the amount of upper body strength required for propulsion.

TECHNICAL DESCRIPTION
Cranking mechanisms are constructed from bicycle parts. Two drive trains consisting of: 1) pedal assembly, 2) front and rear sprockets, 3) chain, 4) connecting tube, and 5) rear tire, are removed from bicycles and their pedal assemblies are replaced with hand cranks.

These drive trains are then clamped to a wheelchair’s frame so that the rear tires and chair wheels are in contact. Springs are used to keep the connection between tires and chair wheels tight so that a maximum amount of energy will be transferred.

Using springs and clamps allow the whole assembly to be adjusted to suit the user’s specific needs.

This project has an overall cost of $145.
Fig. 14.42. Hand Crank Drive Train.

Fig. 14.43. Close up of Spring Attachment.
WALKER WITH RETRACTABLE WHEELS, BASKET AND HOOKS

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INTRODUCTION
Walkers currently available come with no wheels, two wheels or four wheels. This project’s objective is to design and fabricate an aftermarket retracting wheel mechanism for walkers. This design aims to bridge the gap between walker users with zero and two wheels.

Also, it is desired to include modifications, such as baskets and hooks, to make walkers multifunctional. These modifications are a cheaper alternative to purchasing a new walker and may easily be used on most existing walkers.

SUMMARY OF IMPACT
This modification’s retracting wheel mechanism attachment enables users to have more control over deployment of wheels on a walker. A locking device is also added to hold wheels in either an up or down configuration when walkers are in use.

Utilizing these two core functions, walkers currently available can be adapted to mini shopping carts by attaching a basket and hooks for plastic bags.

Fig.14.44. Walker Prototype.

Fig.14.45. Wheel Attachment.

TECHNICAL DESCRIPTION
This modification’s wheel retracting mechanism is made of a combination of aluminum and polyvinyl chloride (PVC) tubing. Its internal mechanism is constructed from aluminum while its frame for holding internal parts is fabricated from PVC tubing.
Users push the handle mounted lever down to lower wheels on both sides and pull up to retract them. Wheel deployment is controlled by springs.

A locking mechanism consists of two conduits that hold the handlebars and a secondary system consisting of pins which prevent handlebars from dropping.

This modification may be easily removed by unfastening the U-Bolt located at the mechanism’s base. A basket and hooks are secondary attachments which aid in the tasks of shopping and holding loose items.

This project’s cost is $130.
INTRODUCTION
A traditional vacuum cleaner requires users to grip its handle in order to maneuver it. Users with minor hand disabilities, such as arthritis, or loss of dexterity, often have trouble with the required gripping. Users with major hand disabilities, such as loss of gross motor function or digits, may not be able to maneuver a traditional vacuum cleaner at all.

This project’s goal is to aid those with minor to major hand disabilities with the use of traditional vacuum cleaners. This is accomplished by creating a handle attachment that requires no gripping; only pushing and pulling. In addition, for cases when a user is not capable of pushing and pulling, an attachment requiring no hands is designed.

SUMMARY OF IMPACT
The biggest accomplishment of this design is reducing strain on hand and elbow joints by orienting a handle in such a way that users are only required to push and pull. It also allows users who were previously unable to use a vacuum to do so with a modification that attaches around the waist. This allows users to operate vacuums with no use of their upper body.

This system allows users to remain self-reliant and does so for a much lower cost than current alternatives. Most alternatives available require users to purchase new vacuum cleaners that are either specially designed or robotic. This design adapts to traditional vacuum cleaners.

TECHNICAL DESCRIPTION
A 1.5 inch diameter, seven inch long piece of poly vinyl chloride (PVC) pipe that is cut axially to 4.75 inches, is placed over the vacuum’s handle. A rubber strip is fixed inside the pipe to achieve a tighter fit around vacuum handles. Velcro is also used to secure this piece.

The component that is held by users is also constructed from 1.5 inch diameter PVC pipe; five inches long with 90 degree connectors on both ends.
On one end, this connector has a two inch long, 1.5 inch diameter PVC pipe. This is connected to a two inch diameter PVC pipe by a bolt that runs through both pipes. This two inch diameter piece contains a 3/8th inch hole which allows the valco to connect the two pieces.

Assembly of the hands free modification is carried out as follows: on the side opposite to the valco hole, two 1.25 inch PVC pipes are connected with bolts. These pipes, about two inches long, are then connected with 45 degree connectors (facing opposite directions) to a 5.5 inch pipe of equal diameter.

To connect the remaining pieces, valco is placed inside the handle cover’s uncut end. This assembly is used to connect both the handle and hands free modifications.

They are then connected using 45 degree connectors (again in opposite directions) to a three inch long pipe. When this is assembled, the last two pieces of pipe are parallel to one another and 12 inches apart. Connected to these two pieces is an adjustable belt that straps around the waist and secures to the device.

This design’s cost is about $20.

Fig. 14.49. Use of Hands Free Attachment.
ONE HANDED BATHROOM TISSUE DISPENSER

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INTRODUCTION
Conventional bathroom tissue (BT) dispensers consist of either a roller mounted into a wall fixture, or a large dispenser with a small opening that BT is pulled through. For a person with use of only one hand, rollers make it impossible to tear BT without pulling out more than is needed. Dispensers may have a serrated edge that is meant for cutting, but the tension and angle required to tear BT can make folding afterwards difficult. Both types require use of two hands to work efficiently.

The goal of this project is to develop a device that can fold and cut BT neatly and quickly with one-handed operation.

SUMMARY OF IMPACT
This device makes the life of a person who has use of one hand easier, especially if they are living alone.

With this device, only one hand is required to dispense, cut and fold BT. It may easily be mounted in either public or private settings.

TECHNICAL DESCRIPTION
This device consists of four main components. They are mounted in the following order from top down: 1) a stationary wooden rod that holds BT, 2) a pair of rollers that pull BT through the device, 3) a pair of spring loaded scissors that cut BT, and 4) a folding mechanism that winds up BT.

All components are attached to a single piece of Plexiglas that serves as a base with the exception of one roller. This roller is attached to a smaller piece of Plexiglas that serves as a cover.

Rollers are made with felt washers that are slid onto wooden rods and kept in place by metal washers and retaining clips. These rods are then mounted into bearings that are fitted into the Plexiglas.

The folding mechanism consists of two smooth rods that are mounted to a thin plate. These rods are spaced approximately four inches apart (side length of a BT square). The thin plate is attached to a short wooden rod. A sprocket that is chain driven by the roller is mounted onto this rod. This rod is then mounted into a bearing that is fitted to the base.

Fig. 14.50. Close up of Folding Mechanism.
The base mounted roller is unique in that it has a sprocket attached between its bearing and retaining clip to drive the folding mechanism. Also, an operating knob is mounted on this roller.

A pair of scissors is mounted into a nylon block that is fitted into the Plexiglas. One of its blades is fixed, and its other is attached to a spring and handle. The spring’s other end is fixed to the base.

The Plexiglas cover is attached so that it moves in a plane parallel to the base. It is hinged so that it opens upward for BT loading. BT is loaded so that the free end’s edge extends beyond the scissors. The knob is twisted so that BT is pulled downward by the two rollers. Also, as the knob is twisted, the rods rotate and can wind up BT when it has extended beyond the folder (approximately eight inches) and is placed between the two rods. Once BT on the rods is of desired thickness, the scissors’ handle may be pulled to cut BT. Users then remove it from the folding mechanism.

This project’s cost is approximately $151.
MULTIPURPOSE CADDY FOR WHEELCHAIR, CRUTCH, CANE OR WALKER

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INTRODUCTION
This purpose of this project is to design a device that carries personal items for people who need their hands free to use a wheelchair, crutch, cane, or walker. This attachment is easily attachable to all of the aforementioned devices. It has multiple inserts (shown in Fig. 14.55) to optimize the Caddy for different situations.

SUMMARY OF IMPACT
This device has potential to benefit a wide population from those who use a cane every day, to those who will only use a wheelchair temporarily. With multiple inserts, the Caddy can be optimized for travel inside and outside of users’ homes. It may also be tailored to each individual’s particular needs. This increases the ability to operate an assistive mobility device while not giving up a standard convenience.

TECHNICAL DESCRIPTION
The Caddy’s design is built upon a requirement that it needs to be easily detachable, but stable while providing a simple area to carry the owner’s personal property. It consists of a rectangular body cavity measuring 5.5 x 4 x 3 inches. Currently, three inserts featuring different style compartments are available. More inserts may easily be created to suit specific needs.

The body is made from 3/16 inch thick acrylic. Attaching clamps (as seen in Fig. 14.54) are made of hard plastic. Clamps are opened by lifting and pulling the plastic node on the clamp’s exterior.

Clamps are closed by pushing their rotatable acr. Rubber grippers on the clamps stabilize the Caddy while attached.
Clamps may be used on any cylinder with a maximum diameter of 1.375 inches. This makes it usable for most canes, crutches, walkers, and wheelchairs.

All inserts are held in place by a force fit with the Caddy’s body. Clamps are connected to the body by bolting on 2.5 x 0.5 x 2.5 inch blocks.

Features of the three inserts are as follows:

1) A three inch diameter beverage holder and molded space for miscellaneous small items such as pill containers, cell phone, music device, pen and keys.

2) Molded compartments that are better suited for carrying larger items than the first insert.

3) A combination of the first two inserts, that is, a beverage container and molded compartments for larger items.

This device’s cost is approximately $20.

Fig. 14.55. Caddy and three separate inserts.
WHEELCHAIR BOWLING ATTACHMENT

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INTRODUCTION
This project is designed to help those with limited use of their arms enjoy a game of bowling. A track, that has been optimally designed to simulate a person's arm movement, fits as an attachment to wheelchairs. Width and height adjustments may be made, allowing it to be used with wheelchairs of varying sizes. This attachment can be used with wheelchairs that are controlled by a sip and puff mechanism, or are electronic.

SUMMARY OF IMPACT
Those using wheelchairs with little or no use of their arms can, with assistance from this device, easily play a game of competitive bowling. While conceptualizing this design, the following factors are considered: 1) ease of portability, 2) device weight, 3) ease of assembly and disassembly, 4) compatibility with most chairs, and 5) device cost.

TECHNICAL DESCRIPTION
A bowling ball rests on the wooden track before approaching the bowling lane. As users stop at the foul line, the ball's momentum causes it to roll down the track, onto the lane. The track is indented where balls rest to prevent them from falling backward.

This device consists of three main components: 1) clamping mechanism, 2) height adjuster (attached to the track) and 3) width adjuster.

Assembly is accomplished in three simple steps. First, two rods are clamped on each side of a wheelchair. Then the width adjuster is attached to these rods, using springs. Finally, the track's aluminum plate is screwed to the width adjuster. Castors are attached to the track's base for portability.

Width of the attachment may be adjusted by first loosening knobs located on the cross bar (Fig. 14.57).
of the track’s outer sides. A locking knob, located in the bars, may be loosened, allowing for vertical motion of the assembly. Once a desired height is reached, knobs are re-tightened.

The attachment’s total weight is 26 lbs. This project’s total cost is $50, not including the wheelchair (donated by Sheridan Surgical).
INTRODUCTION
This goal of this device is to provide comfort while typing to an individual with severe wrist arthritis. Conventional keyboard and desk combinations do not provide comfortable positions for wrists during extended periods of typing. Keyboards should be tilted away from the user in order to avoid straining muscles and tendons in user’s forearms. By modifying a desk with the addition of an adjustable tray that allowed for tilting of keyboards, strain occurring during conventional typing is alleviated. Adjustable armrests add comfort, and reduce stress on upper arms and shoulders.

SUMMARY OF IMPACT
Typing with a keyboard angled towards a user increases strain on forearm muscles and stress on already irritated joints. This discomfort is increased if wrist braces are needed while typing due to the upward position of the wrists. This motion forces the backs of the user’s hands against braces causing irritation.

There are currently no desks available that tilt keyboards away from users. Flat keyboards are available, but these do not eliminate stress and strain to the extent of this device. A flat keyboard in conjunction with this device provides an optimum level of comfort to users.

Fig. 14.59. Desk with Adjustable Keyboard Angle & Armrests.
TECHNICAL DESCRIPTION
This device is designed around the frame of an existing table by replacing the top and adding the desired features.

An adjustable center leaf accommodates varying user arm lengths. This leaf may also be completely removed from the desk if desired. Its overall dimensions are 30 x 30 inches.

In the removable leaf, an adjustable keyboard tray is cut two inches from the front to allow wrists to rest while typing. This tray is hinged so keyboards may be tilted away from users by an adjustment knob. A maximum angle of 16 degrees is allowed by the tray which is 28 inches long and 9 inches wide. These dimensions allow room for a mouse in addition to a keyboard.

The design also accommodates placing a monitor on the removable leaf behind the tray’s adjustment knob.

Retractable armrests are made of pieces of wood (Oak) that are fastened to the desk by sliders, each with two locking hinges. Locking hinges allow for a less intrusive design when armrests are not in use, and easy accessibility when needed. In the down position armrests can slide out of the user’s way. When needed, armrests can be locked into a support position and brought to a desired position along the desk’s front. Armrests are unconstrained laterally along the desk’s front while in their support position to allow for continued support if users move to another position on the desk.

This project’s cost is $70.

Fig. 14.60. Use of the Desk.
ELBOW CONTROLLED COMPUTER MOUSE HOUSING

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INTRODUCTION
People with finger disabilities may have difficulty using a regular computer mouse as fingers are required to maneuver the mouse, click buttons, and scroll.

There are different kinds of pointing devices for persons with disabilities currently available, but they are often inconveniently large and expensive.

This design may be used with any standard mouse to allow operation by elbows, rather than fingers. It does so with reasonable cost and size.

SUMMARY OF IMPACT
Anyone who has trouble using a mouse with their fingers may use this device. This design’s advantages are that it is portable, inexpensive, easy to install, and may be used with almost any mouse. Different sizes may also be developed to accommodate users with different arm sizes.

Use of this device is restricted only to users who have dexterity in their arms and elbows.

TECHNICAL DESCRIPTION
This device has three main components; mouse-housing, elbow rest, and clicking mechanism. A prototype is composed of candle wax for manufacturing convenience.

The mouse-housing is designed to fit most standard sized mice. Since different mice have different curvatures in their shape, the clicking mechanism is designed to be adjustable.

To facilitate movement, one ball transfer and two marbles are attached on the bottom of the device. The ball transfer is used to minimize friction between the device and surface during movement.

However, in order to click, some kind of grip is needed to prevent the device from moving. Hence, a small amount of rubber was placed toward the front of the device to supply this grip when the clicking
mechanism is engaged. The rear of the device, where its ball-transfer is located, does not contact the surface when clicking is performed.

The bar of the clicking mechanism is composed of Aluminum and two springs are attached to each bar. A small spring is attached under the bar where the adjustment screw presses. A larger spring is located on top of the bar to guide it in the correct direction. These two springs are compressed when the bar is pressed.

The armrest is covered with rubber in order to have firm control while in use and is slightly concave for comfort.

To install, the device is placed on a regular computer mouse with its armrest pointed towards the user. The screws are then adjusted to ensure the device is properly located.

This cost of this project is about $40.

Fig. 14.63. Operation of the Mouse Housing.
SUITCASE WHEELCHAIR

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INTRODUCTION
This purpose of this project is to create a wheelchair that is easier for a caregiver to handle. This wheelchair’s size, when unfolded, is equal to that of a traditional wheelchair. However, this design folds up into a small compact package. When in the collapsed position, the suitcase wheel chair can be carried or towed, rolling on casters similar to luggage.

SUMMARY OF IMPACT
Traditional wheelchairs have only a single fold that is not enough to allow them to be placed into small automobile trunks or carried up stairs with ease. This design folds into a box so it can be loaded into a car, or conveniently stored when not in use. Also, transportation of this design, in its collapsed position, is significantly easier than that of a standard collapsed wheelchair thanks to a telescoping handle and a set of casters.

TECHNICAL DESCRIPTION
Material used for a prototype is chosen for strength and workability. In production, this device would be made of materials more properly suited for a medical device.

The case is 24 x 24 x 8 inches, constructed from 0.75 inch plywood. Ideally, wood would be replaced with a lightweight aluminum or a composite such as carbon fiber. Case dimensions are determined through research of current suitcase sizes, and requirements based on items contained inside.

Forward casters are plastic with brakes and rubber wheels. Aft wheels are 17 inches in diameter with bearings. Both forward and aft hardware are attached to struts made from telescoping aluminum conduit.
To allow aft wheels to be placed under the chair’s center of gravity, universal joints are used at the aft hardware and case junction, and their support strut can also telescope. Once opened, aft hardware locks into catch clamps, and then is pinned to prevent unexpected collapsing.

Forward hardware is locked into its open position by a telescoping armature which extends between the lower rung of the footrest and the case.

To form a chair back, the lid of the case is rotated 270 degrees from its closed position. The user then sits on the case’s bottom.

Conduit is used to construct the carrying and pushing handle. This handle telescopes to allow for comfortable towing of the chair in its collapsed position. It is also used to secure the chair back in its open position.

A bend on the carry handle is necessary for comfortable carrying over the case’s center of gravity, and to provide a push handle.

The case locks closed with two hasps. This prototype has a weight of 40 lbs., which is slightly more than traditional wheelchairs. With proper materials, weight could be significantly less than a traditional wheelchair.

This prototype’s total cost is $180.

Fig. 14.66. Use of Chair.
INTRODUCTION
This device is designed to provide users with protection from adverse weather by introducing an overhead canopy. It attaches easily on a traditional wheelchair. This design is simple to install and operate, and is inexpensive.

SUMMARY OF IMPACT
Currently, protection from weather for wheelchair users is offered only by whatever protection a user can carry. Since many wheelchairs are hand powered, having to hold a protection device, such as an umbrella, can be inconvenient.

This device rectifies these inconveniences by offering users protection from weather that is adjustable both vertically and horizontally. The canopy may be moved up and down on its supports, and may also be collapsed backward.

TECHNICAL DESCRIPTION
This device attaches to a standard wheelchair by way of four specially designed clamps. An upper and a lower clamp are used on each side of a wheelchair. These are designed to be placed on a wheelchair’s vertical structural tubing, and hold the canopy’s support tubes. Upper clamps allow support tubes to pass through, while lower clamps do not, ensuring equal height is maintained between canopy support tubes. All tubes are held in place using set screws inserted through holes in the clamps.

Typical pushbutton style height adjusters are riveted onto the support tubes being clamped in place. These height adjusters have seven height choices. Two aluminum tubes, each with a pushbutton, are manufactured to be used in these height adjusters.

The modified aluminum tubes are held together by a segment of aluminum bar. Attached to the top of the tubes are mechanisms which allow for extension and retraction of the canopy.

With these premade mechanisms, a travel distance of up to 20 inches is permitted; this is slightly farther than the chair’s seat edge. An aluminum bar is also used to constrain the moving ends of the extension mechanisms.

A clear, waterproof, vinyl based material is used for the canopy. This design was tested in rainy conditions.
conditions and succeeded in keeping the user dry. This project’s total cost is $85.

Fig. 14.68. Wheelchair with Canopy.

Fig. 14.69. Close up of Clamps.
PORTABLE & STORABLE WHEELCHAIR WORKSTATION ATTACHMENT

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INTRODUCTION
For individuals consistently using wheelchairs, simple tasks such as writing or operating a lap top computer comfortably may be challenging. They are often forced to rely on facilities having flat surfaces designed for wheelchair accessibility.

This main objective of this project is to build a specialized workstation attachment for standard wheelchairs. This workstation is attached directly to wheelchairs so it may be transported by its user rather than being carried by a caretaker. This workstation is a board, supported by a tubular aluminum arm that’s adjustable in length, and rotates, allowing the workstation to be stored behind the user’s head.

SUMMARY OF IMPACT
This project’s design challenges include: 1) having enough clearance between the vertical tube’s lower portion clamp and the chair’s right wheel, 2) having sufficient strength to handle loads induced by workstation components and user’s items, and 3) to make retrieving the workstation from its stored position, and placing it in its working position as comfortable for users as possible.

TECHNICAL DESCRIPTION
The main component of this design is the bracket where both the adjustable arm and vertical swing pipe will be joined. Two pins are inserted; one holds the arm in place for folding down when stored, and a second that locks the arm pipe when in use. This pin prevents the workstation from falling once it has been raised.

Two aluminum clamps with one inch holes on one end and U-slots on the other are attached to the chair.

Fig. 14.70. Workstation Attachment.

Fig. 14.71. Workstation Attachment in Stored Position.

The bracket and vertical pipe are welded together, which allows the supporting arm to be swung around as previously mentioned. The adjustable arm pipe is divided into two pieces an outer pipe
which has a single row of holes on its top side, and an inner pipe which has a dual side V-lock.

These holes allow the vertical swivel pipe to slide into them while the other ends of the clamps grab onto the arm rest frame and are screwed tightly to the chair without modification.

This system allows the workstation to be moved out of a user’s way and placed at different distances from the chair’s back.

This design is ergonomically pleasing, adjustable, and lessens the wheelchair user’s burden. It has an overall cost of approximately $125.

Fig. 14.72. Use of Workstation Attachment.
RANGE SENSING WRISTBAND WITH VIBRATION FEEDBACK

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INTRODUCTION
The range sensing wristband with vibration feedback grants visually impaired individuals the freedom to familiarize themselves with their environment without ever having physical contact.

The distance between users and an object directly in front of the range sensor is translated into vibration pulsations of different frequencies that can be easily felt by users at their wrist, thereby providing an alternative way of visualizing their environment.

SUMMARY OF IMPACT
Common usage of guide dogs or canes by visually impaired individuals to navigate through everyday obstacles can be cumbersome or inefficient. These existing methods are even less effective in places where animals are not allowed or fragile objects are present. This technology allows users to navigate without having to physically touch their surroundings.

TECHNICAL DESCRIPTION
The prototype for this project consists of a microcontroller, range sensor, vibration motor, and power supply.

A PIC16F628A microcontroller from Microchip Technology is used. This model includes analog voltage comparators and CMOS outputs that are used to provide fine control between the range sensor and vibration motor.

An infrared triangulation-based range sensor, manufactured by Sharp, provides an analog voltage output proportional to detected distance.

The vibration motor is similar to those used in modern mobile phones to provide silent notifications.

A power supply provides separate power sources for the various components from a single nine volt battery, while protecting them from current surges.

Remaining components are housed in a plastic box with a built in power switch. Once turned on, the
range sensor begins to output analog voltage to the microcontroller, which then compares this input to various internal reference voltages, and outputs five volt signals to a P-N-P transistor which activates the vibration motor whenever applicable.

When objects are out of range (80 cm for this prototype), the vibration motor begins to emit double pulses. These pulses signal that the device is operating correctly, but no objects are in range. Otherwise, frequency of pulsations increases as objects approach the range sensor, providing the necessary feedback for users to familiarize themselves with their surroundings.

The range sensor and vibration motor are mounted on a Velcro wristband with adjustable straps. A plastic shim is placed underneath the sensor in order to allow its line of sight to extend beyond user’s knuckles.

The average current consumption of this unit is approximately 120 mA while pulsing at its highest frequency. This equates to roughly six hours of operating time on a standard nine volt (650 mA-h) battery. A minimal voltage drop of 7.5 volts must be maintained across battery terminals for the voltage regulator to work as intended.

Shown in Figure 14.75 is a plot displaying range sensor output as a function of distance from objects. Note that due to the nature of infrared based range sensors, ambient light conditions and light absorptivity of targeted objects may affect its output slightly.

This cost of this prototype is about $83.

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**Fig. 14.75. Range Sensor Calibration.**
BATTERY POWERED MECHANICAL GRABBING DEVICE

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INTRODUCTION
Many handicapped or elderly people have problems with hand strength, especially in gripping everyday objects.

The main goal of this project is to create a device that helps people with weak hands regain some measure of grasping ability. It is accomplished by the design of a powered grabbing device that is lightweight and easy to use.

SUMMARY OF IMPACT
Assistive grabbing devices are not a new concept. However, most grabbers currently available are operated by the user’s own hand strength, and do not provide much assistance aside from extending reach.

This device not only allows users to grasp objects typically difficult or impossible to reach, but also allows them to pick up objects previously that may have been too heavy or awkwardly shaped.

TECHNICAL DESCRIPTION
This device uses an acetal roller chain for its fingers. This provides joints for motion during opening and closing of the hand. These fingers are mounted on a shaft through a round-to-square transition piece.

To ensure movement in the correct joints and direction, three restrictor plates are adhered to each of the four fingers. Material is used to increase friction between the fingers and an object, similar to that used in football wide receiver gloves, is also used.

Attached to the ends of the fingers are stainless steel wire ropes which are connected together and run to a linear actuator mounted inside the shaft. The linear actuator is wired to a rechargeable 6 volt battery mounted on the outside of the shaft and a switch is located on the handle.

The handle is similar to those used in arm crutches which include a support around the user’s forearms. Pressing the switch activates the actuator which in turn, closes the fingers by pulling their cables. Pressing the switch in the opposite direction returns
the actuator to its original position thus opening the fingers.

This project’s cost is approximately $210.

Fig. 14.7B. Battery Powered Grabber
MECHANICAL ARM BRACE FOR REDUCING TREMORS

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INTRODUCTION
Currently, the two most common treatments for tremors are medication and surgery. The goal of this project is to design a mechanical arm brace that reduces or eliminates tremors originating in user’s arms. The brace designed is lightweight, universal in size and gives full range of motion to users, while limiting arm vibrations.

SUMMARY OF IMPACT
By suppressing the tremor, this arm brace enables the person to perform everyday activities with greater ease. A damping hinge joint, located at users’ elbows, aids in locking their arms into place when performing tasks such as pushing or pulling heavy objects.

TECHNICAL DESCRIPTION
This device is fixed to a user by two aluminum cuffs; one for the forearms and one for the upper arms or biceps. These are constructed from 0.0625 inch thick aluminum sheets, cut and rolled into an open cylindrical shape. Diameters of about four and five inches are used for the forearm and bicep respectively. Each cuff is approximately three inches in width.

Thin aluminum is used to reduce weight and enable tightening of the cuffs. The first of two damping mechanisms is mounted along the insides of the cuffs. A 0.5 inch thick vibration damping pad lines the aluminum interior of the cuffs to reduce shaking of user’s arms, and provide maximum comfort.

In order to ensure this damping mechanism works as efficiently as possible, Velcro straps are mounted around the aluminum exterior of the cuffs to allow the device to be tightened to various arm diameters.

Fig. 14.79. Brace at Smallest Setting.

Fig. 14.80. Brace at Largest Setting.
The cuffs are connected by a plastic rotary hinge to coordinate movement. This hinge acts as an elbow joint. It gives full range of motion to the user, while also incorporating the second damping device.

A knob is attached to the Allen head bolt which holds the hinge together. This knob allows users to specify the level of resistance offered by the hinge. It can be varied from zero to a maximum where the joint is completely locked.

Hinge arms are 1.5 inch square tubing which fit smoothly inside stainless steel connecting sleeves. One 0.25 inch hole is drilled in each hinge arm, and two 0.25 inch holes are drilled in each steel sleeve. A snap spring is then placed inside each hinge arm. This allows the steel connecting sleeve to be adjusted to different sizes by sliding and locking in place.

To connect the stainless steel sleeves and cuffs, a tab is left on the bottom surface of each sleeve. These tabs are then riveted to the cuffs. The total weight of this device is 5 lbs.

This cost of production of this device is $66.

Fig. 14.81. Demonstration of the arm brace.
INTRODUCTION
Using crutches can be a tiring process. Individuals using crutches may find more need to rest while travelling than before the use of crutches. However, there may not always be a resting place that is conducive to use by individuals using crutches.

This main goal of this project is to provide individuals using crutches with a portable resting place that does not increase burden on the user or require them to purchase new crutches.

SUMMARY OF IMPACT
Need for an individual using crutches to seek out a place to rest is eliminated by this device. Eliminating this need allows users to travel any path desired without worrying about places where they can rest.

This design’s advantages are portability, unobtrusiveness, ease of operation and compatibility with almost any standard crutches.

TECHNICAL DESCRIPTION
There are three main components to this design; leg beams, seat and attachment blocks. Each crutch has two leg beams that drop down to give a stable support for the assembled chair. Leg beams are connected with a bolt through a trapezoidal block that is allowed to rotate.
When crutches aren’t in use, leg beams can be lifted up and clipped away for storage and to avoid obstruction. This prevents the modification from interfering with the main purpose of the crutches.

The seat assembly is a vinyl fabric. There are two hooks on each side of the seat, which can easily be hooked onto the eye lag screws attached to the crutches.

The assembly block’s wooden piece serves as a guide for the leg beams to be set in place and locked.

It also provides the required stability when the assembly is set up as a chair. This prototype has been tested to a weight of 160 lbs.

A three by four inch aluminum block attachment connects and gives support to the crutches and leg beams. The trapezoidal shaped part of the attachment block has a drilled hole that allows the screws to attach the leg beams in such a way that they can be rotated longitudinally.

The total cost of the project is $61.

Fig. 14.84. Use of Modification.
**RECLINING WATER REHABILITATION CHAIR**

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**INTRODUCTION**

For persons who cannot support themselves while submerged in a pool, water rehabilitation requires constant supervision and support by another individual. This harnessed chair allows the user to be fully supported and secure during exercise without aid from another person.

Two floating arm pieces, on either side of the user, are connected with a cross-member creating a stable base for the chair. A fully reclining chair back with adjustable chest strap and waist harness safely and comfortably holds the user in place while performing water rehabilitation exercises.

Three connection locations along the frame allow the center of gravity to be adjusted for varying angle of recline, and user’s size and weight.

**SUMMARY OF IMPACT**

Children and adults who have neurological disorders often need to be held or braced by a caregiver. Requiring such close proximity to another person greatly restricts movement during exercise, and puts caregivers at risk of being injured.

This rehabilitation chair allows the user to safely and securely be in the water without constant contact, thereby giving them a renewed sense of independence during exercise.

**TECHNICAL DESCRIPTION**

This design consists of three main components: 1) floating frame, 2) reclining back, and 3) harness. The harness is a simple four inch wide adjustable waist belt with front clip closure.

The PVC chair frame uses a T-joint, three quarters down the length of the back, which protrudes from the sleeve. Connected to this T-joint is a small section of ¾” PVC (used throughout the device) with a 1/8” diameter tension pin drilled through the top of the PVC and halfway into the bottom (so it only sticks out on top). This pin is used to connect the chair and flotation frame.

The flotation frame is comprised of ¼” plywood and 95% closed cell polyurethane foam composite. Two mirror image arms and a length of PVC pipe create the frame. Each arm started with a 6.5” by 35” by 3.5” ¾” plywood mold which is lined and lubricated so foam could easily be removed. One 35”x3.5” side is made of unlined ¼” plywood, which remained with the foam after removing it from the rest of the mold.
In the permanent section of plywood, four holes are drilled to allow for the inner supporting skeleton to protrude from the foam. The left most hole, as seen in Fig. 14.87, allows a PVC coupling, attached to the skeleton, to protrude from the mold. It is left undrilled and is used in conjunction with another section of PVC to connect the two arms together.

The three other holes drilled into the mold’s permanent section allow couplings with drilled out notches to protrude. These notches allow for the pin connection from the chair to be attached, and prevent the chair from over rotating either forward onto the user, or backward into the water. It is attached to the frame via ties that can be moved forward and backward on the arms, depending upon which center of gravity option is in use.

A Polyvinyl Chloride (PVC) frame is used for the chair’s reclining back. Chest and side straps (used to keep the chair at a chosen angle of recline) are anchored to this frame. A kickboard is also fit into the center.

The frame and kickboard are kept together by a nylon fabric sleeve with holes for straps and a pin which connects it to the flotation frame.

The three different couplings allow users to pick where on the device they want the center of gravity to be located. This maintains frame stability, despite differences in user size and weight, and angle of recline. A person using the chair fully reclined either on their back or stomach would connect the chair at the right most coupling as in Figure 14.87. However, a person using the chair at a vertical angle would connect the chair at either the center, or left notched coupling.

After the skeleton is inserted into the mold, foam is poured in and allowed to set. Incorporating the skeleton into the foam increases stiffness and strength of the arms, and prevents buckling under the user’s weight.

In total, one cubic foot of flotation foam is used. This provides more buoyancy than is needed. Improvements on the arms involve scaling back the height of the foam so arms would sit lower in the water, granting more freedom of movement in the user’s upper body.

Once the foam sets, it is sanded down to be level and removed from the mold and the remaining ¼” plywood is sealed. Exposed foam is covered in heavy duty matte duct tape to prevent wear and tear.

The straps’ other ends, those anchored to the chair frame, are nailed in place at the arms’ front ends. These straps are pulled tight, or loosened in order to keep the angle of the chair back in place during use.

The cost of this project is $76.

Fig. 14.87. Close up of Notched Coupling.
COMPACT AND EASY ACCESS STORAGE SYSTEM

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INTRODUCTION
For the elderly, or people who are physically disabled, obtaining objects from cabinets that are placed out of reach, such as top kitchen cabinets, can be a challenging task. The purpose of this project is to create a compact storage system that is easily accessible.

SUMMARY OF IMPACT
The storage system’s shelves lower down to a height that can easily be reached by persons of varying heights. This system can give persons with disabilities more freedom. Those using a wheelchair may especially benefit since they no longer require assistance to obtain objects from high places. This device also has the added benefits of utilizing higher spaces typically left empty.

TECHNICAL DESCRIPTION
The main frame of the prototype is constructed of ¾” medium density fiberboard with inner dimensions measuring 20” high x 24” wide x 10” deep. A door is attached so that it opens by flipping downward. Rotating shelves are attached to the door’s inner side so shelves are lowered along with the door when it is opened.

Shelves are built so they will rotate, ensuring an upright position is maintained during movement. Two dampers are placed on each side of the cabinet connecting its base and door. Dampers are used to prevent the door from free falling during opening. They also provide assistance with closing the door.

A hand crank is connected to a series of pulleys. These are then connected to a retractable chain system used in closing the door.

The storage system is operated by pulling the handle to open the door, and closing it with the hand crank. The weight that can be placed on the
shelves depends on what types of dampers are used. The load that can be held by this prototype is estimated to be around 10-25 lbs. The retractable chain system’s purpose is to retract excess chain that may cause a restriction while trying to close the door. The cost of this project is $122.
CRUTCH CARRYING ATTACHMENT FOR WHEELCHAIRS

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INTRODUCTION
The objective of this project is to provide a means for disabled persons, who use both crutches and a wheelchair, to carry their crutches securely and conveniently while using their wheelchair.

This device allows users to attach crutches directly to their wheelchair. Assembly consists of a removable bracket which attaches to a wheelchair’s back, and holds crutches securely in a vertical position.

SUMMARY OF IMPACT
This device gives users improved mobility and access to more diverse situations and locations.

This modification does not interfere with the ability to collapse the wheelchair; therefore the modification does not impact portability.

TECHNICAL DESCRIPTION
The attachment consists of three components; the chair attachment bracket, frame, and crutch attachment plate. This design assumes users will typically leave the chair attachment bracket fixed, while removing the frame and crutch attachment plate when not required.

The chair attachment bracket clamps to the chair’s tip levers, and will not interfere with users or operation of the wheelchair. The frame and crutch attachment plate assembly can be detached quickly and easily by removing the thumb knob then sliding it off the chair attachment bracket. This device has been designed to be universal in fitting most
wheelchairs and crutches currently available. Additionally, weather resistant materials have been used, making it well suited for outdoor use.

This prototype’s overall length and weight are 39” and six lbs. respectively. The crutch attachment plate is roughly 4 x 9 x 1 ½ inches.

The crutch attachment plate consists of an aluminum plate, a contoured oak spacer and a rubber draw latch.

This assembly is attached to the frame by a pivoting tube clamp, which is secured using a thumb knob. A plastic/rubber compound is used to coat the oak spacer. Clear coat or paint is used on remaining parts.

Thin-walled chrome plated steel tubing is used for frame construction. An offset bend is used to provide clearance from wheelchair push handles. The attachment bracket consists of an aluminum clamshell clamp screwed to a steel post and yoke assembly. It is secured to the wheelchair frame using a 1 ½” x ¼-20UNC stainless bolt and nut.

The clamshell clamp tightens down on the tip lever using two ¼”x 8-32UNC Allen head machine screws. A ¾ x 1 x 8 inch machined aluminum stiffener is added to enhance stability. Attachment and removal of the frame assembly is facilitated by adding a thumb knob.

The total cost of this project is approximately $25.
INTRODUCTION
The result of this project is a set of hand-actuated roller-brakes which are designed to replace standard wheelchair brakes. Standard wheelchair brakes are designed to keep wheelchairs stationary, similar to parking breaks, and are ineffective in slowing down a moving wheelchair.

To remedy this, roller-brakes are connected to hand-actuated levers, located at a convenient location. These roller-brakes provide effective, user controlled braking. Also, the hand-actuated levers include thumb locks which keep the roller-brakes engaged, adding a parking brake feature.

SUMMARY OF IMPACT
With traditional wheelchairs, users must grab the outer edges of the wheels in order to slow down and stop. This maneuver can become difficult or dangerous on slopes, or if users must stop quickly. This device helps users to safely slow down their wheelchairs on any terrain. In addition, forces required to engage these brakes are significantly less than that of standard brakes.

TECHNICAL DESCRIPTION
This device consists of a pair of roller-brakes and their accompanying levers. Roller-brakes are secured to a wheelchair frame with their moving
components attached to the wheels using an adapter. The wheelchair’s axle bolt keeps wheels, adapters and roller-brakes in place and attached to the wheelchair frame.

Standard bicycle brake cable is used to connect brakes to levers. The brake levers have thumb locks which keep the roller-brakes engaged.

Addition of this device to a wheelchair does not affect its collapsibility. This device’s total cost is $108, excluding the cost of the wheelchair which was donated.

Fig. 14.96. Close up of roller brake assembly.

Fig. 14.95. Close up of brake handle.
FOLDABLE CRUTCHES WITH STORAGE ATTACHMENT

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INTRODUCTION
Crutches are often hard to store in limited spaces such as cars, airplanes etc. Their height can be reduced, but often even at their lowest setting, they are still too large to store. Moreover, a person using crutches is unable to carry anything by hand.

This project is a modification of regular crutches which enables them to fold onto themselves, thereby making them very portable and easily storable. In addition, an attachment to carry hand held items and a cup holder are provided.

SUMMARY OF IMPACT
This redesign not only makes crutches much more portable, but also more accessible to users. These crutches can be easily stored in an overhead compartment of an aircraft, or even a backpack. This makes life more convenient not only for users, but also for caregivers.
The added attachment to carry hand held items will give people with walking disabilities a sense of autonomy when it comes to transporting their personal items.

**TECHNICAL DESCRIPTION**
The folding feature is added by cutting crutches approximately at their midsection. Sleeves are attached to each upper half by force fit. This creates a male and female connection between the two halves. The two halves are connected to each other using a spring that is fish-eyed around the center of bolts that go through the prongs of each crutch half. This spring is capable of generating force greater than the total weight of the crutches, and is in a stretched position when crutches are assembled. This ensures the two halves remain together when crutches are in use.

In order to fold the crutches, users simply pull the two halves apart, and then fold one on top of the other.

The item carrying attachment is similar to a drawer and is made from acrylic. Acrylic is selected for its weight, finish, and workability. The attachment consists of an outer casing, which attaches to crutches using one of the folding feature’s bolts, and a storage bin that sits on drawer sliders in the outer casing. Attaching the compartment in this way allows it to be removed from the crutches if desired. A cup holder is added to the top of the storage bin.

The storage attachment is offset from the crutches for two reasons. The first is that the moment created by this offset acts as a locking mechanism, preventing the attachment from sliding back and forth while a person is moving. Secondly, it allows users to grip the attachment and slide it forward into plain sight by slightly raising the attachment to overcome the moment.

To prevent a permanent set in the springs due to repeated folding, Velcro bands are added to limit the springs’ extension when crutches are in their folded state. The total weight of the attachment is 5.5 lbs.

The total cost of this project is $67.
RETRACTABLE WHEELCHAIR CARGO ATTACHMENT

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INTRODUCTION
The goal of this project is to provide trouble-free storage for users with multiple mobility handicaps by allowing them to store personal belongings on a wheelchair without obstructing their range of motion. This is accomplished by designing a retractable storage bin that is mounted under the seat of a wheelchair.

Aside from being retractable, this modification does not interfere with wheelchairs’ collapsibility, thereby making it portable as well.

SUMMARY OF IMPACT
This attachment benefits anyone who uses a wheelchair. It increases the user’s capability to transport personal belongings. Users can easily access and store their belongings which are located below them. This device is ideal for students transporting heavy textbooks across college campuses. This modification is simple, durable, lightweight and still allows the wheelchair to collapse.

TECHNICAL DESCRIPTION
The storage basket is made from cotton fabric that is woven and treated to resist water and mildew. It has a thickness of 0.028” and weighs 10 ounces per square yard. This fabric is durable, light and extremely flexible. This allows the baskets to be collapsible, while retaining an ability to handle reasonably sized loads. Basket dimensions are 13.25” x 8.5” with a height of 3.875”.

Fig. 14.100. Wheelchair with Cargo Attachment Collapsed.
Fig. 14.101. Cargo Attachment Open.
The basket retracting mechanism is a precision drawer slide. This slide is made from zinc-plated, cold-rolled steel, and has a hold-in dent which firmly holds drawers closed during transportation.

Slides used on this project have an overall travel length of eight inches, and a load rating of 50 lbs. per pair.

Drawer slides are attached to wheelchairs using four standoff brackets. These brackets are manufactured from Aluminum and apply a press fit between brackets and the wheelchair’s structure. The brackets not only attach the drawer slides to the wheelchair, but also allow for adjustment of the height of the basket.

Aluminum sheet stock with a thickness of 0.125” is mounted to the ends of the fabric basket. This sheet stock is mounted by using three pop rivets in each corner of the basket. These Aluminum plates strengthen the overall design, and allow the basket to be mounted to drawer slides. Ten 32 socket head cap screws are used as fasteners.

The total cost of this project is $42.

Fig. 14.102. Cargo Attachment Closed.
KNEE SCOOTER FOR LEG INJURIES

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INTRODUCTION
This device is designed to assist in the mobility of persons having injuries or pain ranging from their shin to toe on a single leg. The Knee Scooter is designed for both comfort, and stability. It provides users with a cheap, quick, and convenient way to get around while they recover.

SUMMARY OF IMPACT
Using this device, individuals having pain or injuries on the lower portions their legs may transport themselves quickly and easily.

This device has several advantages over existing assistive mobility devices including: 1) greater speed than that offered by crutches, 2) less obtrusive than a wheelchair, and 3) less upper body strength required than both crutches and wheelchairs.

TECHNICAL DESCRIPTION
There are three main components to this device; a scooter chassis, a knee pad, and a steering mechanism.

The prototype chassis is constructed mainly from Polyvinyl Chloride (PVC) pipe with the exception of two polypropylene fittings to hold rear wheels, and a piece of composite wood which adds stability and a surface on which to attach the knee pad.
Aluminum rods are used to connect the knee pad and scooter chassis. These rods telescope which allows for pad height adjustment.

The steering mechanism features an oil-impregnated bronze bushing to allow users to easily turn the front wheel. The steering column can be removed by unscrewing a single bolt and the seat can be removed for easy storage of the scooter.

If this device were to be professionally manufactured, it would ideally be made from Aluminum due to its light weight and strength. Also an improved knee pad would be included.

This cost of the device is about $75.
NSF 2009 Engineering Senior Design Projects to Aid Persons with Disabilities
CHAPTER 15
TULANE UNIVERSITY

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POWERED ELEVATING LEG RESTS FOR A MANUAL WHEELCHAIR

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Client Coordinator: Amanda Mountain
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INTRODUCTION
Manually elevated leg rests for wheelchairs are commercially available. However, these systems require the user to unlock, manually elevate, and then re-lock the leg rests into position. For many users, this complicated task requires the assistance of others. The goal of the project is to adapt an existing set of manually adjustable elevating leg rests to be power operated for manual wheelchair users with limited upper body strength, control, or mobility. In addition, many wheelchair users need to be able to use their feet to help propel their wheelchair if they do have reduced upper body strength or mobility. A second goal of this project is to further modify an existing leg rest to permit the calf support pads to rotate to the side to provide the user the ability to make foot contact with the floor. Finally, the system needs to be capable of removal and replacement on the wheelchair as easily as the existing leg and foot rests.

SUMMARY OF IMPACT
The target users of this device are the residents of assisted living facilities. The design criteria for the project are specifically defined by the needs of those users with limited upper body strength or mobility. We focused on a single client, Ms. V. She was able to use the system immediately upon receipt, and her dependence upon the facility’s staff and other caretakers was much reduced.

TECHNICAL DESCRIPTION
The leg rests are elevated by an actuator system that includes two electric linear actuators, a control box, and a remote control to operate the actuators. The actuators are attached to the leg rests via a mounting bracket made from ¾” steel tubing. The actuators are mounted directly to the leg rests instead of the chair to allow for the detachment of the leg rests. This is essential in order for the wheelchair to be easily configured for a particular client, as well as to facilitate disassembly and transport.

The linear actuators are rated at 450 lbs. maximum force and have a linear speed of 21 in/min to ensure the rate of elevation does not injure the user or attendants. An integrated control system powered by a rechargeable battery runs the actuators. The control box continually draws power even when the actuators are stationary. To extend the battery life of the power supply, a remote switch is incorporated to turn the system on and off.

Custom mounting brackets and spacers attach the calf pads and allow them to rotate backward and lock in both the up and down positions. The mounting brackets are machined from stainless steel with a small push plate welded to their outer edge. The push plate allows the user to lock and unlock the calf pads with a wooden J-shaped handle (Fig. 15.2). Downward repositioning is accomplished.

Fig. 15.1. Oblique view of elevating leg rest system.
using the weight of the leg itself. Upward rotation is accomplished by means of a single bungee cord that provides an upward, restoring torque.

The total cost of the project is $900.

Fig. 15.2. Left: handle for manual operation of the calf pads. Right: calf pad mounting bracket and associated bungee system.
CHALLENGE COURSE FOR WHEELCHAIR AND WALKER USERS

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Client Coordinator: Marie Noel
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INTRODUCTION
Children in walkers and wheelchairs do not typically have play areas designed for their needs. These students need to practice the necessary skills associated with using a wheelchair or walker, but are limited, in a number of ways, when using typical playgrounds. Slides, jungle gyms, and monkey bars all have climbing components that our clients cannot use. Swings can also be difficult for wheelchair and walker users to use safely and independently. The objective of this project is to design and build playground equipment that greatly benefits these students by providing a place to develop the skills and strength needed to become independent wheelchair and walker users while also enjoying their recess break. The challenge course is composed of one ramp and a set of platform stairs leading up to a landing. An associated basketball hoop is modified to return balls back to the landing. The children must repeatedly use the steps and ramps to go back up to the landing to release a ball-stop which prevents balls from returning to the shooting area until released (Fig. 15.3).

Fig. 15.3. The challenge course.
SUMMARY OF IMPACT
The Challenge Course for Wheelchair and Walker Users is a unique, cost-effective design that may be installed on any playground, and used by all children, with or without disability. It allows students who use wheelchairs and walkers to practice overcoming obstacles such as ramps and steps that are encountered in everyday life.

TECHNICAL DESCRIPTION
The materials used are designed to withstand prolonged outdoor use. The ramp, platform stairs, and landing all are constructed of pressure-treated wood and connected with galvanized hardware. Ground treated wood (0.40 ACQ) is used for components in contact with the ground. The landing is supported by concrete deck blocks. To protect users from slipping, Shurtape outdoor tape is applied to the ramp and step surfaces.

In order to provide incentive for use, we added a commercial portable and adjustable basketball hoop and backboard. This is modified to return the balls to a designated area on the platform. The return system net is made of several Spalding All-Weather Basketball Nets connected by cable ties. Once the ball reaches the landing, return ramps, made of treated wood and galvanized hardware, return the ball back to the shooter. A square, wooden ball-stop is installed midway along the ball return ramps to prevent the ball from returning to the shooting area. The shooter must travel up the ramp or stairs to the landing to release the ball stop. The Rolbak Net Saver is a commercially available net used to provide an additional ball return for missed shots, and is installed behind the basketball backboard and hoop.

The dimensions of our structure are chosen based on ADA regulations (Fig. 15.4).

The total cost of the project is $1500.

Fig. 15.4. Schematic of Challenge Course.
**INTRODUCTION**

The Desk-Chair System is designed to aid our client’s classroom performance. Our client has arthrogryposis, a congenital disorder causing joint contractures and changes in non-bony tissue (muscles, ligaments, and tendons). Thus, our client must write at a slower pace while exerting more energy. Additionally, our client must support her body at an unnatural angle while using a standard classroom desk, also resulting in more energy expended and early exhaustion. Further, our client needs to lift her arms onto the table, which is challenging due to limited arm strength. To address comfort and support in order to minimize exhaustion, the Desk-Chair System is built on a modified, adjustable office chair, and includes an easily implemented desk surface that pivots out of the way to permit sitting and rising (Fig. 15.5). The desk surface is stowed away for transport. The Desk-Chair System includes wheel-stops to prevent chair motion during sitting and rising activities.

**SUMMARY OF IMPACT**

The client coordinator and her colleagues believe that this chair will facilitate our client’s classroom performance. They also believe that this design meets all the initial criteria that were established in the design proposal.

**TECHNICAL DESCRIPTION**

The Desk-Chair system uses the Criterion® chair built by Steelcase®. This chair is selected because of its robust and versatile design. The frame is made of heavy gauge metal and is able to accommodate the increased weight of added components. Furthermore, the chair is adjustable for optimal comfort. Back height ranges from 22” to 24”, and seat height is adjustable from 16” to 21”. Additionally, the back of the seat reclines and the degree of angulation is easily set. The dimensions of the seat are 16.25” depth, and 19.5” width. The original armrests are replaced with custom armrests made of heavy gauge aluminum tubing. A side bolster is included to provide trunk support, permitting our client to position herself comfortably.

The desktop is made of cabinet grade 5/8” plywood with dimensions of 14” x 24”. It is fixed to a commercially available drawer slide, and is attached to the modified right armrest of the chair with a multi-axial hinge (aMsp®, double pivot hinge, catalog no. MLAT03MTH145). The desktop is centered on this hinge as shown in Figure 15.6. It
pivots 90° in two planes from the standard writing position to allow unobstructed sitting and rising. The hinge permits the desk to be raised from its stowed position on the side of the chair, to full vertical position, and then rotated 90° and locked in the writing position. The teacher positions the desktop. An adjustable snap-on catch locks the desktop in the writing position, with the strength of the catch adjusted by the teacher. The catch consists of two parts that snap-lock together. One component is attached to the bottom of the desk and the other is attached to the left armrest. For safety, standard wheel locks along with a custom foot operated brake engage to lock the chair in place while our client sits or rises from the chair.

The total cost of the project is $638.

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Fig. 15.6. Schematic of the double pivot hinge.
WHEELCHAIR-TO-TOILET TRANSFER SYSTEM

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INTRODUCTION
Our client is a public school serving several students with various disabilities. Transferring students from their wheelchairs to a toilet is a problem. Currently, each time a student using a wheelchair needs to use the restroom, two teachers must assist by lifting, undressing, moving, cleaning, redressing, and returning him or her to the wheelchair. This process is physically taxing on the caregivers, especially as students grow. In addition to the compromise of privacy, using the restroom takes about fifteen minutes, which disrupts class time for both students and teachers. The purpose of this design is to create a device that minimizes the lifting and moving aspects from the process of using the restroom, thereby reducing the amount of time and level of effort required by students and caregivers. The device consists of a hoist and sling assembly that slides on an I-beam. The sling wraps around the student’s legs and is open on the bottom, allowing the student to use the bathroom without removing the sling. The hoist is attached to a trolley whose track runs along the ceiling above the toilet, so the student can be lifted from his or her wheelchair, moved horizontally until over the toilet, and then lowered (Fig. 15.7). The Wheelchair-To-Toilet Transfer System reduces the required number of caregivers to one, and reduces the time it takes a student to use the restroom by approximately ten minutes.

SUMMARY OF IMPACT
This device improves the quality of life for one of our client’s students, a ten-year-old girl with paraplegia, and her caregivers. The Wheelchair-To-Toilet Transfer System allows one caregiver to complete the process, and it reduces the time required to less than five minutes. This improves the client’s quality of life because it reduces missed class time and allows her more privacy because only one caregiver is needed. Our client is in elementary school, at an age where friends are important to the quality of her life. Decreasing the amount of time spent in the bathroom allows her to be more active socially. This device also reduces the physical effort required for transfer, and reduces the chance for caregiver injury.

TECHNICAL DESCRIPTION
This device is a lift transfer system. It enables a caregiver to move a client who uses a wheelchair from her chair to the toilet and back. The system consists of three main components: a horizontal beam with rolling trolley, a manual hoist system, and a sling and cradle assembly.
The I-beam is mounted to the walls so that it runs across both the toilet and a space large enough to accommodate a wheelchair. The I-beam serves as a track for the trolley, creating a means for the lift, sling, and patient to be moved from wheelchair to toilet and back. The manual hoist is a mechanical winch operated by the caregiver. It is connected to the cradle assembly by a chain that raises and lowers when the winch is operated. Avoiding the use of electrical power and choosing a hoist that stops when its operator lets go actively enhance safety. The cradle assembly has connections at six points, allowing for a variety of medical-lift slings to be used.

The total cost of the project is $590.

Fig. 15.8. Schematic of the Wheelchair-To-Toilet Transfer System.
INTRODUCTION

Our client has osteogenesis imperfecta (OI), a condition characterized by brittle bones and short stature. Our client is approximately 31” tall, weighs from 40-45 lbs., and is a wheelchair user. She cannot support her full body weight with her legs, but wanted a workout device for exercise and to help maintain lower body muscle strength. Previously, our client used a workout device for this purpose, but it was lost in Hurricane Katrina. For four years our client has been limited to exercise in her pool, but she feels her workouts are less effective. The device design for this project, The Exercise System For Osteogenesis Imperfecta, shares the same principle as a leg press; the workout load is realized as a portion of the user’s body weight that results from adjusting the incline of the support bench. Additionally, optional elastic resistance is incorporated into the system with detachable surgical tubing components.

Fig. 15.9. Exercise System For Osteogenesis Imperfecta illustrating the inclined bench, foot platform and pin adjustment mechanism.
SUMMARY OF IMPACT
The Exercise System for Osteogenesis Imperfecta enables our client to follow a planned workout regimen using manageable loads. It provides versatile workouts while allowing for increased loads proportional to the user’s increased strength. Since the device is collapsible and easily transported, the client may use the device both indoors and outdoors. Our client reports a high degree of satisfaction with this system.

TECHNICAL DESCRIPTION
The Exercise System in the deployed configuration measures 33” long, 26” wide and 23” tall. When collapsed, the system is 43” long, 26” wide and 6” tall (Fig. 15.10). The system weighs approximately 25 pounds. In addition to being easily collapsible, the design features rotating casters with wheel brakes to allow easy transport and safe storage. Additional safety features include an ergonomic seat and footrest, a safety lever that locks the seat in place before and after exercise, and an emergency stop to prevent injury. The seat is fixed to low-friction drawer slides to restrict the motion of the seat to one direction. The inclined bench may be set at one of eleven positions, resulting in varied portions of her body weight vector acting to provide the exercise load. Optional bands of surgical tubing clipped to the back of the device provide five additional levels of elastic resistance.

In order to help our client in timing her workouts, a removable timer (not shown) is located on the footboard. The instruction manual includes an example workout regimen composed of an exercise schedule, instructions for finding appropriate load levels for a given incline, and for setting elastic band resistance, as well as desired repetition and set counts.

The total cost of the project is $200.

Fig. 15.10. Schematic illustrating how the Exercise System is folded for ease of storage and portability.
INTRODUCTION

Our client is a preschool for students with autism and autism spectrum disorders. This school uses electronic choice communication boards to augment language acquisition and to teach communication. However, currently available designs are inadequate for our client’s purposes because small activation buttons are difficult for students without fine motor skills. Further, the typical membrane switches of most commercial boards wear out quickly under repeated, high-force activations. In addition, their switching logic does not promote sufficient intellectual involvement. The purpose of this project is to develop a custom wall-mounted augmentative communication board for our client’s preschool classroom. The device consists of a wall-mounted wooden case with six large buttons mounted on the front face (Fig. 15.11). Each button has a different interchangeable picture, corresponds to a custom pre-recorded message, and is surrounded by LED indicators. When a button is pressed, the message is played, and the LEDs darken to indicate to the student that the associated message has been played. The button is deactivated and the LEDs remain off until the device is reset. A hinged panel on the top of the device provides teacher access to the controls, such as adjusting volume and recording new messages.

Fig. 15.11. Augmentative Communication Board showing the large size buttons, the LED indicators, and the custom designed button icons.
SUMMARY OF IMPACT
The Augmentative Communication Board enables our client to teach children with autism more effectively. The device eliminates many of the problems with existing communicators, and our clients’ assessment of its performance is positive. They believe that the device will be very helpful to them when teaching. The Augmentative Communication Board will be used by our clients on a daily basis.

TECHNICAL DESCRIPTION
The Augmentative Communication Board consists of a 23” x 16” x 6¼” case constructed of medium density fiberboard, with 6 large buttons, an external speaker and an external microphone. The visible face of each button measures 5” x 5”, with a 1/8 inch thick sheet of clear polycarbonate sheets affixed to an oak board. The polycarbonate sheets permit insertion of new icons, allowing a button’s message to be easily changed by the classroom’s instructional staff. Housed inside the case is a Tech/Talk 6x8 communicator board manufactured by AMD. A hinged door on the device’s top surface provides access to the Tech/Talk’s controls, as well as six push-button switches to allow new messages to be recorded to correspond with each specific button.

The face buttons move on slides made from 1¼ inch PVC pipe, with four springs located at the corners to provide a return force. The PVC slides permit only ¼ inch of travel to protect the electrical push-button switches. The interface circuits access the Tech/Talk through an RJ-45 Ethernet connector. Each interface circuit consists of two four-pole double throw relays, which control the LEDs, the activation of the Tech/Talk and the on/off state of each individual button (Fig. 15.12). Relay contacts parallel each of the commercial board’s membrane switches through the RJ-45 connector.

When a face button is pressed, its corresponding push-button switch activates a relay circuit that turns off the LEDs and plays the message. The button then enters the “off” state. One particular problem is that if a communicator board switch is held closed, then none of the other switches will work. The second relay serves to open the circuit to the board after each message activation. The state of the buttons is controlled by a master reset switch mounted on the case, which resets all buttons and relays.

The total cost of the project is $970.

Fig. 15.12. The circuit diagram for the interface between button 5 and the Tech/Talk board.
CHAPTER 16
UNIVERSITY OF ALABAMA AT BIRMINGHAM

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A WHEELCHAIR LIFT FOR ADULTS WORKING AT GONE FOR GOODTM

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INTRODUCTION
LINCPoint is an affiliate of United Cerebral Palsy of Greater Birmingham, which provides employment services for adults with special needs. One program is called Gone for Good, which employs these adults to sort paper on a conveyor belt for shredding. Many potential employees are restricted by a wheelchair and cannot access the conveyor line, which is too high for them to reach. The client is requesting a wheelchair lift that permits wheelchair bound users to reach the work area, allowing them to do their daily duties. A prototype was completed last year with NSF RAPD support; however, the device was extremely heavy and cumbersome, rendering it unusable. The goal of this project is to modify the existing wheelchair lift, to reduce weight and footprint, and to improve mobility and functionality in the working environment. The device needs to support the weight of the heaviest wheelchair and the user, which is approximately 400 lbs. In order for this device to be useful, it must lift a user of average height 8 in. Each user is allowed to work a maximum of 2.5 hours each day, thus the device must maintain constant elevation throughout their shift. Additionally, the device must fit within the standards of the work environment.

SUMMARY OF IMPACT
This device provides the workers with ample height to reach the conveyor line. The device has not yet been delivered. However, we anticipate a very positive impact on the LINCPoint facility, allowing new users to participate in the Gone for Good program activities. We hope the system proves to be durable and provides years of safe use for the staff and workers at LINCPoint.

TECHNICAL DESCRIPTION
The final design (Fig. 16.1) consists of a base that supports the platform and lift mechanism. The base is constructed of tube steel (A36, 2.5 in. x 2.5 in.) and is able to withstand the weight that the actuators push against it and has a “pull handle” for easy transportation. The aluminum platform (Al 6061, 32 in. wide and 40 in. long) holds the user and wheelchair, lifting 500 lbs. with negligible deflection. An aluminum ramp allows the user access to the platform for loading/unloading, and lifts up and locks into place as a rear toe board. The ramp complies with ADA standards that for every one inch of rise, there must be one foot of run. A gate latch keeps the ramp locked in place. Toe boards are also installed (2 in. tall, ADA Standard A.8.7).

The lifting mechanism involves two linear actuators, which attach to the platform via two aluminum “z-brackets”. The linear actuators (Linak LP 2.1) are salvaged from the original design. They are rated to lift 585 lbs each and stabilize moments of 6200 lb-in on the platform. The initial height of the platform from the ground is roughly one-half inch. Therefore, the z-brackets attach to the top of the actuators and bottom of the platform. Spring loaded casters are used for easy transport of the wheelchair lift. The design of the wheelchair lift is made such that with the load of the lift, the platform will have one-half inch of clearance from the ground. When the weight of the user and wheelchair are applied, the springs collapse the remainder of the distance to the ground. This inhibits the movement of the wheelchair lift when it is loaded under the weight of a user. To further limit movement, there is a rubber strip connected to the ramp that creates friction against the floor.

The total cost of this device is $734.
Fig. 16.1. CAD drawings of Wheelchair Lift.

Fig. 16.2. Completed Prototype of Wheelchair Lift.
THE EASY EATER: AN ASSISTIVE DINING DEVICE FOR A GIRL WITH ARTHROGRYPOSIS

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INTRODUCTION
Arthrogryposis Multiplex Congenita (AMC) is a congenital disease which severely impairs the movement of joints. The most common cause is fetal crowding and/or immobility. Rigorous intervention immediately follows birth, often requiring physical/occupational therapy or surgery. The purpose of the present design is to develop a no-hands spoon feeder for a three year old girl with AMC and limited use of her arms. The goal is to provide a mechanical alternative that utilizes movement of her torso (flexion/extension) to help her effectively dine with minimal assistance. This aim requires the development of an efficient mechanism for power transmission from torso to spoon shaft. Safety and ergonomics are heavily considered, and all materials used are to be FDA approved. The device is also to be portable, simple to setup and essentially maintenance-free.

SUMMARY OF IMPACT
At the time of this document, the finishing touches are needed to improve alignment and ensure smooth mechanical motion and no seizing of gears. We anticipate that, if successful, the impact will be major. The little girl will be able to eat by herself, creating a new level of independence. Her parents will also enjoy new freedom, eliminating the need to spoon feed their daughter at each meal.

TECHNICAL DESCRIPTION
The final design was dubbed the “Easy Eater” (Fig. 16.3) and consists of two main parts: the push mechanism and the feeder unit. The main feeder unit is responsible for transforming mechanical cable pull into precise spoon turn and controlled extension. With only user-provided mechanical power, the design effectively cycles through its gear mechanisms with great efficiency, so as not to discomfort the user. The prototype’s unique bowl, spoon, and serving motion are adapted from an existing commercial device, the Mealtime PartnerTM. Our device is essentially a mechanically powered analog that allows our client to take a more active role in eating.

The main role of the push mechanism is to effectively deliver power from the user leaning forward to the main feeder unit’s linear guide block. Depression of the push mechanism’s chest pad, by the user’s forward lean, pulls the cable end 4 in. Cable pull is transferred via a flexible housing to the main unit where it pulls the linear guide block and the lever actuator/gear rack. The first 2.75 in. of block travel causes the lever actuator to turn the lever, miter gears, and turning gear 90 degrees, which in turn rotates the spoon 180 degrees through the bowl, scooping food. The next 1.25 in. of block travel does not turn the lever as it rides on top of the actuator without impeding further displacement.

During this segment, the extension rack contacts the extension pinion, turning the extension cogs and extending the spoon approximately 3.5 in. Spring return mechanisms built into the turning lever and sliding linear guide block reverse the motion after each bite and keep the cable taut. The device is easy to setup and only requires that a table vice be tightened by hand. The forward lean required to operate the push mechanism also puts the user in a natural position to receive a serving of their meal from the extended spoon. The full four-inch range of motion is ensured to be comfortable with a variable selection of light return springs and a custom manufactured chest pad.

The total cost of this device is $938.
Fig. 16.3. The Easy Eater finished prototype.
NO-HANDS SPOON FEEDER

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INTRODUCTION
The goal of this project is to design a second no-hands spoon feeder for our shared client, the little girl with Arthrogryposis, described previously. In this case, the design has switches and motors to drive the spoon scooping mechanism. Additional requirements of the device are that it should be portable, easy to install, and able to attach to a dining room table.

SUMMARY OF IMPACT
At the time of this document, the student team was still working on the connector arm and switching system. If successful, this device will provide the little girl with Arthrogryposis another feeding device option, in this case a battery-operated one that works with the press of two buttons. Again, this will create a new level of independence for our client and freedom to her parents during mealtime.

Fig. 16.4. CAD Design of the No-hands Spoon Feeder.
TECHNICAL DESCRIPTION

Fig. 16.5 illustrates the final design at the time this report was written, still under construction and without the connecting arm attaching the spoon to the motor. A slab of polypropylene is machined to create the base, the body and arm of the no-hands spoon feeder. The base of the design is 16” long, 12 ¾” wide, and 1.50” thick. The bottom of the base is hollowed out to reduce weight. The base is hollowed out at 0.50 inches from the edge of the base, leaving a 6” diameter circle for the location of the turntable and a rectangle with 3.625” wide and 6.375” long for the location of the battery.

A 12 V DC gear motor with 40 in-lb of torque at 8 rpm creates motion in a 5 in. diameter circular path for a 7 ¼ in. long, 1 in. height, and 1 in. width attached arm. The spoon attaches to the arm with a 90 degree angle at the tip of the handle, and radius of 2 in. at the scooping location of the spoon. There are three bowls that can be placed on the turning plate. A turntable is utilized to rotate the plate for different locations of food, which has a 7 in. diameter and a height of 2½ in. The spoon and turntable are controlled by switches attached to goose necks. A Genesis battery (12 V, 2 Amp-hr) is used to supply power to the motors. Two goose necks (15 inch long arm type C) are large enough to fit the wire going to the control system and are mounted onto the base of the feeder using a rectangular plate or universal plate. The switches control the spoon (right) and turntable (left), and are extended from the base for easier access for the individual.

The total cost of this device is $537.76.
INTRODUCTION
This project involves the design and construction of a wall climber for The Bell Center, which provides day-care services for special needs children ranging from ages one to three. The first and most important concern is safety. The total weight and portability of the climber are important, since the climber will be moved frequently in and out of storage. The different abilities of the children using the wall climber are also taken into consideration since the children have a wide range of mobility. Size and ease of storage is also an important factor in this design. The staff at the Bell Center has limited space to store the climber, so it also needs to break down and take up a minimal amount of space.

SUMMARY OF IMPACT
Although device construction has not been completed, successful delivery and implementation of the wall climber will impact the Bell Center children and staff. Children who previously were unable to access existing climbers will have the opportunity to play and develop motor skills using the new climber. The device is intended to function with only one supervisor needed to ensure the safety of the children. This may free up other staff to supervise additional children who wish to participate in other activities.

TECHNICAL DESCRIPTION
The final design (Fig. 16.6) features a platform that is enclosed on two sides, thus reducing the number of supervisors needed to one. The climbing ramps are designed to accommodate children with both normal and reduced mobility. The ramp for the children with low mobility is oriented with a gradual slope (approximately 30 degrees), and instead of climbing pegs, the surface is a soft rubber mat to allow for maximum grip. The other ramp is similar to a traditional climbing wall. It has the standard climbing grips, but is inclined at a 45 degree angle to reduce difficulty. Both of the ramps are lined with 10 in. barriers on either side to prevent children from slipping and falling off the ramps. At the top of the platform, there are interactive components such as a mirror and a steering wheel that act as an incentive for the children to climb to the top of the platform. On the other open side, there is a slide to allow children to get off of the platform in a safe and entertaining manner.

The enclosing walls at the top of the platform and the hand rails are designed to fold down. The ramps and slide are detachable and can be stored inside the base, which is made to dimensions of 3 ft x 3 ft x 5 ft. The base has wheels on one side that can fold out to allow for easier transport to the storage area. The device conforms to ASTM standards for play equipment, F-2373 and F-1487, which apply to children 6-23 months, and 2-12 years old, respectively.

Construction of this device is underway. The box platform will be constructed with FRP channels. The frame will be covered with thin sections of a polypropylene fiber/polypropylene matrix panel, which goes by the trade name of CurvTM. The climbers will be a composite construction with Honeycomb and Curv. Adhesion between the Curv and honeycomb structure will be created using a specialty 3M tape. The guardrails will be constructed using PVC and then covered by soft foam. The box platform frame will be built with fiber-reinforced plastic (FRP) channels and tubes from Bedford Plastics.

The total cost of this project is $850.
Fig. 16.6. Schematic of the climbing wall to be constructed for the Bell Center.
CHAPTER 17
UNIVERSITY OF CONNECTICUT

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THE TRAVEL COMPUTER MOUNT FOR DYNAVOX VMAX

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INTRODUCTION

Assistive communication devices, such as the Dynavox Vmax, allow persons with disabilities to express themselves. An individual’s communication may be affected by a number of conditions, including cerebral palsy. Our client has a severe case of cerebral palsy and expresses the need for a travel mount in order to access his Dynavox Vmax in a vehicle. The vehicular mount attaches the computer to the front passenger headrest using a unique vice system, allowing for easy attachment and detachment for placement in all types of vehicles. The Dynavox can be removed from the mount with ease upon arrival of destination. The travel computer mount allows for the user to safely and effectively use a Dynavox Vmax in any type of vehicle.

SUMMARY OF IMPACT

The travel computer mount allows for communication in a moving vehicle. Before the mount, communication based on facial gestures was dangerous as it distracted the driver. With the Dynavox Vmax mounted in front of the user, the necessary communication can take place with safety.

TECHNICAL DESCRIPTION

The Dynavox VMax travel mount is made of three stainless steel rods to ensure strength and durability. It easily supports the weight of the VMax, and is light enough to maintain portability. The rods are connected at 90° angles with elbow joints supplied by Daessy, Inc (see Fig. 17.1). The elbow joints make mount assembly very easy. The VMax is attached to the mount via the Folding Quick Release Base from Daessy, Inc.

The base is centered along the horizontal rod and can be used to quickly attach and detach a Dynavox VMax computer (See Figure). By simply pulling a pin, the computer can be safely secured to the mount. The base can also rotate about the horizontal rod, and then be locked in place to achieve optimal viewing angle of the screen.

The mount is installed in a vehicle by tightening down the two attachment plates. One plate, 14” in
length, is welded to the two “L-shaped” rods of the mount. This plate is attached to a shorter plate, 8” in length, via three screws. The plates are aligned on either side of the head rest posts of a car seat and the screws are tightened to fasten the mount in place. A sheet of neoprene rubber on each surface in contact with the headrest posts assures a firm grip. The mount can be easily installed in a variety of car models (see Fig. 17.3).

Fig. 17.3. Installed travel computer mount with client.
INTRODUCTION
The Standing Gardener is designed to aid children with Cerebral Palsy that want to garden. This device is a gardening table that can be raised or lowered, depending on the height and size of the user. It consists of a stainless steel frame, complete system to support the users’ chest, hips, knees, and feet, and a thermally insulated workspace. Its purpose is to provide an area to garden that supports the user in the standing position so that he or she does not lose muscle or bone mass and can continue to grow stronger. Current standers on the market today do not offer the complete versatility and telescoping capabilities that the Standing Gardener offers.

SUMMARY OF IMPACT
The Standing Gardener is made entirely to aid a child or adult with Cerebral Palsy in ways that no other stander on the market can. Our clients’ parents own a gardening business and, because of his poor motor function, our client cannot aid in helping his parents as he would like to. The purpose of this device is to aid our client, and others alike, to work and accomplish tasks that they could not otherwise do.
TECHNICAL DESCRIPTION

The workspace is a completely customizable feature that is made specific to gardening. Pictured in Figure 17.4, is a rotatable pot template which holds the gardening pots below the plane of the table so soil can easily be pushed into them. Below the pot template is a soil catching drawer that will catch any overflow of soil through the unused holes in the template. If the template is not used, a template cove can be placed in its spot to create a flush work surface to do tasks other than gardening. Pot tray holding walls are for finished pot placement after the flower has been planted. Handles are additional features that are on the Standing Gardener workspace.

The steel frame consists of two stainless steel plates 1/8 of an inch thick creating a sandwich effect above and below eight stainless steel legs. Each of the legs has fourteen holes drilled through it, allowing for fourteen different heights of users that the Standing Gardener accommodates. The support system consists of pads that support the chest, hips and knees, and straps that support the feet and keep them in place. The chest support is made up of 3 pads (one in front and one on each of the sides). The front chest pad stays stationary, while the side pads can be moved in and out, depending on the size of the user. A hip belt is located below the chest support to keep the user from leaning too far back and falling out of the device. Below the hip belt is the knee support system. As a whole, the knee support system can be moved up or down along the legs of the device. In addition, each of the knee pads can be moved in and out and side to side to accommodate different sized users. The foot board below the knee support system has straps to secure the users feet and stabilize them.
MULTI-TERRAIN WHEELCHAIR: A DEVICE TO TRAVERSE SAND, SNOW, AND ICE

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INTRODUCTION
The Multi-Terrain Wheelchair is a modified device that gives its user more versatility than a regular wheelchair. Most manual wheelchairs can only traverse smooth and even terrain. The Multi-Terrain Wheelchair can traverse many more kinds of terrain, including sandy, snowy, and icy conditions. The Multi-Terrain Wheelchair uses the technology of extra wide balloon wheels to increase the surface area in contact with the ground to increase the ease of motion.

SUMMARY OF IMPACT
The Multi-Terrain Wheelchair provides more versatility in going places that one could not normally go, including conditions that are icy, snowy, and sandy. The goal of this device is to provide the users with more ways to enjoy themselves and partake in everyday and recreational activities.

Fig. 17.6. Multi-Terrain Wheelchair.
TECHNICAL DESCRIPTION
The Multi-Terrain wheelchair consists of a modified wheelchair frame that has been equipped with large wheels in order to traverse different kinds of terrain. Front brackets are constructed and welded in order to be attached to the front caster wheels, which can spin a full 360 degrees. Because of the design implemented, the front wheels can be placed in two positions. The first position is with the front wheel attachment brackets parallel to the frame of the wheelchair. This arrangement can be seen in Figure 17.7. This position is a traveling position, with the leg supports raised and the weight spread out. There is also an angled position which is used for resting, whereby the leg supports are positioned down to a more comfortable position. The front wheels have spacers to tilt the weight of the wheelchair back slightly so it doesn’t tip forward.

The rear wheels are attached via individual mounting brackets and an axel for each wheel. Having two separate axels for the rear wheels doesn’t hinder the Multi-Terrain Wheelchair’s ability to fold and fit through small spaces.

Foot and leg straps are added to the foot and leg supports. These help stabilize the feet and knees of the user, if necessary.

Fig. 17.7. Front Wheel Positions.
INTRODUCTION
The purpose of this project is to design and build a go-kart for our client, who suffers from severe cerebral palsy. Our client has almost no reliable motor control of his body or limbs, ruling out the viability of a traditionally designed go-cart. The idea behind this project is to design a go-kart based on the client’s abilities affording him the experience of a “real” go-cart. To accomplish this task, a go-kart is built from the ground up to meet his specifications. It has three different modes of control: remote control, joystick control, and steering wheel with pedals control. This allows our client to use the vehicle on day one, and progress to having more and more control of the go-kart with practice. The vehicle is designed with the client’s condition in mind and ensures that his body is positioned correctly for maximum motor control. The vehicle is also adjustable to allow for a wide range of drivers of different sizes and abilities. Additionally, the S-90 has a number of safety kill switches to ensure it is safer, more versatile, and more fun than anything else on the market.

SUMMARY OF IMPACT
The main goal of this project is to provide our client with the experience of operating a go-kart. This go-kart is built in such a way that it can be operated by anyone, and when looking at the design it is as aesthetically pleasing as any traditional go-cart on the market today.

TECHNICAL DESCRIPTION
The go-kart for this project is custom built from the ground up to maximize the efficient use of space, and to ensure that the needs of our client are met. The frame consists of a steel open roll cage design with front suspension and semi-independent rear suspension. A 10 horsepower gas motor provides power for the drive, and also runs a 7 amp alternator. An electric gearmotor actuates a rack and pinion to steer the vehicle. The steering gearmotor is controlled by a PWM signal through a speed controller. The throttle is controlled by a servo motor pulling on the throttle linkage. This servo is controlled directly by a PWM signal from the microcontroller. The brakes are actuated by a gearmotor that pushes linkage into a hydraulic brake line. The braking gearmotor is controlled by a PWM signal through a speed controller.

Each PWM signal is generated by an on-board PWM module on one of the 3 PIC microcontrollers. Each...
PIC has two PWM modules that can generate individual pulse widths over the same period. For the purpose of driving the go-kart’s speed controllers and throttle servo, the PWM period is set to 20 ms and each PWM signal can range from 5-10% duty cycle. PWM output signals can be adjusted in the software by changing special function registers associated with the PWM modules. Each system needing a PWM on the go-kart has a software routine to take information from inputs and adjust the special function registers to create the corresponding PWM output.

The steering software system uses two inputs to create the final PWM output. The first input is the user control input. This input corresponds to the selected control mode. Each mode has its own function that is called in the software to get information from the correct input device. Each control mode function normalizes its input to a standard form, and this data is then sent to the steering update function. A steering feedback potentiometer moves with the wheels and thus keeps track of the absolute position of the wheels at any given time. The steering update function takes the user input data and compares it to data from the steering feedback potentiometer. If the steering update function determines that there is a sufficient discrepancy between the normalized user input and the steering feedback, it updates the PWM registers to move the gearmotor until both inputs are within tolerance of each other. The braking software system works in the same way as the steering software, except that it uses separate user inputs and a different feedback transducer.

The throttle software system is simpler than the steering or braking systems, because it only requires one input. The throttle servo motor incorporates its own feedback system, so the only job of the software is to provide the proper PWM signal. The throttle input corresponding to the correct control mode is selected by calling the proper function, which normalizes the input data. The data is then input into a linear equation that directly updates the PWM registers corresponding to the throttle servo motor outputs. The throttle servo motor is connected to its own dedicated 6V supply. A 4 cubic inch aluminum heat sink is employed to ensure the voltage regulator does not enter thermal shutdown during times of high current draw on the 6V source.

Three possible methods of control are available on a user-selectable basis. The main method of control is the joystick that controls steering, throttle, and braking using a two axis system. The second control system is based on remote control, to allow the client to use the go-kart immediately. A radio controller designed for model aircraft is controlled by a guardian. A radio receiver on the go-kart takes the transmitted signal and feeds it to the microprocessor. The final method of control is a steering wheel and pedals that allows the vehicle to be operated like a normal car or go-kart. These inputs are connected to the microprocessor, through potentiometers, instead of mechanical attachment. Embedded software eliminates the need for complex analog circuits that would otherwise make up a control system like this. The software for the go-kart has two main purposes: to provide overall control of the systems necessary to operate the go-kart, and to recognize when the go-kart is not functioning properly and to shut it down safely.

In addition to the custom control methods, this go-kart has a number of other features tailored directly to meet the client’s needs. The seat is the most important of these features. The Tumble Forms 2 Carrie seating system is designed to keep the client bent 90° at the waist at all times, and can be swapped with a regular seat using a custom modular bracket system. The bracket for the Carrie seat is designed so it can be easily attached or removed from both the S-90 and from the Carrie seat itself. This allows the family to use the Carrie seat as a car seat in addition to its use on the S-90. The mounting platform for the seat on the S-90 is attached to a linear actuator, which provides forward and backward seat adjustment at the touch of a button.

For safety reasons, two head switches and a remote are used as kill switches for the go-kart. One head switch or a remote button activates a software routine that grounds the engine and applies the brake. When one of these switches is activated the software leaves its main service loop and enters a service loop with pre-programmed inputs for throttle and brake. A MOSFET is triggered by the microcontroller, which activates a relay connecting the engine spark plug to ground. A different remote button or the other head switch directly grounds the engine to ensure the S-90 can be shut down even if the software fails.
The drive system for the S-90 optimizes engine output without need for the drive to change gears. A torque converter is attached to the drive shaft of the engine which acts as a constantly variable transmission. At low engine RPMs, the drive belt connecting the driver of the torque converter to the driver of the torque converter remains stationary. As the engine RPM increases, centripetal force causes the driver to engage the belt, which powers the driver. Increasing the engine RPM will cause the driver to further engage the belt. The torque converter is capable of producing a 3.78:1 gear ratio at low RPMs and a 1.04:1 gear ratio when fully engaged. The jack shaft of the go-kart has a ten toothed gear attached to it driving a fifty-eight toothed gear on rear axle of the vehicle, providing a 5.8:1 gear ratio. Using these gear ratios and a maximum engine RPM of 3800 gives the go-kart a theoretic top speed of 39.32 MPH. Accounting for an average mechanical reduction of 20% yields an actual top speed of 31.5 MPH.

The front suspension of the go-kart utilizes a parallelogram design which allows for the wheels of the go-kart to remain vertically aligned when the suspension is compressed. Without this design, as the go-kart’s suspension was compressed, the camber angle of the front tires would change. The steering of the go-kart was designed with zero caster angle in order to reduce load on the gear motor during high speed turning. The toe alignment of the go-kart was designed to be dynamic; there is zero toe under normal operating conditions, but when executing hard turns the toe alignment automatically adjusts to have a slight toe in. This will provide zero rolling toe as the vehicle is turning due to the vehicle’s rear wheel drive forcing the front end of the vehicle down during hard turns. This ultimately compensates for the natural tendency of the front wheels to be toe out due to the rolling resistance and compliance in the suspension. The total turning angle of the front wheel is 95.6 degrees. Under zero resistance the go-kart is capable of turning the wheels through the full range of motion in about one second, this time will increase when the go-kart is loaded. The rear suspension of the go-kart was designed to be semi-independent. The rear portion of the go-kart’s chassis is able to pivot about a central hinge pin, which in turn causes the compression of the coil over springs in the rear suspension.

The cost of parts and materials is $7300.
Fig. 17.10. The S-90 Go-Kart.
ASSISTIVE JUMPING DEVICE FOR TRAMPOLINE

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INTRODUCTION
The assistive jumping device (AJD) allows those with physical disabilities to successfully and independently jump on a trampoline. A jib crane structure supports the user above the trampoline and further aid the user for lift onto the trampoline. The upper arm of the crane has a horizontal trolley system to position the user to the best location on the trampoline. A vertical rail system, attached to the jib crane and the harness system of the user, controls and stabilizes the vertical jump of the user. The AJD utilizes a harness system for full upper body support while still allowing the user to have full range of leg motion to freely create the jumping motion.

SUMMARY OF IMPACT
The AJD allows a person with a disability to enjoy all the fun of jumping on a trampoline. Since the AJD provides a controlled and safe form of not only exercise, but fun, it has a profound impact on the rehabilitation community. The system uses the weight of the user to provide resistance in leg strengthening as well as to increase proprioception awareness of the muscles. In addition to its health benefits, the AJD increases awareness for adaptive products for the disabled as there are a very limited number of such products for fun-related activities. The AJD also increases self-confidence and encourages those who are disabled to strive to accomplish anything they wish.

TECHNICAL DESCRIPTION
The assistive jumping device is supported by a 10.5’ jib crane with a span of 6’. The crane positions the user over the trampoline without being overly obtrusive to other jumpers on the trampoline. The AJD is attached to the top of the jib crane via a crane trolley (see Fig. 17.13). The trolley allows for lateral motion of the AJD along the I-beam of the crane, so the position of the user can be controlled.

The vertical rail and bungee cords are each attached to the trolley with steel brackets that fit along the
bolt of the crane trolley. The bungee cords are able to completely support the weight of the user. The cords make jumping easier, and decrease acceleration down towards the trampoline to prevent injury; while the vertical rail maintains the user’s proper posture.

The user is supported by an integrated harness (see Fig. 17.12). The back of the harness consists of a modified Carrie Junior chair from Tumble Forms. The chair offers head, neck, and torso support. The chest straps of the seat are modified to clip into an added pelvic harness via seatbelt buckles. Pelvic support is maintained by the “Wiz Kid”, a children’s pelvic climbing harness by Mountain High Outfitters. In addition to the seatbelt buckles connecting the pelvic harness to the chest straps, the back of the pelvic harness attaches to the sides of the converted Carrie seat to provide four points of attachment. This attachment technique makes the harness very safe and comfortable to wear. Sheep skin lining along the leg and back straps of the harness add to its comfort.

The entire harness moves along the vertical rail with a rail trolley that is attached to the back of the harness. The trolley is bolted to an aluminum bracket along the back of the harness. The trolley offers minimal friction between the trolley and rail without the need of lubrication.

Fig. 17.13. AJD attached to crane trolley and supported by jib crane.
CHAPTER 18
UNIVERSITY OF DENVER

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Smart Hospital Room Project

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INTRODUCTION
A system for controlling a hospital room’s environment by a person with limited mobility is the focus of this project. The key attributes of the system is the restoration of the ability of a limited mobility patient to control the hospital room environment using basic body movements. Additionally, alternative communication is provided with care providers as well as their friends and family through the use of a virtual phone, the internet, and an instant messaging service to the nurses’ station. This communication can be automated through scripts or customized messages can be created.

SUMMARY OF IMPACT
The target audiences for this system are patients who have recently experienced an accident and are therefore in a highly frustrating and vulnerable phase of their new disability or injury. For the implementation a quadriplegic patient is selected as the user. These patients are paralyzed in all four limbs (arms and legs) for the initial stage of recovery which can be for up to three months. The symptom is usually caused by damage to the brain or spinal cord which causes the person to lose partial or total mobility of all four limbs. Quadriplegic patients initially experience increased anxiety due to unexpected or anticipated lack of control in their surrounding environment. For example, they cannot walk to the TV and turn it on. They cannot control the temperature of the room. In some cases, it is difficult for them to call for help (i.e. the nurse) due to temporary loss of speech.

TECHNICAL DESCRIPTION
A graphical user interface is controlled with a wearable mouse. Interface to the mouse is performed with a reflector placed on the patient’s forehead or on the tip of a ball cap. Fig. 18.1. Smart Hospital Room Graphical Display

Motion of the head or face is detected to move the mouse on the screen. A click is performed by resting the position of the mouse for a few seconds. The patient selects the device to control by inspection of the graphical interface; for instance the call button, lights, fan, bed, TV, or internet. The graphical interface is generated by the processor. The user communicates with the processor via the user input device. The processor transforms the input command into an output command usable by the selected transceiver and device controller. The processor directly controls the access to the internet. The output commands for the external devices are sent through the processor transceiver. The selected device transceiver executes the action needed to adjust the chosen device via the controller.

The computing platform is placed on a stand as shown in Fig. 18.2. This stand has an adjustable arm so the monitor can be placed at a comfortable location for patient use. Lockable wheels are placed on the base so the device remains in place under the bed. As shown in Fig. 18.1, the receiver for the mouse is on top of
the display but this can be moved based on the needs of the user.

The cost of parts/material was about $1,000.

Fig. 18.2. Positioning Diagram for Bedside Stand.
Low Impact Exercise Bike Redesign

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INTRODUCTION
The intended scope of this project is to create an aesthetically pleasing machine that is of a lower cost, weight and bulk, that can help a wide range of people without going extensively into market research and testing. The modeling for the machine is mostly focused on the general needs of a particular patient. The original patient was recovering from knee surgery and wanted to regain the mobility to go on fishing trips. Light to moderate exercise was believed to allow her to complete this goal. After two years, the initial design was becoming rusty and the flywheel design was both wobbly and did not offer enough resistance, and thus a redesign will focus on better longevity and stability while addressing weight and bulk concerns.

SUMMARY OF IMPACT
The proposed exercise machine is a redesign from a 2007 project which was intended for people who are unable to perform common physical activities, however, are able to perform mild exercise routines. The machine design is to help people who may be overweight or unable to exercise by common means. This device may be of use to persons with medical problems, health problems, leg surgery recoveries or any other ailments that do not allow for common exercise routines or regular outdoor activities.

TECHNICAL DESCRIPTION
The base frame is constructed from 2 inch by 2 inch by 14 GA wall A500 rectangular tube steel. All pieces are welded together. Powder coating of all steel pieces is done in order to have a protective weather coating. Adjustable feet, which can be cut from rubber tubing, are placed on the bottom of the structure so the device can be leveled. The 31.5” support bar for the sliding seat is welded to the frame and is constructed of 2”x2” by 14 GA wall A500 rectangular tube steel. The support bar has 1-1/2” spaced holes for maximum seat adjustment. The seat is a prefabricated ‘Koolback’ recumbent seat. The handlebar and connection arm are comprised of two components. The handlebars are standard design off the shelf with an adjustable connection arm and the connection arm. The straight neck design is fabricated from the standard 2”x2” 14 GA steel with a grooved 5” cut to allow for the flywheel clearance of 4” and allowing the hole cut for the drive shaft to secure the straight neck to the assembly. The arm also has resting pins on the aluminum outer frame cover assembly.

The cost of parts/material was about $1,478.
Figure 18.3. Exercise Bike System Level Diagram.

Fig. 18.4. CAD drawing of Exercise Bike.
Knee Rehabilitation Goniometer

Designers: Clay Claus, Ryan McDonald, and Nolan Tallman
Client Coordinator: Dr. Michael Blei, Denver Health Medical Center, Denver, CO
Supervising Professor: Dr. Mohammad Mahoor and Dr. Kimberly E. Newman
Electrical and Computer Engineering
University of Denver,
Denver, Colorado 80208

INTRODUCTION
On a national level, as of 2007, 27% of people aged 18 and older reported some form of joint pain, and 16% reported knee pain. A study in the American Journal of Orthopedics suggests that in-home mechanical therapy may increase the range of motion (ROM) of those afflicted with loss of knee flexion. In-home mechanical therapy is a potential solution to those who a rigorous and costly physical therapy regimen is not available or those wishing to regain flexion without surgery. Therefore, this study indicates that an increase in in-home mechanical therapy among certain patients could stimulate demand for range of motion monitoring and data transmission. Of the approximately 4 million orthopedic procedures performed in the US last year, 555,800 were total knee replacements (TKRs). The number of total or partial knee replacement procedures performed in hospitals in Colorado, between August 2007 and July 2008 was over 10,600.

SUMMARY OF IMPACT
At-home physical therapy is substantially more cost effective to the physician, the insurance company and saves the patient a lot of time. A wearable product enables the patient to rehabilitate his/her joint at home and provide the physician with the necessary information regarding the ROM progress. This will free up the caregivers time in the office as well.

TECHNICAL DESCRIPTION
The contributions this year are improved sensing and communication capability of the device for remote monitoring of progress after total knee replacement surgery. Students used an angular rotation sensor mounted in a knee brace and interfaced this with a Bluetooth module for communication with a smart phone to a remote server. The allows a physician to monitor progress during the critical 10-14 day window after surgery to ensure full ROM is achieved before the tendons stiffen and additional surgical intervention is required.

The cost of parts/material was about $600.
Fig. 18.5. Wearable Sensor and Phone Interface.
PROGRAMMABLE USB BUTTON AND SWITCHING SOFTWARE

Designer: Brian Derrico
Client Coordinator: Debbie
Supervising Professor: Alan Rux
Electrical Engineering department
State University of Massachusetts at Lowell
Lowell, Massachusetts 01854

INTRODUCTION
The programmable USB Button is a device that allows our client to have four people play a cause-and-effect type game at the same time. The switching software allows the client to switch between the applications that are used. To accomplish this, a USB keyboard is modified to produce the outputs necessary for the game, and to package it safely for the client. The device has a switch that will switch a button from controlling the first, to the second, third, and fourth player; therefore each of the buttons can be used to control any of the four players. Currently there are not many devices on the market that can be used for this application, due to the need for a large button instead of a key. The software appears as a small toolbar and has three icons that relate to the three applications used. When the user presses one of the toolbar buttons, that program will be brought to attention on the screen. There are various programs on the market that will allow you to change applications, but none are as customized as this piece of software.

SUMMARY OF IMPACT
Without this device, only one person at a time could play the game, which is a cause and effect game with audible and visual pieces. Before our device, the game could support up to four players, but the button being used for the game could only actuate one player. Now four players can play the game at the same time, and not only get the cause and effect benefit, but they also can interact with each other as they play the game. The switching software allows for better use of the game because each application used can be running at the same time, and the user can switch between all running applications when needed.

TECHNICAL DESCRIPTION
The USB Button utilizes an existing USB Keyboard circuit. When a button is pressed on a keyboard it connects two pins; these pins connect to a microprocessor, and when the microprocessor detects which pins have connected, it sends the proper character to the keyboard. It does this by serially sending the proper bits to the computer through the “data out” pin, at which time the computer will then take over and display the character. To actuate the players in the game, the keys 1, 2, 3 and 4 can be pressed. These four keys share one common pin, and also have their own separate pin. Because of this, the player that the button controls is controlled by a rotary switch (see Fig. 19.2). The switch selects which of the four different pins is connected to the common pin, therefore selecting the player that that device will control. Because each device is connected through USB, this will allow all four to be connected to one computer at the same time because the system will see the device as a keyboard.

Fig. 19.1. Flow Chart.
The software uses the Simple Direct media Layer (SDL) as a visual library, due to its ease of use and powerful capabilities. The software piece displays as a taskbar that can be placed anywhere on the screen. On this bar there are three different icons, each corresponding to a different application the client uses. When one of the icons is pressed, the application it corresponds to is the main focus on the screen. If the application selected is not running, the program executes that program for use (see Fig. 19.1).

The total cost of parts for each USB button is $42, and the software is available at no cost.

Fig. 19.2. Schematic of Circuitry of Device.
AUTOMATIC PEDALING MACHINE

Designer: Brian Healey
Client Coordinator: Lisa, the Nashua Center, Nashua, NH
Supervising Professor: John Fairchild
Electrical Engineering Department
State University of Massachusetts at Lowell
Lowell, Massachusetts 01854

INTRODUCTION
The Automatic Pedaling Machine (APM) is designed to rotate the legs of people with multiple handicaps. The device is simply a motorized set of bicycle pedals that sits on the ground and attaches to a wheelchair. Once the APM has been secured to the wheelchair and the patient’s feet have been strapped into the pedals, the patient selects one of two modules that control the pedals movement. The APM was presented to The Nashua Center in Nashua, NH. The Nashua Center provides care to adults and children with severe and multiple disabilities, both physical and mental. The APM is intended to give the patients a sense of independence from the staff as well as increased circulation to the legs.

SUMMARY OF IMPACT
The design criteria were specified by The Nashua Center. Up until now, the staff spent much time manually rotating the patient’s legs for them. This exercise increases circulation and loosens muscles and joints. The staff desired a machine that would automate the rotation task for them. They also expressed a desire to have a couple of different control modules that the patients could operate themselves. The reason for two separate modules is that the patients have different mental capacities. For some it was necessary to have one button that when pressed would rotate the pedals for 15 seconds and then stop. For those with a stronger mental capacity, a second module with a start button and a stop button was requested. All buttons are big, easy to hit Jelly-bean switches. The APM will give the staff more time to perform their various tasks as well as giving the patients a sense of accomplishment and independence.

TECHNICAL DESCRIPTION
The base of the APM was made from 1.5 inch steel tubing that is welded together to form an H frame. A 12 inch tall tower is constructed from steel sheet metal and welded to the H frame. It is welded at a place that is determined to be the correct distance from the wheelchair so that the patients are correctly positioned with respect to the pedals. The motor is fastened to the tower by bolts.

The pedals are turned by a DC electric geared motor. The motor is carefully selected to have sufficient torque to rotate the patient’s legs, yet not enough torque to injure the patient if a foot or hand blocks the pedal. Thus, the machine is not dangerous for the patient to use. A DC motor is chosen over an AC motor because of the smoothness and quietness of operation. The circuit contains an ACDC converter to supply the motor with DC power.

Aside from the motor circuit, a circuit for the two modules is included in the design. A Basic Stamp 2-IC (BS2-IC) is used to control a solid state relay which in turn gives power to the motor. Each button is wired to a separate input pin on the BS2-
IC. A program was written and programmed into the basic stamp that performs the desired functions.

The cost of parts and material was about $350.

Fig. 19.4. Student Delivering the Device to the Client.
THE INTERACTIVE BALLOON PUMP

Designer: Danny Haynes
Client Coordinator: Tiffany, LifeLinks Inc.
Supervising Professor: Alan Rux
Technical Advisor: Jay Fu
Department of Electrical and Computer Engineering
University of Massachusetts, Lowell
Lowell, MA 01854

INTRODUCTION
The Interactive Balloon Pump is a game that is designed for a class offered at LifeLinks Inc. called Communications through Games – Switch Activated. This class teaches the concept of cause and effect in a fun and sociable manner through the use of audible, visual, and tactile stimulation. It is important that the game allows all users, regardless of their level of ability, to be able to operate and take full advantage of the device’s capabilities. However, finding a commercially available game that meets all of these requirements is a difficult task.

One commercially available game was considered, but rejected because it required users to repeatedly squeeze a spiked ball in order to inflate the balloon. Many of the participants have Cerebral Palsy, which affects a person’s muscle control and motor skills making squeezing a ball quite challenging, if not impossible. In addition, the device does not prevent the balloon from popping or flying off the nozzle due to over inflation. This is a problem as the loud noises caused from these events could startle, or even scare the users. Finally, the last issue with this solution is that it costs $289, which is expensive for a device that does not cater to the needs of all the participants.

The Interactive Balloon Pump will achieve the learning objectives of the class by reinforcing the concept of cause and effect through the inflation of a balloon, the playing of music (audible), the displaying of colors through optical fibers (visual), and the opportunity to interact with the buttons, balloon, and optical fibers (tactile). The device is controlled electronically by two push-button switches, thus providing reinforcement of the concept of cause and effect independent of the users’ ability. The Interactive Balloon Pump also utilizes a pressure sensor that actively monitors the pressure inside the balloon in order to determine when the balloon has been fully inflated, thus preventing the balloon from popping or flying off the nozzle.

SUMMARY OF IMPACT
The design specifications for the Interactive Balloon Pump were determined by the abilities of the clients as well as improving upon the shortcomings of the commercially available product described previously. The electronic activation of the Interactive Balloon Pump gives the users the ability to inflate a balloon while enjoying audible, tactile, and visual stimulation. With two modes of operation, autonomous and manual, users who can and cannot press a button for extended periods of time are able to participate in this game without difficulty. As a result, all participants will be able to enhance their understanding of cause and effect in a fun, exciting, and stimulating manner.

TECHNICAL DESCRIPTION
The Interactive Balloon Pump consists of a series of five smaller sub-systems that work together via a single BASIC 2 Stamp microcontroller. The sub-systems include air delivery and exhaust, pressure sensing, user input, audible stimulation, and visual stimulation.

Initially, the microcontroller waits for user input via the two push-button switches which cause the balloon pump to go into either autonomous or manual mode. If autonomous mode is selected by the user, then the microcontroller sends a HIGH (+5V) signal to the digital transistor switches that control both the solenoid valve and the air compressor. When this voltage is applied to the solenoid valve switch, it drives it into saturation, which energizes the solenoid valve coil opening a pathway between the air compressor and the balloon. Likewise, when the transistor switch is activated for the air compressor, a relay is energized closing the air compressor circuit, thus turning it on.
Next, the optical fibers will be illuminated and begin to transition between the colors red, green, and blue. During every iteration, the air pressure inside the balloon is measured and the microcontroller determines whether or not the pressure is within a pre-determined range. If within the range, a counter is incremented that will keep track of the number of consecutive pressure readings that were in the specified range. If the next value isn’t in that range the counter is reset back to zero. This mechanism was put in place because the sensor sometimes returns inaccurate spikes in pressure which could result in the inflation of the balloon terminating prematurely. This ensures that the balloon will be completely filled every time. If the pre-determined number of consecutive acceptable pressure readings are reached, the balloon pump leaves autonomous mode and enters inflation finalization, otherwise it repeats the above sequence until inflation is complete.

If manual mode is selected by the user, the sequence of operations is very similar to autonomous mode with the difference being that the air compressor and visual stimulation are activated if and only if the manual mode push-button is depressed. Otherwise, it waits for the user to continue inflating the balloon. Manual mode is also safeguarded by the pressure sensor in that it will cease inflation, and enter inflation finalization when the proper pressure in the balloon is reached.

Inflation finalization is reached when the correct pressure is reached. Inflation finalization consists of turning the air compressor off by sending a LOW (+0V) signal to its respective transistor switch, and then activating the audible stimuli circuitry by sending a HIGH (+5V) signal to its transistor switch which will result in the voice chip playing back its stored music clip. This music clip will loop until a LOW (+0V) signal is sent to its corresponding transistor switch. Next, the microcontroller will simultaneously blink the optical fibers providing visual stimulation. Finally, the exhaust valve is opened by de-energizing the solenoid valve, in turn releasing the air from inside the balloon. Once complete, the audible and visual stimulation systems are deactivated and the balloon pump once again waits for user input.

The total cost for parts and materials was approximately $385.
KYLE WIRELESS ALERT DEVICE: A DEVICE THAT ALLOWS DISTANT COMMUNICATION FOR A NON-VERBAL PERSON

INTRODUCTION
The Kyle Wireless Voice Alert System (KWVAS) is an interfacing device which uses a computer program to trigger the transmission of a pre-recorded message through a standard hand held radio (walkie-talkie). Currently the client is not able to call the caretaker when the caretaker leaves the room or goes to an area not accessible by wheelchair. The client must wait until the caretaker comes back to be able to do simple tasks such as using the bathroom.

SUMMARY OF IMPACT
The KWVAS is designed to provide freedom and a sense of security to both our client and the caretaker. Knowing that help is as simple as a mouse click away will not only create a greater feeling of security and independence for the client but will also reduce stress of the caretaker from worrying about leaving the room were the client resides for any amount of time more than a few moments. The device utilizes the computer as a triggering device because the client is usually using the computer.

Fig. 19.6. Schematic of entire device including microcontroller, sound chip, and amplifier.
when not working with the caretaker directly.

**TECHNICAL DESCRIPTION**

The KWVAS utilizes an ISD1790 sound chip to keep a voice recorded alert message in non-volatile memory storage. A PIC18F2550 microcontroller is used to communicate to the PC via USB and control the ISD1790 and hand held radio PTT button. Enumeration between the computer and microcontroller is handled by the on chip configuration registers and drivers provided by the manufacturer microchip.com. Once enumerated, a visual basic program sends a message to the microcontroller when the alert button has been clicked and the microcontroller will start communication with the ISD1790 to play the message. Before playing the message, however, the microcontroller will apply voltage to a BJT used to switch on the PTT function of the walkie talkie. The entire device is powered by the USB port.

The cost of parts/material was about $200.

Fig. 19.7. The client excited about his new device.
THE MULTI-OUTPUT TIMER: A LIGHT-UP
COUNTDOWN TIMER THAT SPEAKS AND
VIBRATES UPON COMPLETION

Designer: James Richard
Client Coordinator: Patti Peterson, Bridgewell, Lynn, MA
Supervising Professor: Walter McGuire
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INTRODUCTION
The multi-output timer is designed to provide students with a way to stay focused on a particular task. The timer has a circular light-up display that fills up with one color when the time is set. As the time expires, the six “pie pieces” of the display begin to disappear. The students know that the time is up when the display goes completely dark. When the time expires, a prerecorded voice speaks “all done” and a vibrating pad is activated. Upon completion, the multi-output timer was presented to Bridgewell in Lynn, Massachusetts. The students that will be using the timer do not have an adequate conception of time as a number, making conventional timers ineffective. The light-up visual display is a concept that is easier for them to understand.

SUMMARY OF IMPACT
Bridgewell requested a device that would help the students stay on task throughout the day. There are times during certain activities when students can become restless. The timer provides a visual representation of how much longer they need to stay focused before they can move on to another activity. Though mainly used as a tool, the timer will also be fun for the students. The light up display is visually appealing and the vibrating button is fun to play with. Because it is battery powered and contained in a fairly small package, the timer can be easily transported between rooms, adding to its versatility.

TECHNICAL DESCRIPTION
The timer is encased in an electronics project box. The size of the box is selected to contain a six inch diameter display while leaving room for the other components on the face of the timer.

A Basic Stamp 2 Module is used to control all of the components of the timer. It is chosen because it has 16 input/output pins which is enough for this application.

Two thumb-wheel decimal switches are used as the input to the timer. The maximum input time is 20 minutes, as requested by the client.

The light-up display is split up into six sections. Each section contains two Super Bright LEDs. Each section is controlled by one of the Basic Stamp’s output pins. A 74AC245 octal transceiver is used to supply enough current to the LEDs without exceeding the current sinking limitations of the Stamp.

An ISD1790 ChipCorder is used for the audio output. A message is prerecorded into the chip that says “all done” when the “play” pin is set low by the Stamp. A 16 Ohm speaker is attached directly to the ISD. A small DC vibrator motor is used to provide the vibration in the pad. A gutted jellybean switch is used to house the motor. The Stamp triggers the vibrator motor by applying voltage to the base of a BJT driver. A driver is necessary to supply enough current to the motor.

The cost of parts and materials was approximately $100.
Fig. 19.8. The Multi-Output Timer.
THE AUTOMATIC PAGE TURNER: A PAGE TURNING ASSISTANT FOR CHILDREN THAT ARE DISABLED

Designers: Jason M. Gustin
Client Coordinator: Bonnie, Kennedy Day School, Boston, MA
Supervising Professor: James Drew
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INTRODUCTION
The Automatic Page Turner (APT) is designed to be a teacher’s aide in the classroom. The teacher only needs to set the APT up in front of the student, and the student can then control whether or not they want to flip a page forwards or backwards. The APT only requires two buttons in order to be controlled, this greatly increases the number of students that are able to use it because the controls are simple. Teachers are also able to connect different types of switches to accommodate different students.

SUMMARY OF IMPACT
The APT (see Fig. 19.10) has greatly increased the quality of life for students at the Kennedy Day School. They no longer require a teacher’s supervision just to read a book, which gives them a sense of independence and allows them to make decisions on their own. This device not only benefits students, it also greatly increases the amount of time a teacher can spend with other students, making better use of the teacher’s time.

TECHNICAL DESCRIPTION
The base frame for the APT is made from an aluminum framing material (1 by 1 inch). The aluminum is a T-slotted extrusion which provides a wide range design advantages. The aluminum provides a light weight structure that is quite durable and strong. The base frame is a standard rectangle which can be angled in many directions because of the design of the stand that it is attached to.

The actual act of flipping a page consists of a couple different motions. First the page must be lifted from the book, and second the lifted page must be pushed across the book. These two motions are very different from one another and required some unique design considerations.

In order to actually lift the page the APT uses a set of silicon suction cups and a vacuum. A standard air pump is used to create a vacuum of around 16 in-Hg. This provides a great deal of suction and assures that the page will not be released. Silicon suction cups with a bellow are implemented because of the softness of the silicon. The bellow allows the suction cup to be very flexible when grabbing the page. In order to actually lift the page up once it has been grabbed, another air pump actuates an air cylinder. The air cylinder is affixed to a rotatable bar to which the suction cups are also attached. Once actuated, the cylinders rotate the bar thus lifting the page.

The job of flipping the page is performed by a bar which is attached to the frame via the T-slots. This
bar rests vertically on the APT and is parallel with the book edge. A timing belt runs down both sides of the aluminum frame and attaches to the flipping bar. The flipping bar rests on a special rubber which is designed to slide easily along the aluminum frame. The side to side motion of the flipping bar is achieved by a DC motor attached to one of the timing belt pulleys. A DC motor was chosen because the control circuit is very simple and the direction of which it spins can easily be altered. Control of the motor is regulated using a special chip (MC33887VW-ND), called an H-Bridge, which simplifies the controls to only two control lines. Once the page is lifted the page flipping bar moves under the page and pushes it across the book. The other side of the APT lifts up, lets the page fall and then comes back down to hold the page in place. To ensure the DC motor does not run the page flipper into the sides of the APT, infrared LED light switches are used. Once the page flipper triggers one of the switches the motor stops running.

All of these motions are coordinated using the PIC Microcontroller 16F690. This chip was chosen because it best fit with the specifications of the APT’s functionality.

The cost of parts and materials was about $500.

Fig. 19.10. The Automatic Page Turner.
TOUCH BRITE: A WIRELESS TOUCH SCREEN CONTROLLED LIGHT BOARD

Designer: Kevin M. Lemoi
Client Coordinator: Lowell Life Links Community Center, Chelmsford, MA
Supervising Professor: James Drew
Electrical and Computer Engineering Department
University of Massachusetts at Lowell,
Lowell, MA 01854

INTRODUCTION
The Touch Brite device consists of a handheld Touch Screen and a Light Board. Portions of the Light Board are illuminated by pressing specified areas on the Touch Screen. Multiple areas of the Light Board are illuminated by dragging a finger or stylus across the Touch Screen. The Light Board is cleared by pressing a specified ‘Clear’ section of the Touch Screen. The Touch Brite also provides a feature to automatically illuminate patterns of lights. This feature is selected by pressing a specified ‘Pattern’ section of the Touch Screen. The Touch Screen and Light Board communicate wirelessly. The Light Board is powered by a standard wall adapter and the Touch Screen is powered via battery. Figure 1 shows a block diagram of the system.

SUMMARY OF IMPACT
The Touch Brite is designed to provide adults with learning disabilities a recreational “cause and effect” activity. The design criteria for the Touch Brite were defined by the recreational activities provided by the Community Center at Lowell Life Links. The Center offers courses designed to stimulate the minds of over 125 adults with learning disabilities. The Touch Brite device is designed to be easily integrated into the Center’s current curriculum. For example, students were able to draw pictures during art class. Also, teachers can use the Touch Brite as a teaching tool.

TECHNICAL DESCRIPTION
The Touch Brite system is divided into four sections: Touch Screen hardware, Touch Screen software, Light Board hardware, and Light Board software. The Touch Screen hardware consists of an 8” resistive Touch Screen, a microcontroller, and a wireless transmission unit. Fig. 19.11 shows a block diagram of the system. The Touch Screen software provides two functions: Touch Screen driver and transmission buffer. The Touch Screen driver communicates with the Touch Screen via five wires. Reference and ground voltages are applied to the Touch Screen by the microcontroller in order to measure the user’s touch coordinates. Once a measurement is taken, the value is converted to a binary number for analysis using the microcontroller’s analog to digital converter. The value is then encoded to a specific light on the Light Board. That value, enclosed in a predetermined data protocol packet, is then buffered and eventually sent to the transmitter unit via the microcontroller’s UART.

The Light Board hardware consists of three parts: a wireless receiver, a microcontroller, and the Light Board. The Light Board consists of a 16 x 16 LED matrix, multiple transistors, latches, and decoders. A technique called ‘row scanning’ is used to drive the LEDs. This technique ensures that only one row of the matrix is enabled at a time while utilizing the
LEDs slow discharge time. High frequency switching ensures that the LEDs appear constantly enabled. The 16 x 16 matrix is separated into 4 - 8 x 8 matrices. Row scanning is performed on each 8 x 8 matrix simultaneously. A decoder is used to control which row is enabled. Transistors are used to source current necessary to drive the LEDs. Transistors are also used as switches to determine which LEDs in a particular row are enabled. The latches are coordinated so that all four sections of the matrix are updated simultaneously. The latches values are stored in the microcontroller’s RAM.

The Light Board’s wireless receiver receives packed data transmitted from the Touch Screen unit and passes the data to the UART pin of the microcontroller. The microcontroller unpacks the data and updates the aforementioned RAM. The Light Board is powered by a 5V, 2A wall mount AC adaptor. The device is fused at 1.5 amps and is designed to never exceed approximately 1.4 amps. Average current consumption is determined to be approximately 500 mA. The Touch Screen unit is powered by battery and consumes an average of 80mA.

The Light Board and Touch Screen are housed in wooden boxes. The Touch Screen provides a switch to enable power. The cost of parts and material was about $300.

Fig. 19.14. Touch Brite Device Delivered to Client.
INTRODUCTION
Our client is diagnosed with Amyotrophic lateral sclerosis (ALS), more commonly known as Lou Gehrig's disease. Our client is paralyzed from the neck down and on a respirator which makes him unable to accomplish daily tasks. He is unable to press buttons which restricts him from not being able to contact the nurse within his own nursing home bedroom, and cannot operate his television. Therefore, our client needs a voice activated system that can recognize his voice to perform these certain tasks. There are a few devices that are currently on the market that could help our client but two major problems arise because they are expensive and cannot be easily adapted to nurse call system already implemented within the nursing home. For these reasons, our client needs a voice recognition system designed specifically to his needs.

SUMMARY OF IMPACT
Upon completion, Person with ALS Control Center (PALS CC) will improve our client’s quality of life. Before the diagnosis, he had full control of his arms and legs and did not need the assistance of a respirator. Now he uses a motorized wheelchair and is dependent upon a respirator. Our client wants to be able to control his surroundings like he did before the diagnosis. Instead of yelling to get the nurses’ attention to change the TV channel he can now do it himself with PALS CC. This has given him the opportunity to feel that he is in control and independent of his surroundings.

TECHNICAL DESCRIPTION
The device, PALS CC, can be broken down into three major parts: 1) voice recognition (using a HM2007 IC), 2) a microcontroller (BASIC Stamp), 3) infrared transmitter (IR Buddy) and is programmable in two ways. Each voice command required to control the nurse button and TV controls is programmed by our client so the system will only recognize his voice. The infrared codes needed for the TV are programmed into the BASIC stamp. Each command spoken by the client will be simple one word commands to make the system easy to operate, i.e. “start”, “on”, “off” etc.

Once the system has been programmed, the voice recognition component determines which command is given and assigns to it a binary number. The particular binary number is then outputted to the BASIC Stamp. The BASIC Stamp then reads the binary code and decides which command was given. If the 'nurse' command was given then it will activate a relay which is hard wired to the nurse jack in the room which simulates someone pressing the actual button. However, if the client would like to interact with his TV then the BASIC Stamp will match the binary code (from the voice system) to the correct IR code already programmed. The BASIC Stamp then copies that specific code into a buffer and then sends to the IR Buddy. The IR Buddy then receives the buffer and transmits the code to the TV or radio up to fifty feet away.

In order to operate PALS CC, two key commands are used to initiate the program. If the second LED
on the box is illuminated then the key word is “start”; if the bottom LED is illuminated then the key word is “go”. The reason for the key words is because the voice recognition is always listening. So if our client is simply talking to someone with the microphone on and says the word ‘on’ the TV doesn’t turn on when he doesn’t want it to.

The device itself is powered using a 5.2 voltage source so the unit is not mobile. However, it doesn’t need to be because there is no room for the unit on his wheelchair. Our client has a wireless lapel microphone that he always wears, allowing him to always have the capability of contacting the nurse and more importantly not having to wear a Bluetooth or headset. This would not be comfortable for him at night when he relies on PALS CC the most to call the nurses.

The total cost of PALS CC is $225; this includes the cost of all IC’s used along with rechargeable batteries and a project box in which the circuitry is enclosed in. This project is not only considerably less expensive than those currently on the market but also addresses our client’s priority of contacting the nurse.

Fig. 19.16. Programming the voice recognition with the client.
ELECTRICAL THREE-HOLE PUNCH AND STAPLER FOR INDIVIDUALS WITH VISION IMPAIRMENT

Designer: LaMount Dean
Client Coordinator: Laila Mangipudi, Nashua Center, Nashua, NH
Supervising Professor: Prof. Alan Rux
Department of Electrical and Computer Engineering
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Lowell, Massachusetts 01854

INTRODUCTION
The electrical three-hole punch and stapler (HPS) is designed to assist visually impaired individuals to perform the functions of hole-punching and stapling papers. The HPS senses paper position and gives audible prompts to guide the user. The HPS is designed for the Nashua Center to assist their visually impaired clients to help with office work. The organization helps individuals with disabilities provide service and employment skills to foster the feeling of fulfillment and accomplishment.

SUMMARY OF IMPACT
The HPS is designed to give the user more control over their surroundings and requiring less assistance from others. The HPS enables the user to hole-punch or staple papers with a single device and gives them the decision making power in the process. The HPS gives the user another opportunity to participate and serve in their community.

TECHNICAL DESCRIPTION
The HPS package depicted in Fig. 19.18, is 16 inches by 7 inches be 3 3/8 inches with a window or slot on the right side for paper to enter the closed box isolating the user from the mechanics of the device. The HPS device is designed to have the speaker and volume control close to the user, the power cord and switch away from the user, the papers moved along the right hand side of the box, and the large ‘go’ button on the left hand side of the box.

The position of the photo sensors in the HPS, represented by the shaded circles in Fig. 19.18, are determined to sense the important positions of the papers using the fewest sensors. The sensor in the middle of the window close to the entrance senses the presence of the paper. The other four photo sensors are positioned to sense when the paper is flush against the edges. The top and bottom sensors indicate presence of the paper at the top or bottom of the window, and the two sensors along the inside
edge of the window are also positioned to sense an 11 inch long stack of paper fitting tight along the top or bottom edge. The HPS prompts the user to push the go button if they want to staple when it senses the paper positioned at the top of the window or to hole-punch when the paper is positioned at the bottom of the window. The go button also allows the user to perform an operation if the sensors along the inside edge indicate the paper is over the 11 inch size.

The HPS has 2 minutes of record and playback message space divided into separate messages to the user to indicate the device status. Messages include a welcome message after power up, prompts to the user to move the paper around in the window for the two different operations, prompts to push the push button if the operation indicated is correct, and error messages if there is a sensor problem or paper jam. The HPS includes recording circuitry to allow administrators to rerecord the messages to clarify the intent of the message to the user.

As seen in Fig. 19.17, the HPS relies on a PIC microprocessor to read the photo sensor and switch inputs and control the message playback and motors to run the hole-punch and stapler. The record function and paper positioning happen at different times, so circuitry is added to reuse these inputs to the microprocessor. The microprocessor program can be rewritten to change or add to the operation of the HPS by plugging the programmer into the board.

The motor driver for the motors used to operate the hole-punch and stapler limit current to the motors during startup or paper jams to avoid damage to the motor and circuitry and avoid over-heating. The motor has a photo sensor to indicate when the motor has returned to its starting position. The HPS senses motor problems through time out functions from this photo sensor.

A typical operation cycle of the HPS is as follows: paper enters the window and the HPS prompts the user to move the paper all the way into the window until the paper is flush with the inside edge. When the paper is flush with the inside edge the HPS prompts the user to move the paper up for stapling or down for hole-punching. When the paper is flush with the top or bottom of the window, the HPS prompts the user to push the go button if the indicated operation is correct. The operation is performed after the user pushes to go button and then the HPS waits for the paper to leave the window and start the process over again.

The cost of parts and materials for the HPS was between $250 and $300.

Fig. 19.19. Student Showing the Project to the Client.
AUTOMATIC DOOR CONTROL SYSTEM USING ACTIVE RFID TECHNOLOGY

Designer: Mark Ramos
Client Coordinator: Lisa Szewczyk, Nashua Center, Nashua, NH
Supervising Professor: Professor Alan Rux, James Drew
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INTRODUCTION

The automatic door control system (DCS) is custom designed to control a pair of Horton 2000 series automatic sliding doors at the Nashua Center located in Nashua, NH. The Nashua Center provides vocational day services for adults with developmental or acquired disabilities. One of the entryways to the Nashua Center consists of two automatic sliding doors triggered by motion sensors, which allows the clients to exit the facility unsupervised. Since some of the clients at the Center require supervision outside the facility, it is dangerous for them to have the ability to easily leave the facility unattended. The DCS system is intended to provide a way to automatically operate the doors while restricting their use by clients who should not leave the facility unsupervised. The DCS system and doors can be seen in Fig. 19.20.

SUMMARY OF IMPACT

The design criteria for the DCS were defined by the staff at the Nashua Center who is concerned about the well-being of their clients. The staff is often unable to provide full supervision of the clients at all times. As a result, clients are able to leave the facility unsupervised through the automatic doors. The clients often do this without realizing and without recognizing the dangers they face outside the facility. The automation of the doors causes a conflicting situation since there are only a small number of clients who are at risk for leaving the facility unsupervised while staff and other clients, particularly clients in wheel chairs, require the use of automated doors throughout the day. The DCS protects clients by allowing the staff to place an electronic tag on clients who are at risk of leaving the facility. The DCS prevents the tagged clients from exiting the facility unsupervised, while allowing untagged staff and clients use of the doors.

TECHNICAL DESCRIPTION

The key components of the DCS are (1) a microcontroller unit (MCU) and (2) an active radio frequency identification (RFID) reader. The RFID reader sends tag information to the MCU when a tag is detected. The data sent by the reader to the MCU consists of the unique tag identification number for the detected tag as well as a received signal strength indication (RSSI) value. The RSSI value reflects the signal strength of the detected tag’s signal in relation to the reader. As the tag gets closer to the reader, the RSSI value increases. Likewise, as the tag moves farther away from the reader, it will decrease. As the tag’s RSSI value approaches the reader’s detectable noise floor, the reader will no longer detect the tag. Using the RSSI value, the MCU can filter out tags that are outside the desired range of the doors.

This is an active RFID system because the tags contain their own power source which is rated for five years. The tags continually transmit a 433MHz ASK modulated signal approximately once per second. When the RFID reader receives a tag’s signal, it demodulates and decodes the signal and then transmits the information using RS232. The MCU in the DCS receives the RS232 data from the reader.

The two automatic sliding doors each have a toggle switch that can be used to disable and enable the sliding doors’ motor. The DCS contains two normally closed relays controlled by its MCU. The DCS connects the relays in parallel with the door’s toggle switches. This configuration allows the DCS relays to replace the function of the doors’ toggle switches.

When a tag is within range of the doors, the MCU opens the two normally closed relays. This will disable each door’s motor and the doors will not
slide open. Likewise, if a tag is outside of the programmed range, the MCU will close the two relays and the each door’s motor will be able to slide the doors open, providing the door’s motion sensor is triggered.

The DCS contains visual and audio feedback as well as override capabilities. The system contains (1) an 85dB piezo electric buzzer, (2) a momentary push button switch used to bypass the system, (3) two rocker switches used to break the connection between the DCS relays and each door, and (4) three LED indicators to provide visual feedback of the system’s state.

The total cost of the parts and material required to build the DCS was approximately $600. Additional tags can be purchased at a cost of approximately $15 per tag.

Fig. 19.20. DCS System (left) and Nashua Center Sliding Doors (right)
INTRODUCTION
The Handicapped Accessible Glider, as seen in Fig. 19.22, is designed to replace the conventional rocking chair used in the “Relaxation Room” at Coastal Educational Collaborative in Salisbury, Massachusetts. Currently, an assistant must transport a client between his or her wheelchair and the rocking chair and manually rock the client back and forth. The Handicapped Accessible Glider enables clients to remain seated in their own wheelchair while experiencing a rocking motion without help from the assistant. The apparatus consists of a frame, suspended platform, two-piece ramp, direct current (DC) gear motor, linkage, and electrical controls. The frame and platform are constructed out of aluminum to provide strength and rigidity without adding unnecessary weight to the apparatus. The DC gear motor utilizes gear reduction and provides sufficient torque to rock the platform back and forth. The DC gear motor also allows the assistant to adjust the rocking to a desirable speed for the client. The client boards the apparatus via a two-piece ramp. The DC chopper is used to vary the input voltage supplied to the DC gear motor, and thus varies the rocking speed. The controls consist of Emergency Stop, Start and Stop, and Speed Control. A protective relay prevents the motor from starting unless the ramp is in its upright position.

SUMMARY OF IMPACT
The Handicapped Accessible Glider allows clients to experience the simple harmonic motion of a rocking chair without leaving the comfort of their own wheelchairs. Many wheelchairs have been modified to fit an individual client. Removing the client from his or her wheelchair may affect how the client feels both physically and mentally. Allowing the client to remain in their wheelchair also makes it easier for the assistant who would normally have to transport the client between the wheelchair and the rocking chair, and manually move the rocking chair back and forth.

TECHNICAL DESCRIPTION
The frame and platform are both constructed out of Aluminum. The frame consists of 1.5” x 2.5” x 1/8” aluminum tubing as well as 1.5” x 1.5” x 1/8” aluminum tubing. The platform consists of 1.5” x 2.5” x 1/8” aluminum tubing providing structural support, 1/8” thick aluminum diamond plate as the surface, and 1.5” x 1.5” aluminum angle acting as joists under the diamond plate. Aluminum angle (1.5” x 1.5”) is used on the surface of the platform to prevent the wheelchair from moving off the edge. The 1.5” x 2.5” x 1/8” aluminum tubing is used to allow space for bearings. A total of 16 bearings are used to allow the platform to rock back and forth. Stainless steel rods (1/2” diameter) connect between the platform, arms, and frame. The platform is suspended from four stainless steel arms that are 11 ¾” x 3” x 3/8”. Stainless steel is used for the arms because of its physical properties to prevent the platform from moving side to side. The client boards the apparatus via a two-piece ramp that consists of a stationary ramp and a second ramp that folds over...
to meet the top of the platform. The two-piece ramp is one unit that can be removed if needed. The two-piece design makes it so that the ramp can be used no matter where the platform comes to rest.

The glider is set into motion with a DC motor and an associated linkage. A 90 VDC 20 RPM gear motor is the driving device for the apparatus. A gear motor provides ample torque to set the platform into motion. A DC motor’s speed is directly proportional to the input voltage, thus the speed is changed by varying the voltage. The input voltage supplied to the motor is varied using a DC chopper. The chopper consists of an N-Channel MOSFET and a timing circuit to trigger the gate. The output pulse of the timing circuit is adjusted by changing resistances, i.e. by using a potentiometer to change TON and TOFF, which can be seen in Fig. 19.21. The output of the DC chopper is the average voltage seen over a specified time period. A linkage is used to displace the platform 1.5” on each side of equilibrium providing 3” of total movement. The displacement can be adjusted by increasing the radius of the linkage from the center of the shaft of the motor.

The total cost of this project is roughly $2,655.

Fig. 19.22. Client using the glider.
A TALKING DIGITAL PHOTO FRAME

INTRODUCTION

The Talking Digital Photo Frame (TDPF) is designed to help individuals with Cerebral Palsy (CP) who are not able to move or speak. The TDPF enables users with CP to communicate their needs by manipulating a large, round, sensitive Jelly Bean pushbutton switch. The TDPF is first programmed with up to ten images, each of which has a simple and short descriptive voice message. These images are pictorial descriptions of basic communication topics. The Liquid Crystal Display (LCD) of the built-in digital photo frame slowly scans through these images in a slideshow fashion. When the user sees an image showing an immediate need, the Jelly Bean pushbutton switch is touched to pause the slideshow and play the associated voice message. The slideshow resumes when the Jelly Bean pushbutton switch is pressed again.

There are a number of similar commercial products currently available. Most of them are software products that are computer based. Moreover, software products are not designed for the special needs of people with CP. Since the applications require a computer, they are not portable. They are also expensive; some can cost thousands of dollars.

SUMMARY OF IMPACT

The goal of the project is to build a simple-to-program, easy-to-use device that helps people with CP articulate their basic needs to others. Examples of commands include ‘I’m tired’, ‘Please read to me’, or ‘I need to use the bathroom’. Vocalizing words can be extremely taxing for people with CP.

In addition to helping people with CP, the TDPF makes the job of their care providing staff much easier. Most people with CP have partially or completely lost their speech ability due to impaired muscle coordination. Not only is it hard or almost impossible for them to communicate, but it is both frustrating for them and their care givers who sometimes cannot understand them. The TDPF makes the relationship between people with CP and their care givers much more encouraging and less stressful.

The TDPF is reprogrammable and portable. These two features make it more adaptable and versatile. The images and voice messages can be easily programmed to the ever-changing communication needs of the users, and the TDPF can be used virtually anywhere as long as an AC outlet is available.

TECHNICAL DESCRIPTION

The overall structure of the device is a 10x8x3 inch plastic cabinet with a 5.6 inch LCD screen, a large, round Jelly Bean pushbutton switch, a 3x4 matrix
keypad, a 16 Ohm speaker, an electret microphone, and other control switches mounted on its top surface. Inside the box are a Winbond ISD2560 sound chip, a Parallax Basic Stamp 2 microcontroller (BS2), and other logic devices.

The TDPF is powered by a 12V, 1000mA wall adapter that comes with the digital photo frame. This power supply is more than sufficient to power all device components since the TDPF does not draw more than 500mA when most of its components are running simultaneously. A 5V regulator circuit was added to power all IC chips and logic circuitry.

The input components of the device are the 3x4 matrix keypad, the electret microphone, and the Jelly Bean pushbutton switch. The keypad makes recording individual voice messages easier and less confusing. Each numeric key is a pointer to a specific address in the ISD2560 memory where a voice message is recorded or played back. A 20-key 74C922 encoder and the BS2 are the interface between a pressed key and its corresponding address in the ISD2560 memory (Fig. 19.23).

The ISD2560 is used for recording, storing, and playing back up to sixty seconds of voice messages. The ISD2560 can be used in different operational modes. For the TDPF, addressable recording and playback mode is used because it is the most efficient. The ISD2560 60-seconded memory is partitioned into ten slots; each slot holds a voice message up to 6 seconds long. Six seconds is long enough for a simple voice message, and ten voice messages are neither too few nor too many for the application. This address resolution is most efficient because it provides ten 6-second voice messages and only requires four address control lines from the BS2. A record pushbutton switch is used to record a message at a pre-defined address. Voice messages can also be manually verified via the keypad.

The playback is controlled by the microcontroller with the POWER DOWN, PLAY/RECORD, and CHIP ENABLE pins. The audio output from the ISD2560 is amplified with an external audio amplifier circuit driven by a low voltage audio amplifier LM386, and through the 16 Ohm speaker (Fig. 19.24).

The BS2 coordinates all activities of the TDPF. The BS2 has 16 I/O ports and they are used to interface and drive all device components. Seven I/O ports are reserved for addressing and controlling the ISD2560, five I/O ports interface the keypad via the 74C922 encoder, one I/O port inputs signal from the Jelly Bean pushbutton switch, and another I/O port drives the slideshow on the digital photo frame via a switching transistor.

The total cost for device parts is approximately $205.
MORSE CODE TO COMPUTER: COMPUTER PROGRAMS TO HELP THE CLIENT WITH USING HER COMPUTER

Designer: Rajesh Kaveti
Client Coordinator: Tom Mercier, Frank Wolfenda
Supervising Professor: Alan Rux
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INTRODUCTION
This project involves writing computer programs for our client who is blind and has poor motor skills, to help her use her computer. The client uses a device called darci that converts Morse code to keyboard commands. This device along with the software called JAWS (screen reading software) allows the user to know what is on the screen and what to type next. Although neither the device nor the software inform the user when the user presses a sticky key (ctrl, Alt, Windows, Shift, insert) on the keyboard or through the darci. A windows based computer program was created to inform her about the status of the sticky keys including the insert key on the keyboard when they are pressed. Two small programs were created for JAWS to provide the user with shortcuts for opening the music player and playing an album. The client has an iMac G3 which she had been using for a long time before it stopped working. It was fixed as part of the project.

SUMMARY OF IMPACT
The programs created for JAWS allow the client to quickly access her music albums and play music in Windows Media Player. Also, when the music player is opened, the focus is moved to the play list so the user can select a track in the album using the arrow keys. The focus can also be moved to the play list by pressing the key ‘p’.

The windows program informs the client about the sticky keys through audio stimulus. For example if the user presses the shift key on the keyboard and holds it, the program plays an audio file that says “Shift On”. As soon as the user releases the key the program plays another file that says “Shift Off”. The darci holds the sticky keys down until another key is pressed. This program is only useful for people who use the darci or any device other than the keyboard. Prior to the installation of the program the client would often retype the Morse code for the sticky key if she made a mistake.

TECHNICAL DESCRIPTION
JAWS can be programmed to do certain things like opening a music player and playing the tracks in the album. When the user presses a certain key on the keyboard, JAWS has a script manager that allows users to write small programs also known as scripts to change the way the software reads the computer screen. It can also be used to program the keys on the keyboard. The two JAWS scripts created allow the user to play an album just by pressing ctrl+p on the album. Pressing ctrl+p simulates the right click on the mouse, selects the “play with windows media player” option and then simulates the pressing of the “Enter” key. When the music player opens, the mouse pointer is automatically moved to the playlist window and a left mouse click is simulated to change the focus to the play list window.

The windows program that interfaces to the keyboard is created using Visual C++. The program has two files, an EXE (executable) file and a DLL (Dynamic Link Library) file. The executable file loads the DLL file and runs continuously, reading key messages from the keyboard. The DLL file communicates with the keyboard driver every time a key is pressed. One of the DLL functions sets up a keyboard hook and another function receives the messages from the keyboard hook. The keyboard driver informs these functions whenever a key on the keyboard is pressed or a keyboard input from the darci is sent to the computer. The keyboard listener function filters the keys to check for the sticky keys (ctrl, shift, Alt, Windows, Insert). When the function detects a key press, the function uses
the operating system resources to play the corresponding audio file.

Fig. 19.26. Product delivery.
AUTOMATED ADJUSTABLE WORKING SURFACE

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Client: Life Links, Lowell MA
Supervising Professor: John Fairchild
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INTRODUCTION
The automated adjustable working surface (AAWS) is simply a flat working surface that can be adjusted from horizontal to vertical. The AAWS is activated when the user presses touch sensitive panels that make the panel move in the desired direction. Once the surface is at the desired angle, the user lets go of the touch sensors and can begin to work on their art project. Ultimately the AAWS is designed to provide the users a greater degree of autonomy thus allowing the staff members to focus on other students’ needs.

SUMMARY OF IMPACT
The Client, Lifelinks in Lowell Massachusetts is a “day-hab” facility for approximately 125 developmentally challenged individuals. The facility is run like a school at which the students take several classes a day, ranging from cooking to art. One of the additional benefits of art classes is that fine and gross motor skills are developed through art projects. The problem is that many of the students have limited mobility of their arms, and require working surfaces to be at different angles, ranging from horizontal to vertical, depending on the needs of the particular user. Lifelinks currently has an adjustable angle easel that is heavy and difficult to use, and requires the assistance of a staff member to operate. The AAWS is designed to allow students to adjust the angle of the working surface to fit their needs without the assistance of a staff member, thus granting them a higher degree of autonomy, and allowing the staff member to work with the other students in the class.

TECHNICAL DESCRIPTION
The overall structure of the AAWS is made from square aluminum tubing (1 x 1 x 1/8 inch). Aluminum was chosen because of its light weight and strength. The frame is designed so that it completely encloses the electrical components of the AAWS and provides strength and high durability.

All additional components are attached to the frame by bolts.

The movement of the frame is accomplished by a Firgelli Automations linear track actuator. A motor internal to the actuator turns a worm screw that is connected to the end of a long threaded shaft. Depending on the direction of the shaft, a block is driven forward or backward along the shaft. This block is connected to two aluminum bars which are connected to the frame of the work surface. The work surface is connected to the main frame by two bolts at the bottom. As the block of the actuator moves back and forth, it pushes the work surface up or down, which pivots on the bolts that connect it to the main frame (see Fig. 19.27).

The touch sensor consists of a Quantum Research QT-113 charge transfer touch sensor. There are four sensors on the AAWS; Right-Up, Left-Up, Right-Down, and Left-Down. In order to make the surface move up, both the Right-Up and Left-Up sensors must be activated. This is done as a safety measure to ensure that the device will not move unless both of the user’s hands are in a safe place. The work surface will continue to move as long as the touch
sensors are being touched or until a limit switch is reached, that will not allow the device to continue further. The inputs from the four touch circuits and the two limit switches are connected to a logic circuit that determines if the work surface should be moved, and if so, the direction in which it should move.

The output of the logic circuit is connected to an H-bridge that controls the motor. This consists of four power MOSFETS that allow the current to flow through the motor in either direction depending on the MOSFETS that are turned on at any particular time.

Fig. 19.28. Product delivery.
ARM STRENGTHENING DEVICE FOR TOTS

Designers: Sidd Shenoy and Karthik Sekar
Client Coordinator: Edie Kahn, OT
Supervising Professor: Richard Goldberg
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INTRODUCTION
Our client is a two-year old boy who loves musical and visual feedback. He has cognitive delays, as well as poor strength, fine motor control, and coordination. His therapist requests a device that helps him improve his upper body strength and coordination. This device also needs to be durable, safe, and engaging so that he is motivated to use it. This design focuses on the creation of a school bus toy that is based on a commercial toy, with the addition of two custom handles. When the client inserts the handles all the way into tunnels that are located above the front and rear bumpers, LEDs illuminate inside the handles. This activity is similar to using an electronic shape sorter and helps with fine motor control. When he pushes the handles against the end panels inside the tunnel, the device provides musical feedback. This helps with arm strengthening, as the client has to push the handles against interior springs.

SUMMARY OF IMPACT
Our therapist commented that she had not seen a lot of toys that really engage him. However, he enjoyed using this device and it was “an adorable, therapeutic, electronic toy”. She is confident that this will help him improve his strength and coordination.

TECHNICAL DESCRIPTION
The outside of the device is from the Playskool Tonka Wheel Pals Cushy Cruisin’ School Bus®. The shell of the bus is made of a single mold of soft, durable polyester fiber. It is “squeezeable”. The bottom is made of hard plastic with an axle attached to plastic wheels. The battery chamber is milled out in the base to make enough room for a nine-volt battery, instead of the two AA batteries that normally come with the toy. The original electronics from the base the stuffing from the interior of the shell are both removed.

There are two handles: one with a circular cross section, and the other with a square cross section. The circular handle is 5.40” long, has a 1” diameter, and is made from hollow acrylic tubing. A 1.20” diameter circular red acrylic piece is fixed on one end to prevent that end from going into the tunnel. The other end is made of concentric electrodes, which power an LED inside of the handle when it contacts the powering electrodes inside the tunnel. As a result, the handles luminesce red when pushed all the way into the tunnel. The square handle is of similar construction. It has 1” by 1” cross section and the length is 5.75”. There is a green acrylic square piece on one end and concentric electrodes on the other end that connect power to internal green LEDs.

Both handles fit into corresponding acrylic tunnels, which are secured to the exterior of the bus, just above the front and rear bumpers, using a custom made acrylic flange. At the end of the tunnels inside...
the bus, there are electrodes that power LEDs inside the handles when they make contact.

Once the handles are inserted all the way into the tunnels, the client can push them further against spring-loaded acrylic panels. The spring action is provided by a standard toilet paper holder that is between the panels and housed in an acrylic box. As the spring-loaded panels slide along tracks, their position is detected by a pair of infrared (IR) distance sensors (Sharp GP2D120) that are mounted at the top of the acrylic box and encased in a custom-made aluminum housing to hold them in position. In this manner, the device can monitor how far the client has pushed in on the panels with the handles.

The signals from the IR sensors are input to a microcontroller. When it detects that the client has pushed the panels in a small amount, the microcontroller activates musical feedback with the programmable uMP3 module (Rogue Robotics, Toronto ON). The module has a built-in SD card slot, where the songs are loaded. The microcontroller pauses the song if the client releases the force and the panels spring back out. If the song has been playing for at least five seconds and the panels are pressed all the way in, the microcontroller triggers the module to start playing the next song on the playlist. An LM386 audio amplifier drives the speaker output. A nine-volt battery powers the circuit.

The cost of the device is approximately $300.

Fig. 20.2. Client inserting handles into the corresponding tune.
INTRODUCTION
Our client is a 13 year old middle school student who has cerebral palsy and uses a power wheelchair. She has significant problems getting books in and out of her school locker due to arm weakness, tightness and coordination. Our client has better muscle strength and control in her right arm, but she seldom uses her left arm. Thus it is hard for her to manage the heavy textbooks using one arm. Being in a wheelchair, she is positioned lower relative to the locker (she uses an upper locker of two vertically stacked lockers). Thus she is forced to lift the books almost to the height of her head. In addition, her wheelchair positions her further away from the locker, forcing her to extend her arm and torso as she reaches into the locker, which puts her in a disadvantaged mechanical position. This project focuses on a sliding shelf device that makes it easier and faster for her to remove books from her locker, as well as place books back into her locker.

SUMMARY OF IMPACT
The client stated, “I think the locker assist will make it easier for me when switching classes because I will not be as dependent on others to get books in and out of my locker. It should make it faster and less stressful for me to make the change. I think it will also help to keep my locker better organized.”

TECHNICAL DESCRIPTION
The design is based on a sliding shelf that mounts to the inside of the client’s locker. There is also a folding flap that assists in loading textbooks. She can easily place the book horizontally on the flap, and then rotate the flap to put the book to a vertical position on the shelf. Also simple velcro straps wrap around any textbook acting as a handle to aid her in grasping and lifting a book.

The base of the entire assembly is made out of 3/8” thick clear acrylic that is cut to fit the dimensions of the inside of the locker. Two 10” long, ball-bearing drawer slides are loaded on to the base using machine screws with nuts counter bored into the base. When fully extended, the drawer jutted 8” out from the locker. To counter the moment created by books on an extended drawer, stabilizing rods are installed that run from the top of the locker down to the base. These rods, screwed into the base, consist of two concentric and hollow rods that are threaded so they can be extended in length to fit tightly in the locker and exert force on the base. The mechanism is similar to a shower curtain rod that pushes against opposing walls. In this manner, the device can be easily removed from the locker and put into a new locker each school year.
A vertical piece of acrylic is mounted to the left side of the base. This provides one “bookend” for one side of the shelf. The rotating flap is also made of acrylic, cut to 4” by 9”, and attached to the right side of the base using two hinges. As the flap rotates vertically, it becomes the opposite “bookend”. In order to keep the bookends tight against the books so that the books stay in place, the flap can slide left and right along the base on a set of two linear rails.

While our client is capable of lifting a textbook, it is difficult for her to grasp it. A book handle is made of a loosely fitting, adjustable Velcro strap that loops around the cover of a book. This also helps to keep the book closed during transfers in and out of the locker. The cost of the device is $245.

Fig. 20.4. The client places a book on the locker assist flap, and then rotates it to a vertical position.
SEE ME MOVE AND GROOVE

Designers: Ariella Nouriel and Kuai Yu
Client Coordinator: Cindy Wyatt, OT
Supervising Professor: Richard Goldberg
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INTRODUCTION
Our client is a nine year old girl with spastic quadriplegia cerebral palsy and cortical visual impairment. While she has severe cognitive impairment, she has normal hearing and demonstrates a positive response to simultaneous audio and visual signals. She wears a brace for trunk support, and manages switch controls with her hands, though their movements still remain highly limited. Due to her visual impairment, she is unable to see peripherally and her right eye is dominant. She also does not detect all colors and therefore prefers brighter shades such as red and yellow against a dark background. She enjoys playing computer games using special software.

See Me Move is intended for home use while in a wheelchair, stander, or in bed. When the client presses a switch, the device responds with musical and/or visual feedback, as well as a shaking toy. The caregiver, parent, or therapist can select the desired feedback. The goal is to improve our client's ability to use her vision together with hearing as stimuli. The second goal is to encourage more targeted and controlled hand movements.

SUMMARY OF IMPACT
The client actively pushes her switch while in her stander and vocalizes positive feedback. Furthermore, the device allows for the client's first active participation in play from her bed. One of her nurses noted that “[this device is] pretty good for her because she's been up [in her stander] for almost an hour and a half ... and she’s still interested in it ... and that’s unusual.” The nurse also indicated that the client will likely use the device often and it will increase her ability to rely on her vision and hearing as a stimulus, as well as create more targeted and controlled hand movements.

TECHNICAL DESCRIPTION
The device is mounted to the end of a microphone boom stand. A wooden base is attached and secured to the bottom of the stand to increase stabilization. The height of the stand is easily adjustable, and
therefore the device can be used at locations of varying heights including the client’s wheelchair, stander, and bed. The commercial switch is mounted to one of the client’s existing trays. A C-shaped acrylic switch holder allows the switch to be placed face-up for normal push down activation, or upside-down for push-up activation. The device includes an acrylic mirror so that the client can see her own hands while pressing a switch, which she finds interesting because her limited field of view often makes this impossible. The mirror is mounted with a friction hinge so that it can be rotated to the proper position, or out of the way if desired.

A custom milled aluminum plate and bracket is attached at the end of the microphone boom. Three microphone goosenecks are attached to this plate to hold the three rewards: a lightshow with two different colored electroluminescent wires, a shaking toy, and a second lightshow with two more different colored wires. The use of the goosenecks allows for the custom positioning of the rewards to the client’s current field of view as well as the ability of running wires through their hollow middles.

The electroluminescent (EL) wires used for the light show rest on acrylic plates that contain numerous pegs which allow the user to create any desired shape with the wire. The pegs are made of clear acrylic rods. The EL wires can be configured to light in sync with the music that the device is currently playing.

The shaking toy is constructed by taking a commercial hollowed out toy and inserting a DC motor with an attached offset weight made of bronze and acrylic.

A PIC18F4520 microcontroller controls the logic for this device. Rewards can last the length of 3, 8 or 12 seconds at which point the music pauses and the rewards stop, encouraging the client to press on her switch once again. In addition, if the client has not pressed the switch for 30 seconds, a short auditory signal is played to encourage her to press the switch. The musical feedback is from the µMP3 player (Rogue Robotics, Toronto ON), which plays music from files stored on an SD card.

An LM386 amplifier drives the speaker. A 12V DC from a wall transformer power both the electroluminescent wires and the DC motor inside the shaking toy.

The electronics box is custom made from acrylic, using an inter-digitated cut pattern. Peripherals connect to the box using standard audio jacks: 1/8” for the client’s switch and three color coded 3/32” for the rewards. In addition, a set of push button switches atop the box provides user input for the reward, song choice, and reward duration. Also on top of the box is a set of LEDs which lets the user know the current output settings. The cost of the device is $600.
INTRODUCTION

Our client is a teenage girl with athetoid cerebral palsy (CP). She enjoys riding her tricycle in the neighborhood. She rides an adult tricycle, the Schwinn Meridian, and her family attached a hip brace for extra support and a pair of adaptive foot cups to keep her feet on the pedals. However, she is not able to use the conventional hand brakes because she has difficulty reaching, grasping, and engaging them. As a result, someone else must run alongside of the tricycle, holding a strap attached to the frame, and stop her by pulling on the strap. This compromises her independence.

This project design focuses on a custom braking system that allows the client to brake independently. It consists of a rotating handlebar that the client twists forward to engage the brakes, and an extended lever arm on the rear band braking system to reduce the force that she needs to apply for braking. The client can use the custom handlebar for both steering and braking, and she does not need to change her hand position to engage the brakes.

SUMMARY OF IMPACT

The custom braking system allows the client to break her tricycle independently using a rotary hand motion instead of using the conventional brake levers. She can apply the brakes without lifting her hands from the handlebar or changing her grip. Twisting forward with her hands applies the brakes and twisting backwards disengages the brakes. True to the intended design, the principles behind the custom brake system are simple and easy for the client to use. As quoted by her mother, "It will be so good for [her] to be able to ride her trike...without having someone run behind with a rope to brake for her."

TECHNICAL DESCRIPTION

The Schwinn Meridian tricycle has a “cruiser” style handlebar, and our custom handlebar is clamped horizontally to it on both the left and right sides.

The custom handlebar consists of two concentric cylinder tubes, made of stainless steel. The outer
cylinder is the rotating cylinder that the client holds and uses for steering and brake activation. The inner cylinder is the stationary support shaft. It mounts to the existing tricycle handlebar, and it provides an axis of rotation for the rotating cylinder.

The rotating cylinder has 1.5” outer diameter (OD). It rides on and contacts the support shaft (1” OD) only on its ends, which are capped with custom-made Teflon bushings. The Teflon provides a bearing surface with low friction and prevents binding between the two cylinders. Two shaft collars around the support shaft prevent lateral movements of the rotating cylinder. Halfway down the length of the rotating cylinder, two holes are drilled 45º apart to secure one end of the brake cable. The brake cable is threaded into the cylinder through one hole and threaded out of the cylinder through the second hole. The stopper on the brake cable end is larger than the drilled holes and, therefore, secures the cable to the cylinder. The holes are drilled 45º apart so that the cable running inside the cylinder does not touch and abrade the support shaft. Non-adhesive foam strips are wrapped around the cylinder as hand grips; the area surrounding the secured brake cable end is left unwrapped.

The support shaft is three feet long, which is about twice as long as the rotating cylinder. The rotating cylinder is positioned in the middle of the support shaft such that equal lengths of the support shaft are exposed on either side. A metal bracket with an adjusting barrel is attached to the front of the existing handlebar to fasten the brake cable housing to the tricycle frame and to allow the brake cable to be pulled. The custom handlebar is mounted to the existing handlebar frame using eight loop clamps that are lined with silicone to ensure a secure grip. End caps are fitted over the ends of the support shaft and existing handlebar as a safety feature.

Polyester Velcro straps are wrapped around the clamps to cover sharp edges.

When the client twists the rotating handlebar, it pulls on the brake cable, which then pulls on a lever arm that engages the band brakes. A new lever that is 2.5 times the length of the original one provides a mechanical advantage by amplifying the applied force by 2.5 times. The extension is a bracket made of stainless steel with three holes drilled along the bracket. The top two adjacent holes are used to attach the extension to the lever to ensure a firm connection. Once attached to the lever, the extension protrudes downwards towards the ground. A brake cable anchor bolt is inserted in the third hole, closest to the ground, to fasten the end of the brake cable. Another metal bracket is placed relatively parallel to the lever extension and is secured to the tricycle frame. This bracket is thicker than the extension bracket to avoid flexure. An adjusting barrel is fitted to this bracket and keeps the cable housing in place.

Total cost of the project is approximately $300.
NSF 2009 Engineering Senior Design Projects to Aid Persons with Disabilities
CHAPTER 21
UNIVERSITY OF TOLEDO

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ADAPTIVE SYSTEM FOR THE HOBIE CAT KAYAK

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INTRODUCTION
Independent kayaking is a healthy, enjoyable and recreational activity that many individuals enjoy. Unfortunately, many others with limited use of their legs are unable to enjoy this activity. A one-armed kayak paddle exists for traditional kayaks, but requires complex motion, transmits very little force, and decreases the stability of the kayak in operation. The objective of this project is to develop a modular adaptive system to allow users to utilize their arms to propel the revolutionary Mirage Drive System of a Hobie Cat Kayak. The Mirage Drive System propels a kayak utilizing the users’ legs via two oscillating foils instead of the traditional kayak paddle. The developed adaptation allows independent kayaking with just one functional arm in a push/pull motion. Two linkages transfer the arms’ motions to the existing drive system. Fig. 21.3 shows the two linkages, while Fig. 21.4 depicts the kayak being operated by one of the team members.

SUMMARY OF IMPACT
Adapting the Mirage Drive System with the two linkage systems allows users to propel the Hobie Cat Kayak using simple arm motions. This provides opportunities for individuals who cannot use their legs to independently enjoy this recreational activity.
TECHNICAL DESCRIPTION

The Mirage Drive System is a third generation propulsion system that transforms the back and forth motion of users’ legs to forward thrust via two oscillating foils mounted to the bottom of the kayak. These foils are modeled after the flippers of penguins and tuna and refined using computational fluid dynamic analysis. As a result, the Mirage Drive generates three times more thrust per stroke than a traditional kayak paddle. The Mirage Drive is a revolutionary device, but still leaves behind everyone without use of their legs. The purpose of this project is to develop a mechanism that attaches to the Mirage Drive to allow anybody with at least one functional arm to propel the kayak.

Weight, adaptability, and functionality are the design guidelines for this project. The design must also maintain the functionality of the existing kayak and meet space constraints inside the kayak without interfering with different sizes of users. This means that the user will be able to sit comfortably in the kayak with or without the mechanism installed. The system to be developed must also be easy for users to install and remove without the use of any special tools. Finally, all of the materials must resist corrosion as well as endure continuous wear in both freshwater and saltwater environments.

Three different designs were considered. The first design consists of two rocker arms hinged at an access hatch just in front of the user’s seat. The arms rock back and forth in opposite directions and are driven by a pushing and pulling motion from the users’ arms. The rockers are connected to the arms of the Mirage Drive by two independent bars. This design generates thrust at maximum efficiency (and highest kayak velocity). The second design also employs the same four bar linkage principle, but replaces the two rocker arms with a crank – connecting rod linkage to the Mirage Drive arms. The crank makes a complete revolution for each 60 degree stroke of the Mirage Drive arms. The crank is similar to the hand cranks already in use on bicycles for individuals with disabilities. This design allows the use of commodity parts that are easily changeable by the user. A rotary motion might be easier for certain disabilities as well. However, this system is heavier and more complex. The third design consists of two cables, one tied to each of the Mirage Drive’s arms. The other end of each cable attaches to a handle. The user pulls one cable at a time, with the pulling motion of one cable returning

the opposite arm in preparation for the next pull. The cables have changeable handles and variable lengths. The most significant advantage of this design is its simplicity and the ease of installation and removal. An obvious disadvantage of this design is the exclusive use of a pulling motion for propulsion. This cuts the amount of power supplied per stroke roughly in half. Another significant disadvantage is that this design excludes one-armed users from being able to propel the kayak, as there would be no means to return the opposite arm of the Mirage Drive.

Using a house of quality, the first design was found to be the best one based on safety, weight, cost,
original function, ease of use, adaptability and durability considerations. Simple four bar linkages are employed. The mechanism consists of three beams connected by pin joints that transmit the input force from the user to the Mirage Drive. Hobie Cat Kayaks include a storage hatch directly in front of the operator’s seat that provides a solid mounting surface. The first draft design proposed mounting directly to the hatch cover because of simplicity, but this would eliminate the use of the access hatch therefore reducing the original functionality of the kayak. It was then decided to use a much stronger aluminum ring as a base plate to mount around the access hatch. This was accomplished by using the existing mounting holes for the hatch to secure the base plate. The base plate has an outer diameter of 11 inches and an inner diameter of 9 inches. This base plate is shown in Figure 21.2. The plate is semicircular in shape, approximately 300 degrees of a circle.

Design limitations arose because there was only a 1 inch wide surface to mount to and approximately 6 inches of clearance between the ring and the inner thighs of the user. Prototyping allowed for inspection of clearances as well as functional limitations with respect to the user and kayak. Scrap steel was readily available and used for building the prototype. The prototype connecting rod was built with several holes at each joint to allow testing of multiple positions for each member. This range of adjustment allowed the team to find the optimum handle height and range of motion. A simple bracket was also designed to mount the connecting rod of the prototype to the Mirage Drive input arms. The mounting bracket was constructed with three different pivot points for testing multiple configurations as well. Once the prototype was completed and assembled, it was installed on the kayak. Prototype testing was then performed on the Maumee River in downtown Toledo. The different prototype configurations were used to operate the kayak by members of the group. From these trials, the optimum length of each link of the four bar linkage was determined. Testing was also done to measure the required input force to the Mirage Drive. Tests were executed with the kayak stationary and moving in the water by using a spring scale attached to the Mirage Drive to apply the input force. It was found that a minimum force of 82 lbs. was required to maintain a moderate pace. Therefore, an input force of 150 pounds was used in all design calculations.

Parameters of the four bar linkage were determined using AutoCAD. The dimensions of the Hobie Cat Kayak were measured and then used to construct schematic representations of the linkage using multiple starting positions and different ranges of motion. Link 1 of the mechanism is considered the rocker arm, while link 2 is referred to as the connecting rod. The existing Mirage Drive system is represented as link 3, and the body of the kayak is the ground link of the four bar linkage. Figure 21.3 shows the four bar linkage.

Aluminum 6061 T6511 was used to construct the system. This alloy has a yield strength of approximately 45,000 psi. A 1 inch box tube with a wall thickness of 0.125 inches was used to construct the rocker arms, and round hollow tubing was used for the connecting rod. Hand calculations were performed to predict the maximum stresses in the rocker arm, the connecting rod and the brackets on the rocker arms and the Mirage Drive. These hand calculations were then verified using SolidWorks and ProEngineer software analysis packages to perform finite element analyses on all the components of the system.

In the final design, each of the two rocker arms and both connecting rods have telescoping features that allow the users to set different lengths to fit personal needs. Pin joints are used to connect the rocker arms to the kayak and the connecting rods, as well as the connecting rods to the Mirage Drive. These pin joints use quick release pins allowing for easy installation and removal of the system. The telescoping tubes also use pin joints, allowing quick and easy adjustments on the water. The kayak, with the final product mechanism attached, was also successfully tested on the Maumee River. The client requested a mechanism to allow users with at least one functional arm to enjoy the Hobie Cat Kayak, and the final product safely and efficiently meets this request.

The cost of the parts was $516. The total time for machining the prototype and final product is estimated at 36 hours total. This machining time was donated by the Reliable Mold and Pattern Inc. of Marshallville, Ohio, and the University of Toledo machine shop.
Fig. 21.4 Demonstration of the device.
INTRODUCTION

Scales currently exist that allow people using a wheelchair to weigh themselves, but they have many disadvantages. These scales are usually platforms that an individual can roll onto with a wheelchair. The scale weighs the person and their chair together. The chair must be weighed separately so its weight can be subtracted from the initial combined weight. These scales are extremely costly with prices ranging up to $1500, and require a large operating area. These scales typically only exist in doctors’ offices or hospitals, meaning individuals must travel to obtain something as simple as their weight. The purpose of this project is to develop a talking scale that provides an easy-to-use and accurate means of weighing an individual with disabilities in the seated position. A scale is incorporated into a toilet seat that allows users to easily weigh themselves. This device uses strain gauge load cells to convert the person’s weight into a change in electric resistance that is converted again into a digital weight reading. An added footrest accounts for the weight of the user’s feet so that the scale measures the total weight of the seated user, including the legs. The scale, shown in Figures 21.5 and 21.6, accurately weighs users up to 440 lbs. with a resolution of 0.2 lbs. and also features an audio function.

SUMMARY OF IMPACT

The new scale that was developed and installed at the Ability Center of Greater Toledo is affordable, accurate, and able to be installed at homes. It allows many individuals with disabilities attending the center to track their body weight and determine if their current diet or exercise regimens are working effectively without having to visit their doctor or a local hospital, or invest in expensive equipment.

TECHNICAL DESCRIPTION

Several design concepts were investigated including creating a seat that would fold up flat against a wall...
and be folded back down to allow someone to sit on a platform and be weighed. However, the design required a more permanent installation. Because of its lack of portability, this design was not considered.

The idea of using a scale that can be installed on a toilet was pursued. Design requirements include maintaining the functionality and ease of cleaning of the toilet. A complete toilet seat design was thus conducted. Weight is measured using four load cells mounted symmetrically between the seat and the top of the toilet bowl. The load cells replace the small feet that are normally mounted under typical toilet seats.

Accounting for the user’s leg weight represented a challenge. This is addressed by incorporating a footrest into the system. The footrest is designed to mount on the left side of the toilet seat. The footrest is connected to a bracket using a pin which allows it to rotate out of the way from the front of the toilet to the side as shown in Fig. 21.5. The bracket is attached to the seat. The design is based on supporting a 400 lb. load applied at the end of the footrest farthest from the hinge.

Since purchasing load cells and displays proved cost prohibitive, a cheaper bathroom scale was purchased and the load cells salvaged. Salvaging components from an existing scale and installing them in a new device posed many challenges. Of these, calibrating the load cells was the biggest issue. The additional components of the design add weight to the scale which throws off the internal calibration. To solve this problem, an initial reading is taken before users apply their weight. Whatever weight is read at this point is set to zero and then the user applies his or her weight to the scale and only that weight is output by the display. The four load cells containing strain gages are wired to a circuit board where their electrical resistance outputs are summed and converted to a weight value. This value is then viewable on a small LED display mounted to the side of the scale. Audible weight readings can also be heard through a speaker on the back of the display. Two AA batteries power the electronics.

The majority of the footrest frame is manufactured from 1” x 1” by 1/8” thick hollow aluminum tubing. The frame which attaches the footrest to the base plate, and also makes up part of the swivel bracket on the footrest, is made using a 1/8” aluminum angled plate. The base plate housing the electronic components and load cells is constructed of a 0.75” thick Ultra High Molecular Weight Polyethylene (UHMW) sheet that is machined to fit the shape of the toilet bowl. UHMW is used because of the material’s strength, relative lightweight nature, machinability and resistance to cleaning chemicals. The base plate ties all the individual components of the system together. The load cells are counter-sunk into the bottom, and the footrest is also attached to the bottom at the side. The base plate is mounted to the toilet using two plastic pins located where a toilet seat would mount to the bowl as shown in the close-up of Fig. 21.5. These pins are designed very carefully to prevent the unit from twisting side to side while also allowing it to slightly rise and fall when weight is applied or taken off the seat. This allows the load cells to work properly. Finally, an elongated toilet seat installed on top of the base plate creates a more functional and comfortable seat for the users.

This project required significant custom machining and welding. The machine shop at the University of Toledo performed most of the mill work. The footrest was machined in an outside shop. The total cost of the materials was $116.17 as several components were donated to the project including the plastic for the base plate.
INTRODUCTION
Wheelchair users are subject to various secondary medical complications that result from a lack of standing. Medical professionals utilize passive standing therapy to lessen the risk of these complications. Passive standing involves a mechanical device which is used to bring a person with a standing disability to a standing position. The device then holds the individual in the upright position allowing therapy to be performed while standing up. The goal of this project is to design a device that stands an individual with disabilities out of a wheelchair and locking into a standing position. Once in the standing position, an adjustable tabletop can be positioned so the individual, while still standing, can perform basic hand motor skills with the occupational therapist.

To raise from a seated to a standing position, a lift harness is positioned under the buttocks of the user. The two sides of the harness are attached to steel arms that rotate via a manual hydraulic cylinder. Movable knee pads are also added to the prototype to prevent the user’s legs from moving or slipping in any direction. Once the individual is raised to the upright position their chest will also be resting against a pad that is connected to the table that they will be working with. Figures 21.7 and 21.8 show the unit that was developed.

SUMMARY OF IMPACT
This sit-to-stand table was developed for the Darlington Center of Toledo. It can accommodate an individual ranging between 5’0” and 6’5” in height and up to 350 pounds in total weight. In addition to allowing the user to stand, the device provides a table on which the individual can perform a variety of activities in the standing position. Standing promotes a variety of physiological benefits including improved bone, bladder, bowel and lung health, as well as less pain and spasticity. In addition, standing provides...
psychological benefits such as fewer symptoms of depression and an increased sense of well-being and self-satisfaction. The device was tested thoroughly to meet safety concerns. It was further tested by one of the Darlington Center’s clients who has given positive feedback regarding its use.

**TECHNICAL DESCRIPTION**

The objective of the project is to allow wheelchair users to have the ability to stand upright. Safety, portability, and functionality are the three main design considerations. Three designs were considered to raise the user: a seat sling or harness, a hydraulic piston, and a winch cable lifting system. Using a house of quality, it was determined that using a seat sling was the most effective.

The sit-to-stand unit consists of a mobile frame and a hoist powered by a manual hydraulic cylinder. The frame is constructed using 2” A500 steel square tubing of 0.125” thickness. One occupational therapist operates the hydraulic cylinder while a second therapist steadies the individual being lifted. An adjustable see-through table is incorporated in the unit as shown in Figures 21.7 and 21.8 to allow the individual to perform various motor skill actions while also seeing their body in the standing position. The table can be moved up or down in order to accommodate different users. Once the individual is in the standing position, the sling position locks and an additional back pad is provided for more comfort and an additional feeling of stability. Shin pads with Velcro straps are also used to secure the individual’s lower legs in place during lifting. The shin pads can be independently adjusted for varying height, width and depth. This feature accommodates stroke patients who may require one foot to be positioned ahead of the other. Locking caster wheels are used to allow easy mobility of the mechanism through a doorway as narrow as 36 inches.

The unit is designed to accommodate waist heights ranging from 34.4 inches to 44.5 inches based on anthropometric data. This constraint is incorporated in the kinematic analysis of the linkages. In order to allow enough room for the therapist to work with the individual being lifted, cables and pulleys are used with the hydraulic cylinder oriented vertically. When pumped, the cylinder applies tension to the cable. A force analysis was then conducted and the tension from the harness on each lifting lever arm was calculated as 217.78 lb. The tension in the cable was then calculated as 1055 lbs. which represents half the force required by the cylinder. The hydraulic cylinder used in this project was obtained from a Hoyer 9805 medical lift; its capacity was estimated as 3631 lbs. The tension in the cable was used to select a cable size and pulley for the sit-to-stand table. As advised by the manufacturer (Web Rigging Supply), the calculated cable tension was multiplied by a factor of five. This takes into consideration the cable end connections as well as any potential impact loading on the cable. A cable with a 7000 pound capacity was used resulting in a factor of safety of 1.32. Four inch cast iron pulleys with a bronze bushing were used to redirect the cable tension to the lever arm and cable cross member via high strength anchor shackles. The levers are attached to the lift harness. Finite element analysis was then conducted using Cosmo Works to perform a structural analysis of the construct and its components.

During operation, the hydraulic cylinder pumps slowly to allow for a smooth lifting process and releases slowly so that sudden shock is prevented when the individual is being lowered. The individual being lifted rests their knees against the padded surface throughout the lifting process and in the standing position. Once in the upright position the table is at chest height. Throughout the entire process of using the sit to stand device, two occupational therapists are required to be in assistance at all times. During the lifting process one therapist activates the hydraulic cylinder and the other guides the patient which also provides a sense of security.

Once the individual is lifted to the standing position and is comfortable, they can work on their motor skills with the occupational therapist. The therapist stands on the side opposite the individual and helps them work on various activities. The table they are working on is clear which gives the individual a visual of where they are in relation to the ground. The sitting process is initiated by releasing the pressure in the cylinder which allows the lever arms to return to the initial position and the individual to the initial sitting position.

The manual hydraulic pump and the sling were secured through donations. The total cost of all other parts was $750. All machining was performed at the Mechanical Engineering shop at no charge.
INTRODUCTION

Traditional use of a fishing pole requires two hands to operate. This makes fishing difficult for people with limited use of their hands. There are some motorized units available on the market to assist persons with disabilities to fish. These units are mounted on fishing poles and reel in the line at the push of a button. However, these units are mostly used for deep sea fishing. They are large, bulky, and expensive, and are not practical for fishing in local ponds, rivers, and lakes. The goal of this project is to adapt a fishing rod with a reeling power assist system. The device allows reeling with or without the use of a hand crank. The user is able to cast the pole in the regular manner. However, the device provides a controlled means of reeling the line back in. A small DC motor is used to create the power necessary to reel in the fishing line. The motor is powered using a 12 volt rechargeable battery. A mounting unit, made of aluminum slotted brackets, is designed to allow the motor to be assembled on multiple makes, models, and sizes of fishing poles and reels. Fig. 21.9 shows the system with the hand crank removed, and Fig. 21.10 depicts the system with the hand crank.

SUMMARY OF IMPACT

A power assisted reel that fits on multiple fishing reels was developed for the Northwest Ohio Spinal Cord Injury Association to provide its members with a means to enjoy fishing in Lake Erie. The units allow individuals to operate them without using hand cranks. The unit that was developed was tested successfully by one of the users. The design that was implemented is universal and the prototype can be easily attached to multiple types, models, and sizes of fishing reels.

TECHNICAL DESCRIPTION

The design objective focuses on retrieval of the line after being cast, and making the design universal so that it will work on multiple reels and fishing poles. This device must be used with an existing reel. This means that the reel must remain intact and installation of the device should involve little to no
modifications of the reel itself. This makes for a design that can be installed quickly by anyone. The design is also user friendly, easy to operate, light weight and fairly small in size.

An electric motor is used to power the reel. Since the user is going to be holding the pole when in use, the motor has to be small and lightweight. If the motor is too heavy, early arm fatigue may occur, which leads to discomfort and a short fishing trip. Direct mounting allows mounting the motor on the reel. The motor is attached to the fishing rod using a mounting unit made of ¼ inch thick slotted aluminum brackets as shown in Figures 21.9, 21.10, and 21.11. The brackets allow the motor to be attached to multiple reels. The drive shaft of the motor attaches directly to the reel as illustrated in the schematic representation shown in Fig. 21.11.

Using data available in the literature quantifying the thrust generated by a bluefish in the water, the thrust generated by a perch was estimated. This thrust is less than the average weight of a perch which represents the line load once the fish is caught and being lifted out of the water. An average perch weight of 1.47 N was thus considered as the design line force. The minimum torque required from the motor was then determined experimentally by using a scale to measure the crank force required to pull in various weights attached to the line as shown in Fig. 21.12. Considering the geometry of the reel, the estimated minimum torque requirement was about 0.3 N.m. (2.6 in. lbf). Based on these calculations, a 12-volt DC motor rated at 6.6 in. lbf. at 100 rpm is used. SolidWorks, a finite element analysis package, was used to perform a structural analysis on the brackets, which were found to be safe.

A hex shaft is used to run from the motor through the reel to a manual hand crank on the opposite side as shown in Fig. 21.10. This allows the client to use either the motor or the manual crank. The manual crank is designed to be easily removed so that the motor will not cause the crank to spin when it is not in use. When a user wishes to use the crank again it is slid back on the hex shaft. The motor is powered using a 12 volt rechargeable battery. The battery comes with a carrying case to make transport to and from the fishing site as easy as possible.

A power button that must be compressed to make the motor reel in the fish is installed to allow for ease of use and safety. This button is depicted in Fig. 21.9. This allows for a more enjoyable and realistic fishing experience as well as to kill the motor quickly when the user wishes.

Three closed face bait casting poles were used. The total cost of the material and the poles was $406. All machining was conducted, at no charge, at the machine shop of the Department of Mechanical Engineering at the University of Toledo.
DESIGN OF A WALKER FOR A VERY TALL PERSON

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INTRODUCTION
A 6’9” tall individual has difficulties using standard commercial assisted walkers due to his extreme height and his physical disabilities caused by a car accident. Using such walkers is unstable and unsafe as depicted in Fig. 21.14. The objective of this project is to develop a custom built sturdy and comfortable walker that will allow this individual to walk safely in his home and in certain public areas. The developed unit includes an armrest attachment on the right side of the unit and a foldable seat as shown in Fig. 21.15. Wheels on all four legs of the walker allow the individual to push the walker instead of lifting for each stride. The walker utilizes a one-handed braking system on the left side of the unit.

SUMMARY OF IMPACT
Our client suffers from a permanent brain injury, calcifications in his hips and right elbow, and limited use of his right hand. He is able to walk but only with the assistance of a walker and his leg braces. However, because of his height of 6’9”, his current walker is unstable and unsafe. Most commercial walkers available on the market are not designed for anyone over the height of 6’4” tall. The only alternative is to use a wheelchair to move around. This individual and his caretakers are concerned that being confined to a wheelchair will increase the rate of muscular atrophy in his legs. Using an assisted walking device in his home and in public can slow or even cease the rate of atrophy. The developed unit was tested successfully by the client as depicted in Fig. 21.15 and allows him to comfortably and safely walk on his own.

TECHNICAL DESCRIPTION
Strength, safety, and the client’s comfort are the three main design considerations. The walker is designed to fulfill specifications for the client’s height and weight. The walker must fit through all doorways, include an arm rest to support the client’s right arm that cannot be fully extended, and consist of a heavy and sturdy design in order to support the client’s weight and prevent the walker from being lifted while walking. In addition, it must be equipped with wheels and brakes to aid in mobility and stopping and have a built in seat to be used for rest periods during long walks.
It was first sought to modify an existing commercial walker. However, standard walkers are too narrow to accommodate a large enough seat and do not allow for a large footprint and walking area. The proposed design uses four wheels on the base of the walker, which offers more stability for the client. The frame of the four-wheeled walker also permits more room for the client to walk. Five inch diameter wheels attach to the bottom of each leg of the walker with fixed wheels on the back legs and swivel wheels with rear glides on the front legs to allow for maneuverability. A tension adjustment device built onto the back wheels is also incorporated in the unit for added friction. The walker height is adjustable at the wheels. The frame of the walker is made from AISI 4140 steel tubing with a 1 inch diameter and a thickness of 0.065 inches. The armrest is made from AISI 4130 steel tubing with 1.25 inch diameter and 0.12 inch thickness. The armrests are attached to the frame of the walker using clamps made of Aluminum 6061. The armrest is telescopecly adjustable and can swivel in and out (closer or farther away from his body). A thin, rectangular shaped piece of plywood is upholstered and seated on the top end of the armrest as shown in Fig. 21.15.

A one-handed brake system is incorporated in the unit. This one-handed brake is identical to a two handed brake system found on most commercial walkers. The only difference is that the brake cables are wired to one hand clamp. Both wires are connected to the left hand brake that is clamped onto the upper left support as shown in Fig. 21.15. The wires connected at the left hand clamp attach to the brakes on the rear, fixed wheels.

A seat, made of upholstered plywood, is attached to the walker by a clamp on the middle steel support bar of the frame. The clamp contains radial ball bearings to allow the seat to fold up and rest on the frame’s front lateral support bar. The seat is attached to three square support bars that lay across the frame and to the fixed clamp using brackets. The support bars are made of Aluminum 2024. Structural analysis was performed on the entire walker using the 3-D modeling software SolidWorks. A maximum loading of 400 lbs. was used in the analysis of the walker frame, and a maximum loading of 135 lbs. was exerted on both the armrest and the handle located on the opposite side of the frame. The unit was found to be safe.

All machining and fabrication have been conducted, at no cost, at the Mechanical Engineering department workshop. Invacare Corporation donated the adjustable wheels. The total cost of all remaining materials was about $550.00.
DEVELOPMENT OF A RECUMBENT ELLIPTICAL MACHINE

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INTRODUCTION

Our client is a college student who was involved in a car accident that resulted in the loss of half of her right foot and four toes on her left foot. Because of this, everyday activities, such as standing up, create increased amounts of pressure on her feet. This increased pressure can cause her pain, limiting the time that she is able to be on her feet. This prevents her from working out for an extended amount of time on devices that require her to stand, including conventional elliptical systems. While in rehabilitation, she used a machine, called the NuStep, which allowed her to exercise in a sitting position. However, this unit is prohibitively expensive for her to acquire. The goal of this project is to design and build a sit-down elliptical-style device that allows our client to easily get on and off of and work out at varying degrees of intensity. An exercise bike that used an air resistance wheel, shown in Fig. 21.16, was modified for this purpose. Two four bar linkages utilizing a shared crank were used to drive the air wheel allowing for a variable resistance. A seat on a sliding track was incorporated in the unit. Foot pedals and handlebars are used to move the crank of the machine that, in turn, spins the air resistance wheel. The finished unit is shown in Fig. 21.17.

SUMMARY OF IMPACT

The developed unit allows the client to work out by achieving arm and leg movements similar to that of an elliptical, all while in a seated position. She can easily sit on the device and adjust it for height. By sitting, she is able to work out for longer periods of time and exercise to the extent that she needs to maintain her health. The developed unit allows for a varying resistance in the workout so that she can control the intensity of the workout. The client was satisfied with her use of the device as is depicted in Fig. 21.17.

TECHNICAL DESCRIPTION

The purpose of this project is to develop an elliptical style exercise device that allows our client to be in a seated position rather than standing up. Design considerations include adjustment for various users, the ability to be moved relatively easily by one person, and allowing a variable intensity workout using a sturdy platform.

The design consists of modifications of a stationary exercise bike such that the final unit looks similar to a recumbent bicycle turned around. The flywheel of the modified unit is mounted in the rear of the frame, under a seat. Resistance is created using a salvaged air wheel from the stationary exercise bike. The foot pad and location are not altered. However, instead of using a one piece handle bar on each side of the unit, a two piece handle on each side was developed. This allows our client to grasp the...
handles in a much more natural position as shown in Fig. 21.18. This two piece handle design also allows the handles to swing out of the way when not in use, making it easier to get on and off the elliptical.

The final design incorporates a seat on a slide track to enable adjustment for multiple users. The seat is placed such that the user faces the opposite direction of the one that was originally on the bike. A standard tractor seat with the adjustment included is used for this purpose. This seat allows for 6" of adjustment forward and back from the foot pedals and gives the elliptical an operating range for individuals between the heights of 5'2" and 6'2" comfortably. Seat adjustment is easily reached in a seated position from the left side of the unit. The seat locks into position utilizing a spring return retention pin to keep the seat from coming out of adjustment during intense workouts.

The salvaged unit includes one set of four bar linkages on each side. Another set is added on each side to the front of the unit to allow for feet motions. Both four bar linkages share the same crank, allowing the hands and feet to move in opposite directions while in use. The shared crank drives the reused air wheel allowing for a variable resistance. Hand motions are synchronized with foot motions by connecting handles directly to the linkages that drive the foot motion.

Careful analysis on both four bar linkages allowed for determination of the exact lengths of the members of the linkage sets. SolidWorks, 3D CAD software, was used to simulate the motion of the device. A kinematic analysis was conducted to determine if the speeds were sufficient to create excessive loading on any members. A maximum angular velocity of around 8 rad/sec and a maximum radial acceleration of around 21 rad/sec² were observed on the stationary bike before it was disassembled. Using these values in the kinematic analysis, the linkages were found to have relatively low velocities and accelerations. A static stress analysis was determined to be the most conservative approach based on this information.

A structural analysis was then performed with simultaneous loads of 400 lbs. and 150 lbs. applied to one footpad and at one handle, respectively, when the linkages were in a stationary, “locked”, position. This analysis was done to estimate the stresses on one set of linkages on one side of the bike when a very strong individual is attempting to use the elliptical if the crank were to be fixed in position. All members were found to be safe.

The final unit is small enough to be used in the home and is also easy to use. It is reasonably lightweight and includes rollers on one end of the frame as depicted in Figs. 21.17 and 21.18, which allows for easy mobility and transportation. The original stationary bike was donated and the total cost of the remaining parts was approximately $575.
INTRODUCTION

Because of the potential for spinal cord injury, trauma victims must be secured to a rigid backboard. However, extended time on backboards has been associated with decubitus ulcers (bed sores), areas of damaged skin and tissue. Patients may be secured to these boards for up to four hours waiting to undergo x-rays. This is more than enough time for these ulcers to become destructive. Experimental studies on dogs have shown that a constant pressure of only 60mmHg for one hour is enough to cause irreversible tissue damage. When patients are on the backboards it has been shown that there is often a high pressure spike at the sacral prominence reaching up to 260mmHg. It has also been reported in literature that when a thin but very heavy gel pad was added to the backboard, the sacral interface pressure was reduced to an average maximum pressure of 188 mmHg. The objective of this project is to develop a backboard with a light pressure dispersion liner to reduce interface pressures on pressure sensitive areas in the supine position. Seven different foams of various densities were tested as pressure dispersion liners. A force sensing array pressure mapping system was used to measure the pressure between the subject's sacral region and the backboard. A simulated backboard made of wood was first built to accommodate the pressure dispersion liners to be imbedded into it. It was found that the two best foam products were the Green Merryweather and the 125-36 CFR. An emergency medical services spine backboard was then modified to allow for the imbedding of a pressure relief system at the sacrum in it. A section of the top plastic shell and inner hardened foam was removed from the backboard and replaced with a dish that houses the liner as shown in Figure 21.19. Final testing results using the modified board fitted the light foams show that there was a very
significant reduction in pressures directly on the sacrum.

**SUMMARY OF IMPACT**

Using a simulated backboard made of wood, considerable pressure reduction of up to 60% in the sacral region was seen when light foam was used as a pressure liner. This pressure reduction was larger than that observed when heavy gel pad was used as a liner. Significant reductions in pressures were also seen at the sacrum when the 125-36 CFR foam was used with the new designed backboard. This reduces the probability of spinal injury victims developing debilitating bed sores. However, large edge effects were observed where the dish and board meet. Further research needs to be conducted to reduce the edge effect where the dish and the board meet.

**TECHNICAL DESCRIPTION**

Seven different foams of various densities were tested as pressure dispersion liners including Green Merryweather and Blue Merryweather, which are memory foams from Merryweather Foam Products, and the following five foams from Custom Foam Products: 0.8527, 25080 CFR, 150-60 CFR, 125-36 CFR and 145-45 CFR. “CFR” simply refers to a special fire resistant coating that meets a standard in California. A Force Sensing Array pressure mapping system was used to measure the pressure (in mmHg) between the subject’s sacral region and the backboard. The system includes a pressure mapping mat that is placed in between the subject and the board and a computer that has supporting software for the mat.

A simulated backboard made of wood was first built to accommodate the pressure dispersion liners to be imbedded into it. This allowed for several tests to be completed comparing the seven types of foams that were tested. Large pieces of foam measuring 12” x 12” and having thicknesses ranging from 1” to 1.5” are used. Tests on the backboard simulator were completed using one male subject for all foam samples. The subject laid on a pressure map attached to the wooden backboard. Eight sacral interface pressures were obtained with and without a wallet in the rear back right pocket. The wallet was added to represent a real clinical situation. An important observation that was made was the dramatic difference in pressures between having a wallet in the back pocket and not having a wallet in the pocket. The pressure mapping system showed that when the patient had the wallet in the pocket, the body pressures were on the wallet and on the opposite gluteus maximus of the patient. This is significantly different from the centralized pressures on the sacrum when the patient had no wallet. It was found that the Green MerryWeather and the 125-36 CFR foams provide the two highest average percent reductions. These two foams along with a Turley Gel Pad obtained from Xodus Medical were then retested on a redesigned backboard using three subjects without a wallet in their pockets.

The final design consists of modifying an emergency medical services backboard to allow for imbedding of a pressure relief system at the sacral region of the board. A section of the top plastic shell and the underlying hardened foam are removed from the backboard and replaced with a dish that houses a liner as shown in Fig. 21.19. The structural integrity of the modified board with the cutout was tested using SolidWorks and found to be safe. The 125-36 CFR provides the most pressure reduction and the largest sensing area. However, the final testing results did not provide a significant reduction in the maximum pressures when using the liner. This is caused by a large edge effect where the dish and board met as shown in Fig. 21.20. The raised lip of the dish shifts the maximum pressures from the sacrum to the outside of the buttocks. Observations of the mappings show that there is a very significant reduction in pressures directly on the sacrum. A maximum sacral pressure of 41 mmHg was observed while using the modified board fitted with the 125-36 CFR foam. At the same time, a sacral pressure of 125 mmHg was recorded when a non-modified backboard with no pressure relief system was used by the same subject.

The total amount spent on materials for this project was approximately $50 but the team was required to drive to Cleveland four times at a cost of approximately $600.
INTRODUCTION
Our client is a young boy who is paralyzed from the waist down and confined to a wheelchair. He is currently learning to play the piano, but is unable to depress the piano peddles with his feet. The purpose of this project is to develop a device that allows him to control the piano pedals. The developed system includes a Sip/Puff switching device and an electrical linear actuator. The Sip/Puff device allows the user to simply blow into a plastic tube in order to depress the pedal when necessary. The linear actuator is used to depress the piano pedal once the signal is received from the Sip/Puff device. A floor unit with a frame made from aluminum is used to house the actuator and allows it to mount directly on top of the pedal. This pedal depression unit incorporates a means of height adjustment to compensate for different piano pedal heights of various pianos. Fig. 21.21 depicts our client using the Sip/Puff device, and Fig. 21.22 shows the depression unit mounted over the piano pedals.

SUMMARY OF IMPACT
Since our client has no leg movement, he does not have the ability to depress the pedals while playing his piano. His playing ability is limited to music selections that do not require the use of pedals. The custom designed and user-friendly device allows our client to depress a piano pedal via a Sip/Puff device and linear actuator. The developed unit was tested by the client who found it to be easy to use, relatively quiet, and adaptable to various pianos. He is also pleased that the unit is lightweight, portable and compact and can be easily transported.

TECHNICAL DESCRIPTION
In order to be able to depress a piano peddle by some means other than a foot, a device that allows the user to activate a mechanical system to depress the pedal needs to be developed. The main criteria include the adaptability of the activation switch, and discreetness so as not to interfere with our client’s playing. The pedal depression device needs to be quiet, quick, and adjustable for various piano pedal heights.

A similar device design was attempted in the 2007-2008 academic year, but was too cumbersome. The device operated correctly, with the user using his chin to depress remote pedals hung on his shoulders, which operated four electric solenoids that mechanically depressed the actual piano pedals. Several problems were identified with this design including an unacceptable amount of noise being produced when the solenoids were activated. This second generation prototype utilizes a Sip/Puff switch as the switching device. This device requires the user to insert a small plastic tube in his mouth.
and “puff” or “sip” into it. This operates an electrical relay wired to a linear actuator used to depress the pedal. A high-speed linear actuator with a stroke of 1 inch, a speed of 2 inches/second, and implemented built-in switches is used. With the short stroke and built-in limit switches, it was noted that no programming of the motor was required to depress the piano pedal. Multiple pianos were experimentally tested and it was found that the average force to depress the pedal was 8 lbs. In order to keep the load on the actuator light and improve its speed and response time, one that was rated at 35 lbs. was selected. The load chart of the selected actuator shows that it can move about two inches per second at 8 lbs. of load. The switching unit consists of a head-mounted blow-through tube that easily sits around the user’s ears. Puffing creates a positive pressure inside the tube, while sipping creates a negative pressure. The pressure is sent down into a remote box that sends out an electrical signal controlling a relay to activate the linear actuator. The Sip/Puff device is only rated for a maximum of 40 mA. Since the linear actuator draws around 3 A, a contact relay between the Sip/Puff control box and linear actuator is needed. A double throw relay rated at 25 A is implemented and controlled by a 12 V signal. By using a series of resistors and transistor, the relay activation current remains well under the Sip/Puff upper limit range. 18 V Zener diodes are added to the wiring system for reliability reasons. All switching devices and the Sip/Puff device can be operated as either a single sip or puff system, or both simultaneously. Since the application necessitates the need for only one piano pedal, only the puff activation system is used. The electrical system is designed so that the linear actuator always returns to the retracted default position. The linear actuator only depresses the pedal when the client puffs into the tube. As soon as he stops puffing, the linear actuator will immediately return to the default position.

By selecting an actuator with a 1-inch stroke, it is possible to depress the pedal by installing the actuator directly over the foot pedal, resulting in less weight and complexity. To limit noise and damage to the pedal, a rubber stopper was installed over the shaft of the linear actuator. To install the actuator directly over the foot pedal, a floor unit is fabricated from aluminum square tubing to which the actuator is mounted. Since the device needs to be adaptable to various pianos, a vertical adjustment acme screw with a handle is installed to allow the entire internal assembly to be adjusted into slight contact with the pedal. The linear actuator is secured to the screw device, which allows vertical adjustment between the specific limits, within 1.5 inch and 3.5 inch above the floor. The floor unit, shown in Fig. 21.23, houses a two stage relay, the sip/puff activation box, the linear actuator, and a power supply. The sip/puff box does not need to be powered allowing the use of a single power source. The sip/puff tube as well as the power supply cord can be separated from the unit making it extremely portable. The cord and tube simply reattach when needed through conveniently placed holes on the floor unit. The entire unit weighs 15 pounds. The size of this floor unit accommodates many different types and sizes of pianos. The unit is positioned so that the rubber stop on the actuator is slightly in contact with the pedal. This allows the fastest engagement and the reduction of any sudden impact noise that may be produced. Wooden panels were used to cover the floor unit. The total cost of the project was $475.00.
CHAPTER 22
VANDERBILT UNIVERSITY

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INTRODUCTION
For a wheelchair user, an improperly fitting chair can have devastating consequences, including pressure sores, tipping over backwards, overuse injuries, restricted mobility, and limited accessibility. The SitKit project at MAX mobility aims to decrease the number of individuals subject to such consequences by providing an accurate and consistent method for clinicians and direct medical equipment (DME) dealers to evaluate and determine the optimal wheelchair set up for a specific individual.

SUMMARY OF IMPACT
Understanding the wheelchair fitting process is essential to identify any areas in need of improvement. The hardware component of the project, a set of tools (SitKit) for measuring an individual and a wheelchair, is selected as the focus of the assessment. A study of the current methods employed to determine wheelchair set up provided valuable feedback for the project. Following clinical observation and collaboration with local clinicians and DME dealers, changes to the tools were proposed. Refining the SitKit tools will increase the feasibility and efficiency of using SitKit while maintaining the overall goal of improved accuracy and consistency in determining the optimal fit of a wheelchair to the user.

TECHNICAL DESCRIPTION
The proposed changes for SitKit apply to the linear measurement tools, which include calipers and a height gauge. The caliper and height gauge are used to obtain a variety of measurements, and tools must be interchanged for the particular measurement needed. Pressure paddles are attached to the end of the calipers when measuring hip width, and a caliper or horizontal laser beam is used to mark a measurement with the height gauge.

During an evaluation clinicians must be able to maneuver tools, obtain and record measurements, and often times support individuals who lack sufficient stability to sit independently. The current set of calipers and height gauge hinders this because they are heavy, cumbersome, and require switching tools between measurements.

Consolidating the caliper set and height gauge into one tool with interchangeable parts, reducing the weight of the tools, and simplifying the method of assembly will make the measurement process more efficient and SitKit tools more desirable to clinicians. Combining the calipers and height gauge into one tool might be accomplished by altering the method for attaching and removing tool components. Creating a system in which attachments are not screwed together, but rather pulled on and off, would allow multiple tool configurations to be efficiently achieved during the course of an evaluation. Removing material from the center of the calipers, measuring stick, and pressure paddles while maintaining mechanical structure and stability is recommended as a way to reduce weight and make the caliper set easier to handle. Additionally, in order to facilitate maneuvering the tools into the correct position, a short caliper is recommended to replace one of the long calipers, with additional attachment pieces that can lengthen the caliper when necessary. Using a caliper, instead of a laser beam, with the height gauge is recommended for measurements where the laser light disappears across the boundary of the body, such as height to top of shoulder. The changes proposed for the SitKit tools are currently under review by the original
project developers, and alterations will be implemented as funding is available. Cost is to be determined but is expected to be in a range of $1500 to $3000 per kit. The tools are expected to be on the market within the next six months.

Fig. 22.2. Demonstration of calipers with pressure paddles used to measure hip width.

Fig. 22.3. Demonstration of height gauge with sliding caliper used to measure lower leg length.
THE MOBILITY ENHANCEMENT SYSTEM FOR WHEELCHAIRS

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INTRODUCTION
A vast amount of fatigue injuries occur in the wheelchair population, creating a great need for a more ergonomic and less injury-prone wheelchair propulsion setup. Several solutions have been previously proposed and can be broken into two categories: power assisted and geared technologies. In power assisted systems a small motor is typically utilized to provide propulsion. The benefits to the user are mainly decreased muscle strain; however, such systems are generally heavy, weighing between 46 and 85 pounds, and expensive (~$7,000). Additionally, the range of the wheelchair is limited by the battery life. Other options including geared technologies have been utilized in a number of different ways, mainly lever drive systems and hand-rim systems that provide mechanical advantage to the user. One downside, though, is that such systems maintain the same arc type path as a normal manual wheelchair and actually demand more full arcing movements to traverse a given distance. Consequently, their use does not prevent injuries.

SUMMARY OF IMPACT
This design aims to allow wheelchair users the option of an inexpensive augmentative power system for their wheelchair. The long-term goal is to make this technology available at low cost as an alternative to more expensive solutions as mentioned above.

TECHNICAL DESCRIPTION
The final design includes an 18 V DeWALT electric motor (part # 393111-15) and transmission (part # 380264-15) with a 25.9 V 10 Ah Li-ion battery. We developed a custom aluminum frame, a drive wheel/belt combination, and a relay controlled high/low speed selection mechanism. With our design the total weight of the system is 11 pounds, and up to 533 in-lbs. of torque can be developed.

Performance tests with a 19lb wheelchair and 170 lb. man indicate the maximum ranges of 4.68 and 3.43 from current and speed measurements at high and low speeds.
The expected MSRP is calculated as a three-fold markup of the total manufacturing cost. It is evident that the battery is both the heaviest and most expensive component. The battery, however, is a critical design component, for it provides propulsive power. Thus the battery capacity represents a conflicting design variable. Increased capacity gives increased range to the device but also increases the weight and cost of the device. Increased weight reduces the detachability of the system, and increased device cost may overshoot target market. Both the motor and control system also present design conflicts however, their weight and cost were much less than that of the battery. The battery design conflict was solved by selecting a battery that fit within our device weight (~10 lb) and cost ($1,500 - $7,500) constraints while providing adequate energy capacity for ranges of above 3 miles. Additionally, battery capacity could be tailored to individual customer demands. Those customers needing only a two mile per day range may opt to purchase this device with a smaller battery in order to reduce the weight and cost of the device. Those wanting increased range may purchase a battery with greater capacity. Estimated expenditures were $1400.
IMPROVEMENTS IN COMFORT FOR WOMEN IN WHEELCHAIRS

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INTRODUCTION

Women who use manual wheelchairs are more likely to develop overuse injuries than men. We interviewed female wheelchair users to assess their usage patterns and needs. Rather than building and designing a completely new wheelchair, modifications are made to an existing wheelchair. These modifications are based mainly on user feedback and research.

SUMMARY OF IMPACT

Wheelchair modifications specifically aimed towards women users may impact approximately half of all wheelchair users in a positive fashion. Specific goals addressed involved high heel use, storage problems, and user modesty.

TECHNICAL DESCRIPTION

Our goal is formally stated as: “To improve functionality and comfort of wheelchairs for women by modifying a wheelchair seat cushion: Modification #1: Develop a new method of securing an individual’s legs when using a wheelchair, Modification #2: Create more accessible storage compartments, and Modification #3: Develop a way to alleviate pressure sores and increase stability when wearing high heels”

To meet the first goal a seat cushion is modified in a way to keep the user’s knees together while in motion. Because wheelchair users usually do not...
have function of their legs, it is difficult to keep their knees together throughout the course of the day. This can be especially frustrating for women when wearing skirts or dresses. The only current method to solve this problem is a shin strap which attaches around the wheelchair and users legs. While this method is very functional, it is not comfortable or aesthetically pleasing. Our solution to this problem is to alter the current structure of a seat cushion by raising the sides of it. Raising the sides of the cushion forces the knees to stay together in a more functional, aesthetically pleasing way.

The current storage methods available for wheelchair users are in the form of a back pack, “fanny pack” or net which hangs underneath the seat; however, neither is optimal for female usage. Back packs are susceptible to theft and are very difficult to access depending on the position of injury. The “fanny pack” or net storage methods hang under the seat of the wheelchair. They are not susceptible to theft, although objects are more likely to fall out and get lost. Like the back pack storage method, this storage method is also difficult to access because it requires the user to reach between their legs to access their belongings. Our solution to this problem is to place two storage pockets on the sides of a seat cushion. Placing the storage pockets here allows the user easier access to their belongings. Here, they are also less susceptible to theft or loss of items because they sit closer to the body of the user. The above two changes may be seen in Fig. 22.6.

The third and last modification made involves creating heel inserts. These inserts are intended to diffuse the pressure on the legs and buttocks while the user is wearing heels. Wearing heels elevates the user’s legs and thighs and increases the pressure on the buttocks. This increase in pressure is one reason pressure sores develop which can be very detrimental to the user as it can lead to infections. Our solution to alleviating pressure sores when users wear heels is to create foam inserts (triangular shaped wedges) to be placed between the seat cushion and seat. These inserts increase the height of the user seat cushion and allow them to place their feet flat along the wheelchair step. This keeps the user’s legs and thighs along the seat of the chair and minimizes the formation of pressure sores when wearing heels.

Fig. 22.7. Above wheelchair with triangular insert for high heel use.
INTRODUCTION
Children that are born with mobility impairments have been shown to develop perceptual skills more slowly than active children. These children, when prescribed power wheelchair use regimens, have perceptually developed at increased rates and have been able to adapt earlier and more fully than children who continued to lack the stimulation provided by auto-mobility. Injury amongst these children is a serious concern due their inability to pilot the wheelchairs properly. To decrease the chance of injury, this design is focused on creating a prototype proximity detection alarm system.

SUMMARY OF IMPACT
Our first goal, to create a system that reduces the chance of injury when using a wheelchair, is achieved through the proximity sensor modifications and the designated pre-made sensor choice. This system as a unit enhances the safety of patients using wheelchairs, even those that are unable to pilot the wheelchair without some aid. The low cost of the proximity sensor (~$90 plus labor, installation, and training costs), meets the specifications laid forth by the second goal. The third goal, adaptability and versatility of the system, is met by designing modular stages capable of providing side-discriminating, distance-discriminating, or both side- and distance-discriminating outputs. The fourth goal, adapting the output to the target demographics’ needs, is achieved through the use of auditory outputs rather than visual or otherwise. Our final goal is longevity, reliability, and maintainability. Our system does not use quickly consumed or fragile components, so we feel strongly that, if installed with proper care, the system will be resistant to damage and wear-and-
TECHNICAL DESCRIPTION

This design implements the “GERAFLAG Parking Sensor System”. This system retails for $20 each. It uses an ultrasound sensor system and is able to detect objects in the range of 0.3 - 1.5 meters. The unit comes with four sensors (2 left, 2 right.) The associated electronics detect the object within the minimum distance in the left or right position. Modifications of this system include an output of two different sounds. These sounds correspond to detection on the left and on the right. As the object approaches, the system engages and beeps with higher pulse frequency when the object is closer. There is a 0.19s beeping delay for a 1.0-1.4m detection distance, a 0.32s beeping delay for a 0.5-0.9m detection distance, and a 0.70s beeping delay for a 0.3-0.4m detection distance. The analog circuitry contains two capacitors that delay the start of the beeping by about 0.5s and the stop of the beeping by less than 1.0s. We believed that this delay is acceptable, and furthermore that the delay in sound cessation is beneficial. The noise in the signal does not cause sporadic breaks in output when the capacitors must be discharged before sound stops. A schematic of the desired detection system may be seen in Figure 22.8. A schematic of the circuit desired and developed may be seen in Figure 22.9 below. The prototype system is demonstrated but has not yet been field tested on an actual wheelchair system. Modifications such as an automatic override of wheelchair power in case of an imminent crash must be considered for future implementations.

Estimated expenditures are $120.

Fig. 22.9. Circuit schematic and breadboards for system.
CHAPTER 23
WAYNE STATE UNIVERSITY

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INTRODUCTION
Our client, a young man aged 24, obtained a C4-C5 spinal cord injury in a motorcycle accident. He is a computer engineer and both he and his employer want him to continue to work from his home until he is able to return to his office. Michigan Rehabilitation Services provided him with an eye-gaze mouse control system and Dragon Dictate. Fig. 23.1 shows the original setup.

There are significant problems with the original setup. He cannot sit in his wheelchair for very long and he spends about 80% of his time reclined or in bed. This pattern of use will change over time as our client begins to recover. This means that someone has to reposition the computer monitor for each new position. This can cause problems because the eye movement mouse control system requires a nearly perpendicular eye gaze angle to the pickup camera. Also, he sits very high in his wheelchair and is relatively low when in bed or reclined. Consequently he has a very difficult time with the eye gaze system. He cannot work in another room. Therefore he is confined to his bedroom for long periods of time. He wants to be able to move the computer system to another room to work. This computer is also the shared home computer and therefore he requests a design that allows his children and wife be able to use.

SUMMARY OF IMPACT
The workstation has thus far satisfied all of the client’s requirements. The combined adjustability of all the components enabled the client to very quickly gain control of the eye-gaze system and hence computer operations. Being able to adjust the top shelf height and pull out the keyboard enables the client’s family members to access and use the

Fig. 23.1. The original setup in the client’s bedroom.
computer. Being self-contained with one power cord and on casters, the workstation can be easily moved into other rooms of the house allowing the client to work outside his bedroom. By satisfying all these requirements the workstations exemplifies a universal design using agile systems technology (Creform).

**TECHNICAL DESCRIPTION**

Figure 23.3 shows the new workstation. The workstation frame is made from Creform, a pipe and joint technology. The cost of the workstation, monitor mount, power strip, plastic shelving, and retractable drawer assembly is approximately $1,920. Fig. 23.2 shows the monitor mount. It costs about $80.

The electronically controlled hydraulic lift system is the most expensive component, $789 of that total. The ability to easily and quickly adjust the height of the workstation is essential given the relative frequency of the client’s working position and accessibility requirements for other family members, especially his children.

![Fig. 23.2 The flexible mount for the computer monitor.](image1)

![Fig. 23.3 The mobile adjustable computer station with casters.](image2)
ERROR PROOFING SYSTEM FOR PACKAGING

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INTRODUCTION
Goodwill Industries of Greater Detroit (GIGD) has a spectrum of programs and services for individuals with disabilities. In particular GIGD has a strong automotive section which provides employment for a variety of jobs including the packaging of license plate installation kits. The majority of these kits contain 2-3 different parts, typically 2-4 plastic nuts, 2-4 metal bolts, and 2-4 metal rivets. The number and quantity of parts varies depending on the associated vehicle. These kit packaging jobs require anywhere from 200 to 2,000 kits per day with very strict quality control requirements.

This project designs and builds a prototype error-proofing system for the licensing plate installation kits. The original packaging process included a workstation with a heat seal plastic bagging capability. A worker would place a handful of nuts, bolts, and rivets on the workstation top and then count the required number of each sliding the parts to a funnel which directed the parts into a plastic bag. Stepping on a foot switch activated the bag sealing step and advanced the next bag. This process resulted in too many errors. The new system promises to reduce errors and improve productivity.

SUMMARY OF IMPACT
The prototype error proofing system functions very well. With this system the workers are relieved of the task of keeping count for each part. The worker only needs to concentrate on adding parts to each funnel until the LED corresponding to each funnel turns yellow. Each time a worker error causes an over count, a resettable electromechanical counter is incremented. This allows the supervisor to monitor worker performance. With the old system, workers stop when 100 bags are filled and visually inspect each bag. This is time consuming and still does not catch all the miscounts.

With the new system the workers are purposely slowed down in counting by the dispensing and channel configuration. However, the instrumented counting eliminates the necessity for a visual inspection after every 100 bags, thereby greatly increasing overall productivity and reducing errors.

Goodwill staff note design modifications that they believe will further enhance quality and productivity. Based on the prototype design Goodwill staff have started a bidding process to build between 10-15 error proofing systems.

TECHNICAL DESCRIPTION
The prototype system is shown in Fig. 23.4. Three dispensing tubes, one each for nuts, bolts and rivets, present workers with inventory at the entrance to a channel. Each channel leads to a funnel which is instrumented with an infra-red sensor to count parts as they fall through to the plastic bag. A process controller can be programmed with the required part count for each channel. An indicator light on the dispensing tube is green until the correct number is counted and then turns yellow. It turns red if there is an over count.

CATIA software is used to design the funnels, the channels, workstation layout and wiring harness layout. Four funnels are designed; one for each channel and one large collection funnel dispensing into the plastic bag. Commercially available inexpensive plastic funnels and channels are used for prototype evaluations. The error proofing system is mounted on a Creform support that is designed to be disconnected from the bag sealer, thereby making it easy to perform required periodic maintenance on the bag sealer.

The process controller is realized by using standard CMOS 16 bit decimal and hexadecimal counters in conjunction with one-shot chips and comparators. The design of the circuit enables an accurate pulse...
width detection to minimize and/or eliminate erroneous part counts. Setup of the device is easy – the count for each part is set by the use of one button per channel and one button to confirm all the three set values. The set values are retained even when the power is turned off. When the correct number of parts has been dropped through the funnels into the bag, an LED indicates that the foot pedal connected to the sealer can be pushed to engage the bag sealer. An under or over count will prevent the sealing of the bag.

Fig. 23.4. The completed prototype of the error-proofing system.
INTRODUCTION

Visions Unlimited is a post-secondary educational program operated by Farmington Public Schools. The school serves 18 through 26-year-old young adults with developmental and physical disabilities. The school day focuses on developing transitional skills from school to work. Emphasis is given on improving the students’ life and work skills. Through classroom and community-based instruction, these goals are achieved. Vision Unlimited uses Positive Behavioral Support (PBS) principles. The staff wanted a system consistent with PBS strategies that would enable their students to gain experience with a “debit” card like process that uses a point system rather than money.

Students earn points as a “reward” for designated behaviors such as successful completion of jobs and appropriate behavior. Students can then “spend” their points at the school department store. The debit cards are passive RFID tag cards in the form of a plastic debit card. The school’s PBS logo, a bulldog named Buddy is printed on the front of the card. The RFID card has limited read/write memory for holding a student’s name, school ID number, and the current point count in the student’s account.

Each homeroom has an RF Reader connected via a USB cable to the associated staff’s computer. Only the staff can add or remove points from the students’ debit cards.

All the computers are networked to a central server which contains the student account database. Figure 23.6 shows an RF Reader and debit card. The student account database contains a detailed record of all student transactions. A report of student transactions can be generated and printed by staff as required.

Transaction information includes a coded description of the transaction. Transaction descriptions include; job completed on time, reported to workstation on time, bought Milky Way candy bar at the school store, etc. The level of transaction detail is determined by the staff and any IEP (individualized education plan) student performance tracking requirements.

SUMMARY OF IMPACT

The system has just been installed and is not fully operational. After the installation, the staff requested some program modifications and additional features. Modifications will be made to the system during the summer and the system is planned to be operational by the beginning of the new school year. The initial reactions by both staff and students have been very positive.

TECHNICAL DESCRIPTION

The system uses a 13.56 MHz RFID Tag with at least 32 Bytes of user (R/W) memory. The project provides 200 printed RFID tags but at some point in the future the school will need to purchase additional RFID tags. The system’s software is
written in Visual C++ dot Net. The drivers for the RFID reader are provided by the manufacturer as a library file. This library file is compatible with the Microsoft visual studio.Net IDE.

The program consists of three major sections; 1) RFID reader communication, 2) database communication, and 3) the user interface. Sufficient error handling is incorporated into the program. The program uses an MS Access 2000 database with several tables. These tables store tag information, points accrued or spent by students, and also purchase history. The database is stored on a shared drive on a server accessible by the desktop PCs used by the staff. Each desktop PC is secured by a username and password. Since the database is on a shared drive, communication between the desktop PC and the database is simplified and is accomplished using an absolute path to the database. In the application code, the database is accessed using the standard DAO control and the tables are read and written to whenever there is a debit card transaction. In the case of a lost tag, a new tag can be added to the system and associated with the previous tag thereby maintaining the points earned by the student.

The user interface is very simple and intuitive. There are four functional control screens; 1) adding or deleting a student, 2) creating a report, 3) adding or deleting a transaction, 4) an information screen for the students showing the student’s name and current points. When a tag is to be assigned to a new student, it is read and is shown as read only and is populated by the RFID reader. The name and current points for the student are entered and stored in the database as a new entry. Figure 23.5 shows the report creation screen and illustrates the screen design.

The RF tag readers cost about $100 each and the tags cost about $1.00 each.

Fig. 23.6. The passive FID tag and the RF reader which connects to a PC via a USB cable.
CHAPTER 24
WRIGHT STATE UNIVERSITY

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INTRODUCTION
Cognitive disabilities affect millions of people all over the world. At Montgomery County Mental Retardation and Developmental Disabilities (MCRDD), the staff serves both children and adults suffering from significant developmental disabilities. They work to provide the support these individuals need to live, learn, work, and participate in their communities. The goal of this project is to develop a traffic light device that can be placed in the classroom setting in order to aid in the development of necessary skills in children suffering from cognitive disabilities, including Down syndrome and Autism.

SUMMARY OF IMPACT
The table traffic light (Fig. 24.1) aids teachers in alerting children to changes in school activity. The light, which can be manually changed through remote control or set up to change after a specified amount of time, also gives the children a focus object during class. Further work on this project will be centered on developing a warning tone to alert students as to when the light is about to change. This feature would be most helpful in the timer mode, when the teacher is not aware of how much time is left before the light changes.

TECHNICAL DESCRIPTION
The total combined circuit (Fig. 24.3) shows the configuration of the battery, DC-DC converter, receiver relay, timer relay, and light stack. The battery is a 6 volt 4.5 AH that is controlled by a master on/off switch. When in the off position, the battery is disconnected from the converter, allowing the battery to be recharged when needed. The battery is fed into a DC-DC converter that ups the voltage to a positive 12 and negative 12 volts. The DC-DC converter is necessary because each of the two mode circuits require 12V of input voltage, while the light tower itself needs 24V for operation. This light tower, donated by Helix Medical LLC, provides a 360 degree view of the lights.

The positive 12 volts line is controlled by a second switch that latches either the receiver relay or the timer relay. This switch controls which of the two functions is selected, manual or automatic, the traffic light is being operated through. Once the latch is closed, this gives 12V of the required 24V required to power the lights. The negative 12 volts line is the output from pin 4 of the DC-DC converter and is
connected to the other end of the lights. When combined, this gives 24 volts and the light corresponding to its respective latch is lit up.

The design of the automated timing solution is implemented in part with three 6062 Altronix timers. These timers act as the counter and adjustment for the amount of time desired. With the timers and associated circuitry, timing options can be adjusted anywhere between one and thirty minutes. For the design of the manual solution, where with any press of the button, the user is able to change the light color, a HD4RX 4-Channel RF Receiver Board and Remote are used. With the four channels of the receiver board and remote, one channel is allotted to each light, and the fourth relay acts as the MASTER reset. This means that when this button is chosen, any illuminated lights will extinguish. In addition, this device can hold a range of up to 250 feet which will be ideal in a classroom setting. The receiver requires 12 volts DC power, which matches the timer circuit’s power needs. Due to the factory design of this receiver board, some additional circuitry design is required so that the manual light setting works in a more practical manner for a classroom setting. With the modified receiver circuit shown in Figure 24.2, subsequent presses of the same button to turn the same light on and off are not required. Instead, the lights change with the push of the next color choice, thus extinguishing any previous lights and lighting only the desired color choice.

The total cost of the project was $780.
INTRODUCTION
Psychological, emotional, and physical injury resulting from burns present a significant problem for the medical community. More than two million American citizens require treatment for burns annually. Of these, three to four thousand result in fatal injury. In addition to the tragic loss of life, burns are often accompanied by extended and expensive medical care. One of the most commonly used burn treatments is the application of mechanical pressure, which has been empirically related to decreases in scar formation and recovery time. Total Contact, Inc. utilizes this phenomenon to aid burn enhancement by designing custom-made pressure masks that apply mechanical pressure to patients. However, pressures applied to patients have not been quantified. The goal of this project is to develop a system capable of quantifying interfacial pressures resulting from the application of the masks from Total Contact, Inc. The pressure readings should be taken simultaneously from different parts of the face.

SUMMARY OF IMPACT
There are several ways in which the newly developed mask (Fig. 24.4), will impact the study of burn treatment. First, physiological reactions vary with the degree of tissue damage, so it is possible that optimally applied pressure for recovery could vary with tissue damage. Since the capacity to correlate pressure-recovery relationships is entirely diminished without quantifiable data, these relationships are not obtainable with the current masks. In addition, if a physician prescribes a particular pressure to be applied, the Total Contact masks are incapable of satisfying the request. The newly developed mask, which measures interfacial pressures and outputs multiple pressure readings concurrently with a high degree of accuracy, addresses these issues. Second, there is a strong interest in identifying relationships between mask attachment designs and resulting applied pressure. Typically, masks are connected to the patient by elastic or Velcro straps. Currently, straps are connected in either four or five locations. Differences in applied pressures for different attachment configurations have not been developed. The newly developed mask will allow for further study of mask attachment configurations. Third, the effect of anatomical curvature and bone structure on applied pressure and localized pressure distributions is poorly understood. Pointy and rigid portions of the

Fig. 24.4. Pressure mask worn during testing.
face may undergo different mechanical stresses when compared to flat, fleshy portions of the face. The newly developed mask will also allow for further study of pressure distributions across different parts of the face.

**TECHNICAL DESCRIPTION**

The new system (shown in Fig. 24.5) is safe and comfortable for the patient. All wires run away from the patient, including those leading to the computer. All components in contact with the patient (more specifically, the mask and the pressure sensors) are biocompatible. Masks donated by Total Contact are reusable. The chosen Flexiforce sensors withstand exposure to isopropanol, which allows them to be cleaned and potentially reused. Reusability of the masks and sensors helped to keep design costs low.

The spatial arrangement of the sensors, which can be easily adjusted, allows for pressures to be evaluated on curved bone, flat bone and fleshy areas without bone. After two adhesive sprays were found to be incompatible with human skin, sensors were attached to the hard plastic and soft silicon masks by a combination of Scotch double sided tape and packaging tape. The non-sticky side of the packaging tape made contact with the patient.

The sensor is designed such that increased pressure results in a decreased resistance across the sensor. This variable resistance measurement process is appealing because the resistance is easily converted into a voltage using a circuit suggested by the manufacturer. Since the relationship between applied force and the algebraic inverse of the resistance (conductance) is linear, the circuit is designed such that the output voltage from the variable resistor is amplified and linearly related to the inverse of the variable resistance. An amplifying circuit using an inverting operational amplifier is utilized to accomplish this. The inverse operational amplifier converts an input voltage to an output voltage using the following relationship:

\[ V_{out} = -R_f \times R_v^{-1} \]

where \( R_f \) is a resistor with a constant value, \( V_{out} \) is the output voltage, and \( R_v \) is the variable resistance from the pressure sensor.

A DC-DC converter is used to convert the incoming 9 volt power supply from the wall adapter to -12 and +12 volts, from pin 1 into pins 4 and 7 respectively. These output voltages are used for the \( V_{cc} \) voltages in the amplifying circuit for the two quad amplifiers. Once the output voltage is amplified, it is sent to a DataQ device that converts the voltage into pressure and exports the data to the corresponding software. The Flexiforce sensor is found to be compatible with a DataQ instrument, which is, in turn, designed to interact with an available software package. The software allows for easy conversion from voltage to pressure. It also allows the user to record live data and save it as a spreadsheet that can be analyzed in Microsoft Excel.

To test the system, a known pressure was applied to a sensor, and the resulting output voltage was measured. This output voltage was then evaluated in the analysis software. The relationship between output voltage and pressure was tested for linearity, and shown to be approximately linear over the tested range between zero and forty mmHg. The cost of the project was $625. The system is reusable, so additional device costs should be negligible in the future, with the exception of repair costs.
INTRODUCTION
This project is designed to help three individuals who attend Gorman Elementary School. Currently, the classroom has a U-shaped table around which the children sit for their daily classroom activities. The height of the wheelchairs of the three clients is taller than the group table used by other students, and as a result they cannot slide underneath the table comfortably. Sometimes their knees bump into the table and cause minor bruises or scrapes. Their inability to slide their wheelchairs underneath the table limits their interaction with fellow classmates and group activities. The teacher finds it difficult to provide constant assistance as they are not able to reach the group table.

SUMMARY OF IMPACT
The newly designed multi-height table (Fig. 24.7) can be elevated to a height greater than the height of the arm rest of the wheelchair so that the wheelchair can slide underneath and the clients can rest their arms on the table. This encourages more interaction in the classroom activities. The new table top is able to tilt allowing our clients, who have a very limited range of motion and muscle control, easier visibility to their books. Also, the table has a cut-out space which helps in the positioning of the wheelchairs. After testing the table for a week, the client coordinator stated “We are enjoying the table very much”.

TECHNICAL DESCRIPTION
Telescoping legs built of galvanized steel are used for the legs of the design. A knob on the outer leg holds the inner sliding rod to a fixed height. Frictional wear and tear is very common for telescoping legs and thus provides a hindrance in height adjustment. In order to minimize this problem, an indented inner rod is used. An inclined articulating surface is used to provide tilt to the table top and an inner rod, which is both indented in the middle and curved at the end, is used to maximize the utility of the materials. A tilting bracket, fastened to the base of the tabletop with screws, articulates on the inclined inner rod with two pins. Triggering the bracket displaces the tabletop to pin two, tilting the tabletop downward. Releasing the trigger brings the tabletop back to the horizontal position.

Taking into consideration the accessibility of the table, a curved cut-out space of 12” deep and 20” wide is provided in the design. These measurements are based on the width measurements of the wheelchair and waist of the child. A 20” wide clearance is provided so children can easily slide into the table. Dimensions of the multi-height table are shown in Figure 24.6.

Safety was the main concern throughout the entire design process. In order to avoid abrasion caused by
sharp edges of the tabletop, the edges are covered with non-toxic, latex free cushion pads.

There are no weight specifications given by the client for the design of the table. Since the table is designed for students with very limited range of motion who are always fastened to their wheelchair, the team designed a lightweight yet sturdy table. In order to test the stability of the table, we placed free weights at the center of the tabletop. The adjustable legs were attached to the base of the tabletop at the centerline as well. The table failed to remain in a stable position with an applied load of 110 lbs. Therefore, it is highly recommend that direct forces beyond 80 lbs. not be applied to the table top for the safety of the operator and the children. Also, children should be supervised while the table is in use.

The total cost of this project was $660.

Fig. 24.7. Client Demonstrating use of Multi-Height Table.
INTRODUCTION
Low level light therapy (LLLT) is a field of research that is steadily becoming acknowledged and accepted by the scientific and medical communities for the benefits that it can bring to medical patients. LLLT uses different colors of LED light to heal wounds, aging lines, pain, acne and many other ailments. The products that are currently available on the market for this field of healing require the patient to sit in front of the device or hold the device over the affected area for a pre-determined period of time, possibly multiple times a day. The product being proposed is a LLLT mask (Fig. 24.8) made up of red LEDs placed at even intervals throughout a facial mask to cover the targeted area. The target area being considered for this project is the area encompassing the eyes from right to left across the face, one inch below the lower eyelid to just above the eyebrows. This allows the mask to serve multiple purposes: healing the area around the eyes after surgery, removing bags from under the eyes caused by fat and collagen buildup, removing “crow’s feet” from the edge of the eyes, and other purposes in the cosmetic surgery field. This mask is held in place by straps and allows the user to move freely about their normal lives during the treatment period, without being confined to a particular spot for the duration of the treatment.

SUMMARY OF IMPACT
The team designed a mask which delivers low level light treatment and therapy to patients using red LED lights in an effort to correct facial problems without requiring patients to remain in one position. The flexible mask that exposes the patient to controlled red LED light levels for their treatment allows the patient to continue with their day to day tasks during the treatment process. The mask is of a general shape and made of a clear flexible silicon material that will fit the majority of the population without significant changes being necessary. The system may be used both in clinics and in homes of patients, which complements busy on-the-go lifestyles. It should also be noted that this therapy technique has potential applications for multiple epidermal disorders including acne, aging effects, pain and swelling. The mask designed is safe to handle and use, and it allows the patient to maintain and sustain treatment without detrimental effects.

TECHNICAL DESCRIPTION
The final design meets each of the original design requirements. It is easily adjustable to different head sizes utilizing straps on the mask. The circuitry is contained within the mask and is secured by silicone gel which makes the mask waterproof. It is durable enough to handle multiple treatments, and the surface is easily sanitized with Clorox wipes.

In order to ensure the proper treatment time period, a timer is attached to the circuit to shut off the mask after the required time. The mask is battery operated with two rechargeable 9 Volt NiMh batteries to provide the required power to the circuit and the timer.

The LED light is not harmful to the user and the enclosed circuitry allows the mask to protect the user from any unexpected electric shock. The mask fits the majority of the population, in its final form, without requiring major changes. In order to produce a mask that fits the majority of the population, a pre-existing sleep gel mask was manipulated. This mask is already made to fit the majority of facial structures and adjust to multiple head sizes. Once the gel was removed, the cleared area provided a secure place for the circuitry and batteries to be housed.

The cost of this project was $725.
Fig. 24.8. Client Using Low Level Light Therapy Mask.
AUTOMATIC CAN CRUSHER

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Supervising Professor: Dr. Chandler Phillips
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INTRODUCTION
The goal of this project is to design a desk-height device to crush aluminum cans that can be operated by people with severe handicaps and physical limitations at United Rehabilitation Services (URS) of Greater Dayton. The Can Crusher also needs to count the number of cans that are crushed in each session, withstand minimal impacts, and be able to run for hours without overheating. It needs to have a push button method to start crushing and a collection area. It also requires some type of automatic loading device to make feeding the cans easier.

SUMMARY OF IMPACT
The device will be an addition to the manual can crusher already in place at URS. Some clients, that have cerebral palsy, have had a stroke or other neurological disorders, cannot use the manual can crusher. They have a very limited range of motion due to damage to the motor control centers of the brain. Other symptoms of these clients include abnormal muscle tone, reflex, or motor development and coordination. The clients can at times have spasms, other involuntary movements, unsteady gait, or problems with balance. By designing a simple to use can crusher, shown in Figure 24.10, the clients will be able to participate in activities just like others at URS.

TECHNICAL DESCRIPTION
One of the main engineering analyses performed was the force analysis of crushing a can. To find the force required to crush a can, force analyses along the vertical and horizontal axes of a can were completed. A force of 130lbs along the can’s vertical axis was found to be sufficient to crush the can. The force was applied using a linear actuator that, under full load, applied up to 400 lbs. force.

By using the linear actuator and a relay limit circuit (shown in Fig. 24.9), self-latching relay control of the crushing component’s travel is accomplished. The user pushes the button and as a result, the relay self-latches and the actuator travels forward crushing the can and hitting the first limit switch. This causes the actuator to travel back. The actuator then hits the second limit switch and as a result, the flow of current to the actuator is stopped until the process is repeated again.

The can crusher is considered to be very reliable. The actuator is powered by AC power, eliminating the need to charge batteries, and also eliminating the potential for batteries to die during a crush. The fuse system, wired between the AC power and the actuator, prevents an overload from blowing the actuator’s motor and an extra fuse has been
provided for URS. During trial runs, the can crusher was found to have minimal number of jams in the crushing area (as with any hopper system, jams will occur).

Based on the criteria given by the client, the crusher meets almost all expectations. The device crushes five to six cans per minute (greater than the required minimum of four). The individual using the product is unable to stick an appendage or body part into the crushing area during the crushing sequence, enhancing the safety of the device. The can crusher is equipped with two locking hinges that allow for authorized personnel to open the crusher to clear jams or other issues. The device is also very easy to use. The hopper is designed so that one individual loads the cans while the client operates the Can Crusher by pressing the “CRUSH” button. The hopper allows for up to 11 cans to be loaded at a time. The cans are counted electronically and can be reset with the turn of the key. This eliminates the manual counting of cans and allows for fast and reliable payment to the client after completion of the task. The Can Crusher counts when the can passes through the photoelectric beam located in the exit chute. The chute dispenses the cans into a bin making for easy clean up and collection. Due to time and cost limitations, no automatic loading device was developed.

The total cost of this project was $1,110.
SELF-ADJUSTING HARNESS FOR CHILD RESTRAINT SYSTEM

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INTRODUCTION
A study for the US Department of Transportation, National Highway Traffic Safety Administration found that 58.9% of forward facing convertible car seats exhibited loose harness straps. The objective of this project is to design a system that will reduce or prevent misuse of such seats by providing self-adjusting straps. Currently all commercially available child restraint systems must be manually adjusted. The system may also be used in conjunction with a wheel chair or other seating device utilizing a restraint harness.

SUMMARY OF IMPACT
By incorporating mechanical retractor driven by a 12V DC motor controlled by a microcontroller, the team was able to adjust the straps of a child restraint system (CRS) to a “safe yet comfortable” tension in a specified time period. The optimal solution, if time had allowed, would be to use a force sensor or load cell to detect the exact tension in the straps to comply with any child. The final prototype is a compromised system represented by the Hybrid III anthropomorphic test device. It is based on helping children that are on average 3 years of age and approximately 35 pounds.

TECHNICAL DESCRIPTION
Through integrated circuitry and use of mechanical components, the team designed a self-adjusting CRS harness system based on a readily available forward facing car seat to provide the utmost safety and comfort for the child. The device is shown in Figure 24.12.

Our design is composed of various materials, including a wooden base, a Graco car seat, various circuit components, and a steel retractor system designed using Solidworks. The entire system is approximately three feet long by one foot wide by three feet tall.

The first required specification is that the system created must automatically adjust the harness straps. This is achieved through the use of a BASIC stamp microcontroller. This device is programmed to adjust the straps to a tension of 2.2 lbs. in each of the harness straps (the “safe yet comfortable” tension in each shoulder strap according to the Transportation Research Center). The second required specification is that the system must incorporate a safety mechanism in case of malfunction. Should a malfunction exist, either system or user induced, there are two safety features added to prevent harm to the child using the car seat. First, a torque limiter is introduced as a coupling between the motor shaft and the retractor shaft. According to the device specifications, it disengages at four in-lbs. Through experimentation, it was discovered that the device would disengage after five seconds of tightening, reaching tension forces of up to 10 lbs. in the straps. Therefore, incorporating this torque limiter ensures that the child will not be harmed due to excessive forces. Second, an error subroutine is included in the microcontroller’s code to ensure that if both switches
are pressed, the system will fail to react. This is important, because if the microcontroller does not understand the input, it may cause the system to act in unexpected ways, which could potentially result in harm to the child.

The mechanical retractors, driven by a 12V DC incorporated into the design, produced the desired tension in only 3.9 seconds, and released the straps in 3.85 seconds. Therefore, the entire adjustment process lasts a total of 7.75 seconds.

The microprocessor is powered by a 9V battery. To tighten the straps, the red button is pushed. This causes a 5V pulse to be sent across pin three of the micro control which sets pin five to high. When pin five is set to high an LED within the opto-isolator is turned on. The light receiver, also within the opto-isolator, detects the LED completing the second circuit. The second circuit contains a transistor that amplifies a signal and turns on the relay that turns on the motor for 3.9 seconds allowing the straps to retract. Once the 3.9 seconds has elapsed the motor will stop and the microcontroller will then wait for another pulse.

To loosen the straps, the black button is pressed. This causes a 5V pulse to be sent across pin four which sets pin six to high. When pin six is set to high an LED within the other opto-isolator is turned on. The light receiver within the same opto-isolator then detects the LED completing another circuit. This is also connected to a transistor which amplifies a signal turning on another relay that reverses the polarity and allows the motor to receive the opposite signal than the first for 3.85 seconds which will loosen the strap. Once the 3.85 seconds has elapsed the motor stops and microcontroller will once again wait for a pulse.

The total cost of this project was $890.
KNEE EXTENSION DEVICE

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INTRODUCTION
A Pneumatic Muscle Actuator (PMA) is a very lightweight and flexible actuator, driven by compressed air, capable of producing very large forces. The modeling of PMAs in recent years has brought about a greater understanding of their functionality. Because of this, the inaccuracies of controlling PMAs that once plagued their development are now less of a burden. This leaves PMAs prime for development in their role as the force behind biomedical devices such as orthotic assists. The goal of this project is to demonstrate the effectiveness of pneumatic muscle actuators in an orthotic assist device. This project is focused on the implementation of a design to aid in knee extension for those with weakened quadriceps.

SUMMARY OF IMPACT
The device, shown in Figure 24.14, is able to provide 50% of the force required for knee extension as well as produce full extension of the knee while maintaining safe operation. A voltage controlled pressure regulator (VCPR) ensures the device is safely regulated. The design has been tested repeatedly and has shown no signs of fatigue or wear on the brace or PMAs. Since it is easy to repair, it is very low maintenance. Whether used in physical therapy for sports injuries or a nursing home for post-surgery rehabilitation, the pneumatic muscle knee extension device is capable of assisting anyone with weakened quadriceps extend their lower leg. This allows the person to slowly build the strength of their quadriceps and flexibility of their hamstrings.

TECHNICAL DESCRIPTION
The design consists mainly of parts acquired through donation, including two large PMAs and a used knee brace. On both the left and right lateral sides of the brace, a PMA is stretched over a central pivot and is attached to the top and bottom of the brace. Force balance investigations provided sufficient evidence that the design is capable of generating the required motion and force. The force analysis was confirmed after testing the prototype device. The first prototype design consisted of a commercial brace outfitted with a single PMA connected to an adjustable air compressor. Preliminary testing showed that even with only one PMA, the design had enough force to fully extend a team member’s leg. The second prototype was outfitted with two PMAs, one on each side connected by an airline. The device lifted a 95th percentile mannequin leg to full extension and did so at varying rates of extension.

Precision pressure control is provided through a voltage controlled pressure regulator (VCPR). The VCPR used in the final design is a Festo MPPE-3-1/8-6-010B. This device requires a 24 VDC power supply and a voltage control signal. This control signal is generated by taking a 10 VDC signal generated by the VCPR and feeding back some portion of that DC value to the proportional input of the regulator. If the whole 10V is given back to the regulator, the output pressure is set to roughly the full value of the regulator’s input pressure. If a value
less than 10V is supplied back to the regulator, the output pressure is set to the same proportion of the input pressure.

The device must provide safe extension assistance, which generally requires controllable, slow, smooth motion. While the controlling of the extension can be accomplished with a simple switch connecting and disconnecting the input voltage to the pressure regulator, this quick change in voltage can create rapid movements of the device. To change that dangerous step action of the switch into a smoother onset or offset, a single capacitor is placed in parallel with the reference voltage. The presence of this capacitor retards changes in voltage to the input. Furthermore, by varying the value of this capacitor, the time with which the device reaches full extension can be varied to suit a particular use.

The knee brace itself is a standard, commercially available knee brace, which is often used as a post-surgical restriction and stabilization aid. Because of the non-custom nature of the brace, the theoretical force limitations of the brace are unknown. However, the device was shown to support the weight of a mannequin leg, which represents 95% of males and the PMA force required to statically sustain such weight.

The PMAs are both 20 mm fluidic muscles from the Festo Corporation. As delivered from the manufacturer, these muscles are rated to withstand an excess of 120 psi. The PMAs used in the final design, however, include custom manufactured ends (Fig. 24.13), which are estimated to decrease the maximum pressure rating. Due to this modification, the PMAs were never loaded with more than 100 psi, but withstood this amount of pressure throughout several applications.

The total cost of this project was $1150.
SHOULDER STABILIZATION DEVICE

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INTRODUCTION

Total shoulder arthroplasty (TSA) has become the basis of therapy for many painful shoulder conditions after non-operative therapies have failed. Shoulder arthroplasty (shoulder replacement) may be necessary due to shoulder injury, rheumatoid arthritis, or osteoarthritis. Once the patient has received the total shoulder replacement, routine check-ups (after one year, five years, and beyond) are performed to identify complications, such as loosening, etc. A standard radiographic series which includes anteroposterior views of the shoulder and glenohumeral joint, a lateral “Y” scapular view, and an axillary view should be performed on all patients during the routine check-ups. Although x-ray images are helpful in detecting loosening, the positioning of the body for imaging of the shoulder is very uncomfortable to the patient. The discomfort of the patient results in patient movement, which results in blurring of the generated image. Since the images are not standardized, it is hard to determine loosening of the glenoid component from patient to patient. The goal of this study is to address these problems by designing a shoulder stabilization device that is comfortable for the patient and provides better standardized image quality.

SUMMARY OF IMPACT

The final design of the shoulder stabilization device (Fig. 24.15) completely resolves the issue of discomfort of the patient but only solves part of the problem of standardization. The device provides comfort to the patient while the patient is standing still to take the x-ray image by providing support for their arm. The support of the arm reduces movement during the imaging process which in turn reduces the blurring of the images taken. This does help in the standardization of the images in that it reduces blurring and places the patient’s elbow at exactly 90 degrees. Even though it does help somewhat in the standardization process, there is still a problem in the way the x-ray technician places the patient’s shoulder against the x-ray machine. The final design does not place the shoulder in the same position; only the arm and elbow are in the same position. The design provides an optimal solution to patient comfort and a compromised solution for standardization under the constraints of the project. With the new stabilization device, patients may be more likely to come back for
check-ups knowing that the procedure will be comfortable and painless. The device may benefit X-ray technicians by reducing the amount of time it takes to position the patient.

**TECHNICAL DESCRIPTION**

The shoulder stabilization device is a free-standing table for the patient to rest their arm during imaging. The table has a supportive base that can be moved to either the right or left side of the patient depending on which shoulder is being imaged. The swivel features of the arm rest provide for easy movement from AP Neutral x-ray position to the “True” AP x-ray position. The device does not interfere with the x-ray equipment or procedure, is easily fitted to the patient and is easily adjustable for different patients. The device accommodates patient heights ranging from 4'11” to 6'0”. The device is light weight and easy to transport (approximately 7.5 pounds).

The three forces applied to the top of the platform are the weight of the upper arm (18.56N), the weight of the forearm (11.07N), and the weight of the hand (4.28N) of an average 154lb. male. The device weighs 32.93N. Therefore, the normal force provided by the feet is 22.28N. A solid steel construction for the base with a Young’s modulus of 190-210GPa is chosen to provide more stability than aluminum and aid in the welding process. The platform is made of a solid wood construction with a Young’s modulus of 11GPa. The swivel component of the design is built using a Lazy Susan normally used in cabinetry. The specifications for the Lazy Susan indicate that it can hold up to 500lb, which is strong enough to support the expected weights determined in the aforementioned static analysis.

Finite element analysis was performed using SolidWorks and COSMOSWorks. Expected forces and construction materials were applied to the system to check for system failure and system deformation. Deformation and stresses were on the $10^6$ order of magnitude. Therefore, no major construction problems exist with the design.

The device is intentionally built to be lightweight and easy to move to prevent injury in case of a fall. The device also has three legs to provide stability and allow the user to stand right next to the device without stance interference. Soft materials for the platform and round edges are used to prevent injury caused by grabbing sharp edges, in case the user loses his or her balance.

The device has been raised and lowered many times and no problems have been encountered. Over time, the paint and height markings of the device may wear, but a glossy clear coat is spray painted onto the base to increase the paint life for as long as possible. Heavy duty vinyl fabric is used on the platform to prevent fabric wear.

Patients at Miami Valley Hospital varied in age from 58 to 85 years of age. The patients received total shoulder arthroplasties for varying reasons and have had check-up x-ray images taken to determine if loosening is occurring. A Java-based program called “ImageJ” was used to analyze the x-ray images received from Wright State Physicians. Plot profiles of the x-ray images (Fig. 24.16) were used to obtain the distance between the glenoid cavity and the humeral head component of the shoulder joint replacement by the number of pixels. Using this image analysis and the stabilization device to standardize the x-ray images, an automated system can be developed to allow physicians to quantify the liner wear rate over time.

The total cost of this project was $610.
FOOT-ACTIVATED TOY FOR AUTISTIC CHILD

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INTRODUCTION
Individuals with cerebral palsy can have difficulties performing activities of daily living. The condition itself can cause a multitude of different physical and mental afflictions. In several instances, a person with cerebral palsy has difficulty seeing and the inability to properly use their hands. Therefore, a child with cerebral palsy may require a means to activate a toy with a different part of their body, as well as a way to keep the majority of the toy’s activity within their range of sight. For our client, the most logical way to activate the toy would be by using his feet as shown in Fig. 24.17.

SUMMARY OF IMPACT
Our client has limited mental capacity, limited range of vision, and an inability to properly use his hands. Currently, he is in his preteen years. Our client uses a wheelchair, but is not able to operate it on his own. He also does not have an effective way to communicate with the rest of his peers. The client is also affected by vision impairment, which includes difficulty seeing objects from afar and the inability to look directly at objects. To compensate for this, the client will use his peripheral vision most of the time to view his surroundings. The objective of the project is to find a way to help our client with cerebral palsy enjoy the sights and sounds of a common toy by simply using his feet. The toy designed can be activated without the assistance of others, allowing our client more independence. The visual component of the device falls within the client’s range of vision, and the device assists the client in learning cause and effect.

TECHNICAL DESCRIPTION
A Playskool: Busy Gear toy is modified so that it can be controlled wirelessly by two foot pedals. An appropriate transmitter and receiver set is chosen to allow multiple signals to be transmitted at the same time, while having minimal outside signal interference. The toy operates using two different voltage sources: a nine-volt battery, which powers the motor and the receiver, and three AA batteries, which power the lights and sound components of the toy. The toy has a switch on the back of the device that controls the type of songs that can be played, as well as the length of each song. The switch offers three options. The first top option allows the toy to play a variety of songs that are 10
seconds each. The second middle option turns the toy off. The third bottom option allows the toy to play the song that is used for demonstrations, which lasts for about 17 seconds.

The table to which the toy can be attached has an adjustable height. The client also has the ability to change the position of the toy’s holding unit. The neutral position of the table is achieved when the table is at the lowest height and the toy holding apparatus is in the downward position.

The toy is designed to be used by a person that is either lying down (Fig. 24.17) or sitting in a chair (Fig. 24.18). There is a knob in the middle of the table that controls the position of the toy. If the person using the toy is lying down, then the table should initially be placed in its neutral position and the front legs of the table should be raised about two inches. This causes the front legs of the table to be higher than the back legs of the table.

There are two foot pedals, which have Velcro backings on the foot pedal board, so that they can be positioned wherever it is pleasing to the client. The foot pedals perform two different functions. One foot pedal triggers the motor of the toy, which causes the plastic gears to spin and the other foot pedal activates the lights and sound of the toy. The foot pedals can be pressed at the same time or in any desired order. However, the toy must finish an action before the same action can be performed, so there is some refractory period in which pushing the buttons will not result in any reaction from the toy.

The base (with sandbags) is to be used when the child is lying supine on the ground so that he or she may kick the pedals without causing motion. There are multiple sandbags, each weighing approximately seven to eight pounds. The client can add or subtract the sandbags based on how many they feel is necessary to keep the base from moving while the child is kicking. The use of smaller bags of sand allows for easier transportation of the foot pedal base. Therefore, lifting the bags separately makes portability of the toy easier than trying to lift all the weights at once.

The following factors were taken into consideration during the engineering analysis of the device. First, the table had to withstand enough weight so that if someone were to lean on it, it will not collapse or fall over. Second, the table and foot pedal base had to have rounded edges to prevent injuries to young children who might also be in the room. Third, the foot pedal base had to have enough friction to oppose any forces that the child might exert while lying on the ground. All of these factors were taken into consideration during the design process and were implemented successfully.

The total cost of this project was $650.
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