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ENGINEERING SENIOR DESIGN
PROJECTS TO AID PERSONS WITH
DISABILITIES

Edited By
John D. Enderle and Brooke Hallowell
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Edited By
John D. Enderle
Brooke Hallowell

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Welcome to the fifteenth 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 (BRAD) program of the Emerging Engineering Technologies Division of NSF, 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 describing these projects, entitled NSF 1990 Engineering Senior Design Projects to Aid the Disabled, was published. North Dakota State University (NDSU) Press published the following three issues. In NSF 1991 Engineering Senior Design Projects to Aid the Disabled, almost 150 projects by students at 20 universities across the United States during the academic year 1990-91 were described. 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.


This book, funded by the NSF, describes and documents the NSF-supported senior design projects during the fifteenth year of this effort, 2002-2003. Each chapter, except for the first five, describes activity at a single university, and was written by the principal investigator(s) at that university, and revised by the editors of this publication. Individuals wishing 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, writing about

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1 In January of 1994, the Directorate for Engineering (ENG) was restructured. This program is now in the Division of Bioengineering and Environmental Systems, Biomedical Engineering & Research Aiding Persons with Disabilities Program.
and working with individuals who have disabilities are also included in this book.

It is hoped that this book will enhance the overall quality of future senior design projects for persons with disabilities by providing examples of previous projects, and by motivating faculty at other universities to participate because of the potential benefits to students, schools, and communities. 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 that were built under this initiative is to assist individuals 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 was 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, 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, and Gil Devey, 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.

We acknowledge and thank Mr. William Pruehsner for technical illustrations, and Ms. Julie Lundy and Ms. Alexandra Enderle for editorial assistance. We also acknowledge and 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 editors 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 John Enderle 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, Enderle also served as NSF Program Director for the Biomedical Engineering & Research Aiding Persons with Disabilities Program while on a leave of absence from NDSU. He now serves as Director of the Biomedical Engineering Program at the University of Connecticut. Brooke Hallowell is Associate Dean for Research and Sponsored Programs in the College of Health and Human Services, Director of the School of Hearing, Speech and Language Sciences, and Co-Director of the Appalachian Rural Health Institute at Ohio University. Hallowell's primary area of expertise is in neurogenic communication disorders. She has a long history of collaboration with colleagues in biomedical engineering, in the areas of research, curriculum development, teaching, and assessment.

The editors welcome any suggestions as to how this review may be made more useful for subsequent yearly issues. 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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ENGINEERING SENIOR DESIGN
PROJECTS TO AID PERSONS WITH
DISABILITIES
CHAPTER 1
INTRODUCTION

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Devices and software to aid persons with disabilities often require custom modification, are prohibitively expensive, or are nonexistent. Many persons with disabilities do not have access to custom modification of available devices and other benefits of current technology. Moreover, when available, personnel costs for engineering and support make the cost of custom modifications beyond the reach 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) has enhanced educational opportunities for students and improved the quality of life for individuals with disabilities. Students and university 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 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 emphases of the program are 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 with a similar need. Examples of projects completed in years past include a laser-pointing device for people who cannot use their hands, a speech aid, a behavior modification device, a hands-free automatic answering and hang-up telephone system, and an infrared beacon to help a blind person move around a room. The students participating in this program have been richly rewarded through their activity with persons with disabilities, and justly have experienced 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 2002-2003.
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 effectively address 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, 17 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 the device modification is usually included. Next, a technical description of the device or device modification is given, with parts specified only if they are of such a special nature that the project could not otherwise be fabricated. An approximate cost of the project is provided, excluding personnel costs.

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 individuals with disabilities.

**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. Many call this the capstone course. Engineering design is a course or series of courses that brings together concepts and principles that students learn in their field of study. It involves the integration and extension of material learned throughout an academic program to achieve a specific design goal.

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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 a simple cause-effect relationship.

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 to help 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, and 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](http://www.abledata.com)
- (800) 227-0216.

More information about this NSF program is available at:

[http://nsf-pad.bme.uconn.edu](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.

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

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

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

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

**Electrical Parameters**
- Interfaces
- Voltages
- Impedances
- Gains
- Power output
- Power input
- Ranges
- Current capabilities
- Harmonic distortion
- Stability
- Accuracy
- Precision
- Power consumption

**Mechanical Parameters**
- Size
- Weight
- Durability
- Accuracy
- Precision
- Vibration

**Environmental Parameters**
- Location
- Temperature range
- Moisture
- 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 the 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 that often require a multidisciplinary system or holistic approach for a successful and useful product. This stage of the design process is typically the most challenging because of the creative aspect to generating problem 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, PSpice, a circuit analysis program, easily analyzes circuit problems. 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 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 should be analyzed and constructed with safety as one of the highest priorities. Clearly, the design project that fails should fail in a safe manner, a fail-safe mode, 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; thus, 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 also 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 then the project is given to the client. Ideally, the design project in use by the client should be periodically evaluated for performance and usefulness after the project is complete. Evaluation typically occurs, however, when the device no longer performs adequately for the client, and is returned to the university for repair or modification. If the repair or modification is simple, a university technician will handle the problem. If the repair or modification is more extensive, another design student is 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 required 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, such as OrCAD or AutoCAD.

The two-page reports within this publication are not representative of the final reports submitted for design course credit, and in fact, 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. Usually, photographs of the device are not included in the final report since mechanical and electrical diagrams are more useful to the engineer to document the device.
CHAPTER 2
BEST PRACTICES IN SENIOR DESIGN

John Enderle and Brooke Hallowell

This chapter presents different approaches to the design course experience. For example, at Texas A&M University, the students work on many small design projects during the two-semester senior design course sequence. At North Dakota State University, students work on a single project during the two-semester senior design course sequence. At the University of Connecticut, students are involved in a WWW 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 a grant from the National Science Foundation, and is offered each fall. The course size 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 insure 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 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 of 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 orientated 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 submit to interviews.

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

- Determine a product, name the company, and generate a market analysis.
- Determine the process for company name registration, 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.
- Students must meet with patent attorneys, real estate agents, and members of the business community, bankers and a venture capitalist.
- Students must fully understand the cost of insurance and meet with insurance agents to discuss health and life insurance for employees and liability insurance costs for the company. Students are required to explore OSHA requirements relative to setting up development laboratories. Students are expected to generate much of the above required information using direct person-to-person contact and the vast amount of information on the www.

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 presentations 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 accessing the problem, defining the needs, and making a decision as to whether or not they want 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 a 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 is the project and its technical specifications?
- Why is the project necessary?
- What technical approach is going 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 Engineering**

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. Texas A&M has participated in the NSF program for six years. 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 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, as well as pursue his or her own project. Each student is required to participate in the project definition session, which adds to the overall design experience. The meetings take place at the beginning of each semester, and periodically thereafter as projects are completed and new ones identified.

The needs expressed by the collaborating agencies often result in projects that vary in complexity and required 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. Projects are carried out by individual students or a team of two.

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 their project reports.

Throughout each phase of the project, the faculty supervises the work, as well as the teaching assistants assigned to the rehabilitation engineering laboratory. These teaching assistants are paid with university funds. 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. In addition to individual and team progress, the rehabilitation engineering group 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 be 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 project be revised and reworked until they meet faculty approval.

At the end of each academic year, the faculty 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 "opinionnaire" 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**

North Dakota State University (NDSU) has participated in this program for six years. All senior electrical engineering students at 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 disabled individual within 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 consists of an introduction to the project establishing the need for the project. The body of the report describes the device; a complete and detailed engineering analysis is included to establish that the device has the potential to work. Almost all of the NDSU projects involve an electronic circuit. Typically, devices that involve an electrical circuit are analyzed using PSpice, or another software analysis program. Extensive testing is undertaken on subsystem components using breadboard circuit layouts to ensure a reasonable degree of success before writing the report. Circuits are drawn for the report using OrCAD, a CAD program. The OrCAD drawings are also used in the second phase of design, which allows the students to bring a circuit from the schematic to a printed circuit board with relative ease.
During the second semester of the senior year, each team builds the device to aid an individual. This first involves breadboarding the entire circuit to establish the viability of the design. After verification, the students build a printed circuit board(s) using OrCAD, and then finish the construction of the project 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 receive 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 show. 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/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, waveform generator, oscilloscope, breadboard, and a collection of hand tools.

The second laboratory contains Intel 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 implementation stage. Analysis software supported includes Microsoft EXCEL and Lotus 123 spreadsheets, PSpice, MATLAB, MATHCAD, and VisSim. Desktop publishing supported includes Microsoft Word for Windows, Aldus PageMaker, and technical illustration software via AutoCAD and OrCAD. 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 in 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 were many projects constructed at NDSU (and probably at many other universities) that proved 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. This NSF project was a pronounced change from previous design experiences at UConn that involved industry sponsored projects carried out by a team of student engineers. The new Biomedical Engineering Program at UConn has now replaced the ESE Dept. in this effort.

To provide effective communication between the sponsor and the student teams, a WWW 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 conferencing, the WWW, telephone, e-mail, postal mailings, and videotapes.

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 (time-lines), 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 a disabled 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://design.bme.uconn.edu/.

The first phase of the on-campus projects involves creating a database of persons with disabilities and then linking the student with a person with a disability. The A.J. Pappanikou Center provided a database with almost 60 contacts and a short description of the disabilities in MS Access. The involvement of the Center was essential for the success of the program. The A.J. Pappanikou Center is Connecticut's University Affiliated Program (UAP) for disabilities studies. As such, relationships have been established with the Connecticut community of persons affected by disabilities, including families, caregivers, advocacy and support groups and, of course, persons with disabilities themselves. The Center serves as the link between the person in need of the device and the Design course staff. The Center has established ongoing relationships with Connecticut's Regional Educational Service Centers, the Birth to Three Network, the Connecticut Tech Act Project, and the Department of Mental Retardation. Through these contacts, the Center facilitates the interaction between the ESE students, the client coordinators (professionals providing support services, such as the speech-language pathologists, physical and occupational therapists), individuals with disabilities (clients), and clients' families.

The next phase of the course involves students' selection of projects. Using the on-campus database, each student selects two clients to interview. The student and a UConn staff member meet with the client and/or 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 involve 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 WWW based approach is used for reporting the progress on projects. Students are responsible for creating their own WWW 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.

Team Work
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. 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.

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, the two most essential

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11 Cottell, P.G. & Millis, B.J., Complex cooperative learning structures for college and university courses. In *To improve the Academy: Resources for*
determiners for success in teamwork are positive interdependence and individual accountability. Positive interdependence, or effective synergy among team members, leads to a final project or design that is better than any of the individual team members may have created alone. Individual accountability, or an equal sharing of workload, ensures that no team member is overburdened and also that every team member has 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 usually vital to success, eliminates most management issues, and allows the instructor to monitor the activities by student team members. For this to be a success, activities for each week need to be documented for each team member, with best success when there are five to 10 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. 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 time-lines 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 far too difficult, scheduling of team meetings was too challenging, they did not have the proper background, 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, completing a project according to specifications and on time, this approach lacked the important and enriching multidisciplinary team experience that is desired by industry.

NSF Projects Year 2
During the second year of the NSF senior design program, seven students worked in 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 would have three students working on individual projects, projects that required integration in the same way a music system required integration of speakers, a receiver, an amplifier, CD player, etc. In general, when teams were formed, the instructor would facilitate the team’s 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 student is required to update the timeline 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 that allows the course professor or instructor to gage project progress. This allows the instructor to determine over the “larger picture” if the student is falling behind at a rate that will delay completion of the project within the required due dates.

Also during the second semester, the student is required to report via the web on a weekly basis project progress. Included in this report are sections of their timeline that focus on the week just past and on the week ahead. During these meetings the instructor can discuss progress or the lack thereof, but more importantly the instructor can take mental
note of how the student is proceeding on a week-by-week basis.

**Theory**

The Senior Design Lab utilizes what is perhaps the most easily understood project-planning tool: the timeline. The timeline, or Gantt chart, 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. An example of a timeline showing concurrent tasks is shown in Figure 2.1.

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. With the timeline, by using time loading (resource management) a project manager schedules people and resources to operate at their most efficient manner. For example, optimum time loading keeps a machining center from being overloaded one day and then 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 should a task require more time than expected or if a design methodology turns out to be unsatisfactory with the result of new tasks being 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 out of 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 or 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 – higher detail allowing the project manager to follow the plan with greater 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 followed 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 manufacture 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 then publish his/her timeline and proceed to follow their 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/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 and on the WWW site. Weekly report structure for the WWW 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/or client coordinator uses the WWW reports to keep up with 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 WEB 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 was issued for a “Four-Limb Exercising
Attachment for Wheelchairs” and another patent has been allowed for a “Cervical Orthosis.”
CHAPTER 3
USING MEANINGFUL ASSESSMENT TO ENHANCE DESIGN PROJECT EXPERIENCES

Brooke Hallowell

Of particular interest to persons interested in the engineering education are the increasingly outcomes focused standards of the Accrediting Board for Engineering and Technology (ABET). This chapter is offered as an introduction to the ways in which improved foci on educational outcomes may lead to:
(a) improvements in the learning of engineering students, especially those engaged in design projects to aid persons with disabilities, and consequently,
(b) 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, and evidence that assessment results have led to improved teaching and learning and, ultimately, better preparation for entering the professions. 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.

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

Although what constitutes an "ideal" outcomes assessment program is largely dependent on the particular program and institution in which that program is to be implemented, there are at least


some generalities we might make about what constitutes a "meaningful" program. For example:

An outcomes assessment program perceived by faculty and administrators as an imposition of bureaucratic control over what they do, remote from any practical implications... would not be considered "meaningful." Meaningful programs, rather, are designed to enhance our educational missions in specific, practical, measurable ways, with the goals of improving the effectiveness of training and education in our disciplines. They also involve all of a program's faculty and students, not just administrators or designated report writers. Furthermore, the results of meaningful assessment programs are actually used to foster real modifications in a training program.15

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. Still, 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.16 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 (or 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 of 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 and 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, and by agreeing to develop outcomes assessment practices from the bottom up, rather than in response to top-down demands from administrators and accrediting agencies, current skeptics on our faculties 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
- demonstrate means by which certain assessments, such as student exit or employer surveys

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); and notice and reward curricular modifications and explorations of innovative teaching methods initiated by the faculty in response to program assessments.14

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 in particular 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 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 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-post tests to assess "value added",
- Design portfolios,
- 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.

We welcome contributions of relevant formative and summative assessment instruments, reports on assessment results, and descriptions of assessment programs, rubrics and pedagogical innovations that appear to be effective in enhancing design projects to aid persons with disabilities.

Please send queries or submissions for consideration to:

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APPENDIX: Desired Educational Outcomes as Articulated in ABET's “Engineering Criteria 2000” (Criterion 3, Program Outcomes and Assessment) 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 engineering problems

(f) An understanding of professional and ethical responsibility

(g) An ability to communicate effectively

(h) The broad education necessary to understand the impact of engineering solutions in a global and societal context

(i) A recognition of the need for, and an ability to engage in life-long learning

(j) A knowledge of contemporary issues

(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

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 accreditation19. 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.

19 Engineering Criteria 2000 (Criterion 3, Program Outcomes and Assessment)

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 probably varies widely 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: A) form and formatting, B) accompanying images, C) grammar, spelling, punctuation, and style, D) overall content, and E) 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 themselves.

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 and 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\(^\text{20}\). 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 on such flaws as grammatical errors, misspellings, and misuse of punctuation, and to 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**

As 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, is impractical or impossible for many instructors to handle providing 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.

It is the profound hope of the editors of this book that future improvements in reports submitted for NSF-sponsored publications will reflect instructors’ increasingly greater attention to the quality of student-generated writing. With continuously enhanced attention to the development of engineering students’ writing through improved foci on writing skills and strategic assessment of written work, all with interest in design projects for persons with disabilities will benefit.

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\(^{20}\) Ohio University Center for Writing Excellence Teaching Handouts [on-line] (2002). Available at: http://www.ohiou.edu/writing/3_Ls_of_Revision.htm
### 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 size type 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>
</tbody>
</table>

**Total points for form and formatting** /15

<table>
<thead>
<tr>
<th><strong>B. Images</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<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>
</tbody>
</table>

**Total points for images** /10
### 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 (e.g., &quot; 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>
<td>1</td>
</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>
</tr>
<tr>
<td>In lists, items numbered, with commas between them (e.g., “The device was designed to be: 1) safe, 2) lightweight, and 3) reasonably priced.”)</td>
<td>1</td>
</tr>
<tr>
<td>Consistent punctuation of enumerated and bulleted lists throughout the report</td>
<td>2</td>
</tr>
</tbody>
</table>

**Total points for grammar, spelling, punctuation, and style** | 15

### D. Overall content

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<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>
<td>1</td>
</tr>
</tbody>
</table>

**Total points for overall content** | 15
E. Section content

Introduction

Includes a brief description of the project in laypersons’ terms /4

Includes problem addressed, approach taken, motivation for the approach, a summary of usual or existing solutions, and problems with these solutions /4

Summary of impact

Includes a brief description of how this project has improved the quality of life of a person with a disability /5

Includes a quoted statement from an educational or health care specialist who supervises the client, or from a significant other /2

Includes a description of the project’s usefulness and overall design evaluation /5

Technical description

Clear, concise technical description of the device or device modification such that others would be able to replicate the design /10

Detailed parts lists included only if parts are of such a special nature that the project could not be fabricated without the exact identity of the part /2

Text refers to circuit and/or mechanical drawing of the device /3

Includes analysis of design effectiveness /5

Concludes with approximate cost of the project, including parts and supplies (not just the NSF’s contribution) and excluding personnel costs /5

Total points for section content /45

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 word-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. One classification scheme proposed by the WHO, the International Classification of Impairments, Disabilities and Handicaps (ICIDH) employs the general terms “impairment”, “disability”, and “handicap”, while a more recent scheme, the ICIDH-2, employs the terms “impairment”, “activity”, and “participation”, to refer to the various contextual aspects of disabling conditions one might experience. Health care 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 that it is essential to keep current regarding changes in accepted terminology.

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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. 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 course work and other educational experiences. Likewise, polite and constructive corrections of others using inaccurate language helps encourage more positive communication as well as more enabling positive societal attitudes, widening the arena for empowering persons with disabilities.
CHAPTER 5

CONNECTING STUDENTS WITH PERSONS WHO HAVE DISABILITIES

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23 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 disability 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 will 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 insuring 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, who holds the onus, and the ways that 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 phenomena 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 and/or family carry 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 “with the grace of God he/she overcame the disability.”

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 and a variety of factors are assessed in terms of barriers and or 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 their 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 very powerful and 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 they are, not for what they do or do 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 general guidelines on person first language, a keyword internet search will reveal many resources. For guidelines on writing, see Chapter 4.

**Assistive Technology and Universal Design**

Assistive Technology 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, and can include off the shelf items as well as special design. 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 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 replacement of 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 are available for review at www.design.ncsu.edu, The Center for Universal Design, North Carolina State University. Those basic principles provide the philosophical interface between functional limitations/disability and best practices in design. In fact, universal design principles can oftentimes 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, and cognition including memory. 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.

In order 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) and their Sports and Outdoor Assistive Recreation (SOAR) project along with the university’s Special Education program.

With this assembled team of professionals, we assigned specific duties 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/her family members, caregivers, 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 Figure 5.1. Overall, an individual with a disability was linked with a student engineering team to provide a prototype custom designed assistive device specific to his/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 their 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 multidisciplinary, meaningful, community service design projects,
- Provide persons with disabilities assistive devices to empower them to achieve the maximum individual growth and development and afford them the opportunity to participate in all aspects of life as they choose,
- Provide engineering students education and awareness on the special needs and challenges of persons with disabilities, and
- Provide undergraduate engineering students exposure to the biomedical field of engineering.

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

**Resources**

**Resources on Disability:**
The Family Village is a website maintained by the Waisman Center at the University of Wisconsin-Madison, http://www.familyvillage.wisc.edu/index.htmlx
The Library section allows individuals to search for specific diagnoses or general information on numerous disabilities.

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

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

Another valuable source is the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) http://www.resna.org/. This is a transdisciplinary organization that promotes research, development, education, advocacy and the provision of technology for individuals with disabilities. In addition, by using the technical assistance project link on the home page, one can then locate all of the state assistive technology projects and obtain contact information for their 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
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INTRODUCTION
A device has been designed to assist a person with a stroke in swallowing liquids. Individuals with dysphagia, a swallowing disorder, experience difficulty while swallowing due to damage of the muscles or nerves associated with the swallowing process. This device, which is essentially a straw with valving, assists the drinking process by delivering a small, specified volume of fluid, requiring the user to release negative pressure and swallow before another volume is delivered. The limited volume delivered prevents the patient from aspirating dangerous amounts of fluid. Similar devices on the market make use of a cup or container to deliver a specified amount of fluid. A cup, however, lacks versatility and may not work well for some individuals with muscle weakness or tremor.

SUMMARY OF IMPACT
This device will facilitate the drinking process for individuals with dysphagia, and it may enable them to regain control of the muscles associated with swallowing. It will also help prevent associated problems with dysphagia such as choking and aspiration of fluids.

The design is versatile. It is small enough to be used with most types of drink containers and may be transported effortlessly and discretely. It is simple to operate and clean, and it is made of durable components that can be safely used over a range of temperatures for drinkable fluids. There are two limitations of the design. The device is intended for use with fluids near the consistency of water and thin soups, but it will not operate effectively with thicker liquids. There is also a delay of approximately one second after negative pressure is released before another drink can be taken.

TECHNICAL DESCRIPTION
The device is a straw-like tube containing a dual check valve that controls the amount of fluid delivered and prevents backflow. The check valve tubing consists of two Delrin tube sections that screw together. Two small acrylic balls are contained within the tubing separated into two chambers by three small pins that protrude inward. The lower ball is a simple gravity operated one-way check valve which prevents hard-won fluid from flowing back through the tubing. The upper ball controls the volume of fluid delivered. When negative pressure is applied, the fluid flows upward through the tubing, carrying the upper ball with it. When it reaches a narrowing, it cuts off the flow. The volume of fluid delivered is approximately equal to the interior volume of the chamber. When the user releases suction to swallow, the ball sinks downward through the interior volume of fluid. A length of compliant Tygon tubing attached to the barbed upper end of the check valve provides a flexible interface so that the user can keep the upper end of the tubing within the mouth even if the cup moves because of tremor. Another length of Tygon tubing may also be added to the bottom of the Delrin tube, but is not required.

The primary design specification that required analysis was the volume of fluid that would be delivered with the application of negative pressure. The target volume was five ml. This volume is a function of the density of the ball within the check valve and the length of corresponding tubing. It is critical that the upper ball be made of material with a specific gravity slightly exceeding that of the fluid, and have a diameter only slightly smaller than the inside diameter of the tube. If the upper ball’s diameter is too small, the ball will not rise with the fluid; if it is too large, it will not sink through it to “recharge” the system. An analysis of forces acting
on the ball over small increments of time yielded the distance it was required to travel to deliver the appropriate amount of fluid.

Figure 6.1. Schematic of the Drinking Device.

Figure 6.2. Drinking Device.
INTRODUCTION
The Redesigned Computer Interface Device was developed for a client with a brain injury who has limited motor skills. The encouragement of the client’s independent control is necessary to continue the recovery process. Prior to the accident, the client spent much of his free time on the computer. While physically strong, his abilities vary, due to spasticity and high levels of muscle tone, especially in his hands and arms. In order to encourage the client to continue the physical recovery process, a computer interface device was specially designed.

This device was built to withstand the client’s exceedingly strong grip and to encourage the client to have a consistent gripping process. Existing computer mouse and assistive technology products are not designed to withstand uncontrolled, high strength muscle spasms, and do not encourage the use of a consistent grip.

SUMMARY OF IMPACT
With the Redesigned Computer Interface Device, the client can now access the computer and Internet. With the device, he now has some independent control over cursor movement and mouse clicks. Eventually, the device may have the desired effect of motivating the client to learn to control his hand movements and aid in the recovery process.

TECHNICAL DESCRIPTION
The Redesigned Computer Interface Device was designed to be 1) durable, 2) lightweight, and 3) oriented for the end user’s grip. A small computer mouse was purchased and disassembled to obtain computer compatible components. A new, prefabricated base for the computer mouse (complete with circuit, trackball, and cord) was designed, as well as a redesigned top covering. The top covering was machined from a solid block of Lexan for strength and was assembled with plastic adhesive. Also, plastic tabs, harvested from the original mouse, were used to firmly secure the top portion of the device to the base. The top covering was novel in shape, based on a quarter sphere (to serve as a rest for the palm). The flat surface served as a thumb rest. The large diameter and spherical shape prevented the user from exerting directly opposing forces, gave the user strong visual cues, and may be grasped with either the left or right hand. Stresses were distributed effectively, and the Lexan surface may be made quite thin except at the corners. Future improvements include an internal shock mount for the circuit board.

Cost for the device was $261.99
Figure 6.3. Computer Interface Device.
INTRODUCTION
The Golf Handbrace was designed for a client with hemiplegia who has a permanent shortening of the muscles in his right hand. This is a redesign of a prototype handbrace developed two years ago, which functioned properly, but caused sores to develop on the client’s hand. The redesigned orthotic brace enables the client to pull his hand back into a locked position, thus increasing his ability to hold and control a golf club with his right hand. Ultimately, the brace is designed to increase the client’s enjoyment of the sport.

SUMMARY OF IMPACT
An adult client diagnosed with stroke-induced hemiplegia, requested a new orthotic brace to help him play golf. His goal was to swing and control a golf club utilizing both hands. His right hand is contracted strongly in wrist adduction, so to swing a golf club with relative ease and to increase the length of his swing, it was necessary to design a device that temporarily pulls his right hand into a neutral position. This allows a club to be inserted into his fingers, and swung normally. It must also be released quickly after a swing to prevent pressure sores from developing. The brace is designed to be used with all clubs with different lengths, weights, and associated body positions. In addition for use while golfing, the brace could potentially be worn at night with light pressure to increase the flexibility in the client’s wrist.

TECHNICAL DESCRIPTION
The design incorporates three main components. The first is a Steplock hinge, made by the OTS Corporation. The hinge is designed with multiple locking points. The ratchet action from the hinge allows for nine different positions including a full 180 degree angle (neutral wrist angle). The second component is a neoprene glove made by the Bentek Co. The neoprene glove provides comfort to the customer without sacrificing durability and wear.
of the client’s hand. The Velcro strap that is sewn to the outside of the glove is pulled over the top of the plastic piece and is mated with hook component Velcro that covers the topside of the plastic piece. This Velcro strap sewn to the outside of the neoprene glove utilizes the shear strength of the Velcro, while the Velcro sewn to the back of the glove utilizes the normal strength of the Velcro.

When the client has secured his arm and hand in the brace, he then has the option to pull and lock his hand into nine different positions. The StepLock hinge works to the advantage of the client who requested that the brace should be unretracted while he is putting it on. Other design specifications include: 1) the brace must not create lacerations of the skin surrounding his thumb, 2) the hinge must be easily contracted and retracted without exerting a large amount of force or time, 3) the weight of the brace must not dramatically hinder or slow the swing of the client, 4) the brace must allow the client to grasp the club with his right hand, 5) the brace must pull the clients hand back to neutral, 6) the brace must remain comfortable through the duration of a round of golf, and 7) the benefits of the brace outweigh the additional weight, sweat, and expense in using it.

When the client has secured the brace and chosen a position of the hinge, he has the ability to swing and play, as he desires. The hinge can be retracted into a lower position for putting with a flip of a small lever. It can then be contracted back with a flip of the lever in the opposite direction. The client has used the device to hit 50 balls at a golf ball driving range. He suggests that the plastic be heated and slightly reformed to better fit the shape of his lower arm. He also suggests that a narrower piece of Velcro be added between his thumb and index finger. This additional piece would be used in addition to the piece on the outside of the glove to pull his hand back tightly against the plastic piece.

Many of the materials used for the Golf Hand Brace Design where donated by various companies. The StepLock hinge was donated by the OTS Corporation. Prosthetic Orthotic Associates in Scottsdale, AZ donated the labor, polypropylene plastic and Velcro. The overall cost of the remaining parts and materials totaled $125.
OFFERING A HELPING HAND: THIRD WORLD
PROSTHETIC ARM SOCKET INTERFACE

Designer: Jacob Hantla
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INTRODUCTION
There are an estimated 20 million amputees needing assistance in the world, of which approximately two million people could use a prosthetic arm or hand. Over the past decade, a project has been underway to develop an inexpensive, custom made prosthetic upper extremity device, made from materials that can be found around the globe, which can be fitted without the aid of a trained prosthetist. The arm, end-effector, locking elbow, and socket have already been developed and are undergoing testing. The socket-arm interface (SAI) has not been studied to the same extent. The SAI is designed here to improve the connection between the fiberglass-epoxy socket and a PVC tube used to replace the upper arm or forearm.

The resulting prototype device is a single piece of PVC (machined here, but more practically molded) that provides a secure and reliable means of attaching the socket to the tube. This interface piece was considered necessary as an improvement to previous models because the prior versions of the SAI did not have the strength required to maintain the connection between the socket and the arm over extended periods of hard use.

SUMMARY OF IMPACT
Prior work and worldwide surveys with prosthetists have indicated that a low cost prosthesis made of PVC components, which can be replaced by bamboo or wooden components, would be well received. More recent interviews with medical doctors and other healthcare professionals in a Mexican have confirmed that the majority of the arm prostheses available: 1) are too expensive, 2) are not functional, and 3) are subject to very limited availability. By making the SAI of readily-moldable PVC, the low cost of the prosthesis is maintained. The SAI is both strong and easy to install. Both of these characteristics enhance the overall functionality of the prosthetic arm. The low cost of the prosthetic arm will facilitate widespread distribution. As a result, it is hoped that worldwide aid organizations can make large quantities of the arm available to amputees.

TECHNICAL DESCRIPTION
The socket-arm interface, designed for compatibility with the existing ASU Arm, measures approximately three inches high and two-and-a-half inches wide at its widest point. The SAI is designed to press-fit on the distal end into a standard three-quarter inch section of schedule 40 PVC piping. In
the event that PVC pipe is not available, a second attachment mechanism has been provided for. A 3⁄8 inch hex bolt can be inserted flush from the proximal to the distal side in the SAI. The hexagonal hole into which it is inserted holds the bolt in rotation so that a nut can be easily secured on the distal end. This can allow connection to other tubular arms made of other materials, which may not facilitate a press-fit connection.

The proximal end is designed to be wrapped within casting tape and glued in place when it is impregnated with epoxy resin. In order to accommodate users with a variety of stump sizes, the proximal section is thinned significantly, so that it is inherently flexible. Longitudinal slices in the proximal portion of the SAI create “tongues” which can be cut to shape and wrapped under the fiberglass casting tape. It is estimated, using finite element analysis, that the device can accommodate an increase in circumference up to two-and-one-quarter inches. According to interviews with prosthetists in the Phoenix area, this would be sufficient to fit the vast majority of people needing prosthetic arms. Once developed into prototype form, however, this size appears to be too small.

The bowl-shaped section is thick at its base allowing minimal flexibility and maximum support, and gradually thins to one-thirty-second-inch as it reaches the rim of the bowl. This thin portion offers maximum flexibility while still distributing the load over a larger area, minimizing stress. To increase its flexibility further, it should be made with a deeper bowl and transparently thin sides, but this cannot be accomplished with machining processes. In actual production, molding can accomplish very thin sections, and is recommended for mass production.

The final cost of parts and materials for the prototype, which was machined from a solid block of PVC, was approximately $40.
METACARPO-PHALANGEAL THUMB SPLINT

Designer: Jamie Berger
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INTRODUCTION:
Bursitis of the thumb is the inflammation of the bursa, a small structure inside every joint that helps to lubricate and cushion it. The bursa can become irritated due to overuse with repetitive motion or strenuous activity. Immobilizing the joint in a thumb splint is one way the pain can be assuaged. One particular client has bursitis of the thumb in her metacarpo-phalangeal joint, commonly called the “knuckle joint,” and was unsatisfied with the quality of the thumb splints available in the current market. Typical thumb splints in the existing market addressed this condition by immobilizing not just the metacarpo-phalangeal joint, but also the second joint in the thumb and the wrist as well causing the user’s hand to become cramped and uncomfortable. In addition most devices were large, cumbersome, unattractive, and didn’t allow for normal gripping of objects because the tip of the thumb was covered with very thick, bulky material. The objective of this project was to design and develop an innovative product that immobilized the metacarpo-phalangeal joint while addressing the aforementioned concerns, and would meet the needs of the client with bursitis as well as the larger market for thumb splints.

SUMMARY OF IMPACT:
When the client tested out the Metacarpo-Phalangeal Thumb Splint she found the product very satisfying compared to other thumb splints she has tried, but stated that additional concerns need to be met before the device is ideal. The following statement depicts the client’s evaluation:

“When I first tried to put on the thumb splint it was somewhat difficult and I had to get someone to help me put it on. While this was not that big of a deal I am still concerned that I will have trouble putting it on when I am in a situation with no one around to help me. That being said, once the splint was on I felt a dramatic difference in the way the thumb splint felt. It was very comfortable and attractive.
circulation somewhat. It was not overly uncomfortable, but if this problem could be addressed it would greatly improve my appreciation of this device.”

This project is considered to be a success in that many of the deficiencies of current thumb splints were addressed and solved with this device. The uncomfortable fit of the thumb is something that could easily be fixed by adding a buckle strap that would relieve some of the pressure. However, because of the streamlined design, more pressure is needed in this area than was needed in other thumb splints because the device does not rely on the rest of the hand to support it. In addition, the device is difficult to put on with one hand because of the same reason. Minimizing the area of the hand used to support the device makes it smaller and more difficult to control when putting it on. This concern could be solved by installing a buckle strap around the wrist. This buckle would allow for the strap to be looped around the wrist and then adjusted for fit.

**TECHNICAL DESCRIPTION**

A thermoplastic strip for the rigid thumb support is used. The length of the thumb support measures from just below the carpal joint to just above the second joint. The thumb support is bent at 10 degrees and tapers toward the interphalangeal joint.

There are two adjustable Velcro straps: one around the wrist and another around the base of the proximal radioulnar joint. The material of the glove portion is composed of BioSkin. Ventilation is built into the design by exposing the palm of the hand as much as possible, providing a breathable mesh support around the back of the hand.

The prototype is produced by first cutting out the thumb support, then filing smooth the edges. Two bends are performed sequentially: a longitudinal bend to produce a slight “U” shape, and a bend perpendicular to the axis to provide the 10 degree bend. These are produced by creating bending forms, designed to create the right shape consistently. Even with the bending forms, it is difficult to form the plastic thumb support with a heat gun so that it conforms to the shape of the user’s thumb. A better option would have been to design an injection mold so that the thumb support dimensions would better conform to the intended design. The rest of the elements of the design work smoothly to accomplish the intended goal of immobilizing the metacarpo-phalangeal joint of the thumb.

The total cost of the product was $222.75.
DAY SPLINT FOR AID WITH PLANTAR FASCIITIS

Designer: Jason C. Wilson
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INTRODUCTION
A splint was designed to aid with plantar fasciitis, a condition that causes pain and inflammation in the heel of the foot. This splint was designed to be worn during the day by a person who works in an office setting. The Day Splint pulls the foot upward, exerting a mild and steady dorsiflexion moment. Over a long period of time, it is hoped this will stretch the tendon and eventually reduce the inflammation and pain associated with plantar fasciitis.

SUMMARY OF IMPACT
The client has difficulty functioning day to day without experiencing severe pain in the heel. The client found that stretching of the Achilles tendon and physical therapy provides some relief. The client wears the Day Splint to provide less pain while sitting behind her desk at work during the day, and for a few hours after work.

TECHNICAL DESCRIPTION
The Day Splint pulls the foot upward in dorsiflexion so that the Achilles tendon can be stretched. The Achilles tendon is shortened which causes a heel spur and inflammation. The inflammation appears to be relieved by stretching the tendon. The Day Splint provides the stretch without bending the midfoot by providing a rigid aluminum footbed, which is pulled upward by adjustable nylon straps.

The specifications for the design include that the device be: 1) lightweight, 2) portable, 3) easily adjustable, 4) demanding of little effort to put on and take off, 5) compatible with a variety of shoes, and 6) unobtrusive to wear behind the desk.

The Day Splint consists of a series of flat and tubular one-inch nylon webbing straps connected to D-rings that are secured to an aluminum foot-shaped plate. The nylon straps have buckles incorporated to allow for adjustment to put on and take off the device. The nylon straps are secured using Velcro and are easily adjustable when needed. The device is donned by placing the foot flat on the aluminum plate, securing the strap around the calf, and securing the strap over the top of the foot. Once the device is secure, the two main straps can be pulled tight to pull the foot into dorsiflexion and secure using the Velcro closures.

To make sure the strap around the calf does not slide down the leg, flat brass rods of half-inch by one-sixteenth cross-sectional dimension are inserted into the tubular straps running length wise down the leg to the aluminum plate. The brass is sturdy enough that it does not buckle easily. The brass rods are riveted to the nylon webbing. The edges of the nylon are fused to reduce fraying over a length of time.

Tests were performed to ensure the Day Splint’s strength and durability. To test the joints where the rivets held the nylon and brass together, two sample pieces of nylon were riveted together and pulled to failure. The force at failure (25 pounds) significantly exceeded the maximum force that could be exerted by the client. The quarter-inch cast aluminum plate, originally produced as a vehicular gas pedal, was not tested for durability but is not expected to fail.

The total cost of the Day Splint is approximately $60 in parts and materials.
Figure 6.9. Splint for Aid with Plantar Fasciitis.
INTRODUCTION
The MP3 Player Interface was developed for a client who loves music, and was born with spinal meningitis. This condition resulted in the loss of neurological pathways as well as partial blindness and an inability to perform fine motor movements. While the client would like to operate the controls of a portable MP3 player, she is unable to locate and gently press the small, fragile buttons. A mechanical transduction device was built to house the MP3 player and external speakers, and enabled the large motions of her hand and fist to operate the controls.

SUMMARY OF IMPACT
The design of the MP3 player is catered to individuals with limited motor movements. Such individuals are unable to operate many controls and devices because of their gross motor movements. This device augments the buttons required to activate the MP3 player and allows the user to operate the device with her specific abilities. The user operates the MP3 player through activating the enlarged buttons. Without the device the user would not be able to control music choices. The MP3 interface allows the user to operate the RCA RD-1060, a commercially available MP3 player.

The MP3 player interface has been tested by the designer and the client. The user responded positively to learning the functions of the different buttons. She is able to activate the buttons and to select the song she prefers. The client distinguishes between preferred songs and songs that she would rather skip.

TECHNICAL DESCRIPTION
The design evolved around the selection of the MP3 player. The RD-1060 was selected because of its ideal geometric relations. All of the main buttons activate the device from the top, which facilitated the design of a mechanical system to activate these buttons. The device protects the RD-1060 from crush and shock, and has fully rounded edges to decrease the risk of user injury.

The device is fabricated out of conventional ABS plastic. The designer selected ABS because it is easy to machine, economically ideal, and durable. Plastic was also considered due to the relatively low stresses that are characterized by the device. The
only components that are exposed to any significant level of stress are the force limiting lever arms, which can transform the user’s fist punch into a delicate finger press. Made of ABS, the long lever aspect ratios enable the beams to bend easily, which limits the force applied to the RD-1060 and reduces the bending stresses. Displacement is also limited. As a result, the device is anticipated to function over many thousands of cycles.

The essential design are that: 1) the client must be enable to interact with the activating mechanisms inside the box, 2) the user buttons must be greater than four square inches, 3) the force required to activate the buttons must be less than five Newtons, 4) the activation of buttons must respond quickly to promote user conditioning, 5) the box should be lightweight and portable, 6) the components should be easily assembled or disassembled to facilitate repairs, 7) the device should not cause any potential harm to the user in any manner, and 8) the only moving interfaces of the device will be limited to the four buttons that activate the MP3 player.

The MP3 player interface is developed from 23 manufactured components as well as necessary hardware. The conversion mechanism featured by the device is similar for each of the four buttons. It consists of a large button that is press-fit with a hollow shaft. The button and shaft is then inserted into the top of the device. A two-inch spring inserts in the hollow shaft and an e-clip slides around the shaft to prevent the button from falling out of the top of the device. The force reducing lever arms consist of three components: the lever post, the lever arm, and the lever plate. The lever arm assembly attaches to the inside of the top of the device by using two screws. The screws are inserted into predrilled holes and tapped into the machined components. These lever arms actuate the device, and their durability is expected to outlast the life-span of the MP3 player.

The device stands alone, houses the MP3 player and speakers, and is self-contained. The augmented buttons control the stop, play, fast forward and rewind buttons of the device. This allows the user to power the MP3 player, scroll through music, and choose songs to play.

The final cost of the finished MP3 player interface was approximately $95, excluding labor and machining costs.

Figure 6.11. Details of the Force-Reducing Lever.
INTRODUCTION
A daily assistance doorknob-gripping device was designed for a client with diminished grip strength due to rheumatoid arthritis. The assistance device enables the client to grip round doorknobs and turn them by converting the twisting motion involved in opening spherical doorknobs to a levering action. The device is a compact, portable design that allows the client to carry it in her purse for use at offices, stores, and at other facilities equipped with round doorknobs.

SUMMARY OF IMPACT
A client with rheumatoid arthritis experiences difficulties in grasping small objects due to pain and diminished grip strength. This lack of grip strength makes it difficult for her to grasp round doorknobs with sufficient grip pressure to turn the doorknob and open the door.

The Doorknob Gripper is designed to convert a relatively open palmar grip accompanied with pronation/supination, into a more comfortable grip size. Rotation of the doorknob is accomplished via leveraging rather than pronation.

TECHNICAL DESCRIPTION
This design is a two-tong assembly with a pre-fabricated ergonomic rubber handle for an easy handgrip. The tongs are positioned in a Y-shaped configuration, with each tong at +/- 22.5-degree angles from the handle’s centerline. This allows a fast and snug fit over various diameter doorknobs. The one-inch wide tongs are rubber coated to increase the coefficient of friction and decrease slippage between the doorknob and the tongs. The device is placed over a round doorknob, with the inside opening of the Y facing the knob. The client then pushes the opening of the Y onto the door handle, making contact with each arm of the Y, and pulls or pushes upward on the handle to turn the knob. The simplicity of the design facilitates placement in other, potentially more comfortable orientations.

The primary design specifications included: 1) the device is lightweight and portable, 2) the device fits a wide variety of round doorknobs, 3) minimal handgrip strength is required to use, 4) the device converts a twisting motion into a lever action, eliminating the need to pronate the forearm, 5) the device is easy and convenient to use, 6) the tongs provide a high friction/no slip region and are wear resistant, and 7) a large, ergonomic handle surface is incorporated into the device.

The Doorknob Gripper is comprised of three separate assemblies. A “Y” shaped Delrin substrate forms the base portion of the device. A prefabricated ergonomic Oxo-Goodgrip handle press fit over the stem of the Delrin base. The tong assembly of the “Y” shape substrate is rubber coated with...
rubberized vinyl. The vinyl coating increases the static coefficient of friction between the tong assembly and the doorknob interface from about 0.3 to greater than 0.9 (when clean). The inside notch of the Y is radiused to produce a more gradual tapering of the arms. This distributes stresses better and extends the life of the device.

The Doorknob Gripper has been tested on various sizes of doorknobs and various ranges of doorknob torques. The device performed superbly in all situations and in no situation did it fail to open a round doorknob. Situations such as dirty or greasy doorknob surfaces may cause a problem in operation for the device. Fouling of the rubberized tong assembly with accumulated dust will also reduce its effectiveness temporarily, but this can be easily cleaned. In cases of wear, the tongs can be recoated.

The final cost of the Doorknob Gripper is approximately $36.40. This cost includes a block of Delrin that the base substrate was milled from, the Oxo-Good Grip Handle, and the rubberized vinyl coating.

Figure 6.13. Doorknob Gripper in Use.
INTRODUCTION
A step and rail system was designed for a child with cerebral palsy and hydrocephalus. The client needed assistance from his mother to use the toilet. The device enables the patient to use the toilet without assistance.

SUMMARY OF IMPACT
The patient desires more independence and privacy while using the toilet. This device enables the patient to get onto and off of the toilet independently, through the use of a step and stabilizing handrails.

TECHNICAL DESCRIPTION
This device incorporates the use of a step with supporting rails. The device can be disassembled into three pieces for portability. The pieces include two handrails and the step. The rails fit tightly and concentrically into nylon bushings mounted within two of the legs which support the step. At the ends of the rails there is a slot that slips over pins in the legs, which keep the rails from rotating while the device is assembled. The other end of the rails are designed to rest on the floor and against the wall behind the toilet to ensure the device does not slide backward while in use. The legs are fitted with adjustable feet with skid resistant washers added to ensure stability on a wide range of surfaces.

The primary design specifications included: 1) the device must be safe to use, 2) the device must assist the patient in using the toilet without human assistance, 3) the steps on the device must be small, 4) the device will be portable, 5) the device will be universal for use with most toilets, 6) the device must be durable, 6) the device will have rails to support the weight of the patient, 7) the device will not impede normal use, and 8) the device can be easily stored.

The device is made from 6061 aluminum with the exception of the following: 1) the adjustable feet, 2) skid resistant washers, 3) stainless steel pins, and 4) nylon bushings. The sheet aluminum for the step is designed to be a quarter-inch thick in order to withstand more than five times the weight of the intended user. The aluminum rails are one-inch diameter with one-eighth inch thick walls in order to withstand the given weight loads. The intended user weighs approximately 35 pounds, and the device withstood testing involving a 245 pound man.
Figure 6.15. Bathroom Assistant in Use.
INTRODUCTION
A writing device was designed for a client with lymphedema in her right arm. She has difficulty holding a pen and moving her arm simultaneously, and requires the use of her left arm to support her right arm while writing. The act of writing is laborious and painful.

SUMMARY OF IMPACT
The device allows the client to write without pain in her hand, arm or shoulder and improves her handwriting. The device allows the client to write without assistance, and without using her left hand to support her right arm. The device was designed specifically for use with lymphedema but could potentially be used as an aid for arthritis.

TECHNICAL DESCRIPTION
The Handwriter Helper is essentially an armrest which helps the client to stabilize a pen, and slide her right forearm across a horizontal writing surface with minimal friction. This design incorporates a forearm piece made of T6061 aluminum that extends underneath the hand piece made of Delrin. The pen rests comfortably in the hole of the hand piece allowing the client to rest her pointer finger and middle finger around the pen to give the illusion of holding the pen without having to have the strength.
or movement to do so. The hand piece is ergonomically shaped similar in dimension and feel to a computer mouse. The client is able to move the hand piece in the shape of any letter as the tip of the pen protrudes through the bottom of the device and makes contact with the writing surface. Letters written by the client with the device are more legible than letters written without the device.

A small section of the hand piece is cut out to allow the client to see what she was writing. Plastic slides are placed on the bottom of the device to reduce the friction and allow the device to move easily over almost any surface. Any type of pen can be used since the washer that secures the pen is adjustable and the pen can be changed at any time.

The primary design specifications included: 1) the client must be able to write with less discomfort, 2) the device must support the forearm, wrist and hand, 3) the client must be able to use the device without causing pain or adding stress, 4) the device must be lightweight, 5) the client should be able to use the device with little or no help from others, 6) the device should be able to be used over compression sleeves and clothing, 7) the device must be comfortable, 8) the client must be able to write better using the device, and 9) the device must be aesthetically pleasing to the client.

The device was fabricated with the assistance of The Tech Group of Tempe, AZ.

Figure 6.17. Handwriter Helper.
CHAPTER 7
DUKE UNIVERSITY

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ADAPTED BASEBALL GLOVE

Designers: David Chong and Billy Watson
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INTRODUCTION
A nine-year-old boy was born with a shortened radius, and his index finger was surgically moved to replace his missing thumb. His right arm and hand have approximately one-half the strength of the left side. He enjoys playing baseball, but the gloves he previously used limited his playing ability. The gloves were either too small or too difficult to close. An adapted baseball glove was created that is easier to close and relatively lightweight. This was accomplished by modifying a commercially available Wilson EZ-Catch glove, adding a V-flex notch, extending the Velcro strap, and including an aluminum extension for his thumb.

SUMMARY OF IMPACT
The glove improves the client’s ability to catch, while having a normal appearance. With the new glove, the client is able to make one-handed catches, which he could not do with either of his previous gloves. His ability to close the glove is markedly improved, and he likes the look and feel of the glove. His mother said, “He is using it now for spring baseball and it really helps. It has fit into his life very smoothly, and he has just improved in skill and in confidence. He doesn't even really think of it as a help anymore! It's great that he feels that way, and that he's not wearing a brace for stability.” The client said, “It definitely helps and it’s very comfortable.”

TECHNICAL DESCRIPTION
An existing glove was modified instead of creating a new one, so the final product would look as normal as possible. Several different commercially available gloves were examined, and it was decided to combine features from each into one glove. The Wilson EZ-Catch (Figure 7.2, left panel) was chosen as the base glove for modification. It had an increased catching area, and by hand-testing, it was the easiest to close of all the gloves. It also had only three finger stalls, as the design called for the third and fourth finger to be used in one stall for more power. This feature worked out well, since the client had three fingers.

The V-flex design of Mizuno youth gloves were incorporated into the base glove, using a slightly different cut, as shown in the left panel of Figure 7.2. A cut at the client’s natural hinge was optimal for increasing flexibility and closing the glove. His hand was relatively small, and the existing Velcro strap did not close the glove enough to secure his hand. Thus, an additional piece of Velcro was attached to the glove to allow tighter binding of the Velcro strap, as shown in the center panel of Figure 7.2.

To allow the client’s relatively short fingers to reach further into the stalls, finger extensions were created. After testing several prototypes of varying hardness and lengths, it was determined that

Figure 7.1. Client Demonstrates Adapted Glove.
aluminum offered the best combination of light weight and strength. Small, rectangular sheet aluminum strips were rolled into cylinders, and the top was flattened to slip into the glove easily. Trials were performed with different combinations of finger extensions of the client’s fingers and thumb. The finger extensions added a measure of stiffness that could hinder the flexibility of the glove. The best solution was a slightly bent aluminum extension for his thumb only (Figure 7.1, right panel). Foam padding was added for comfort and safety.

The cost of parts and material for the Adapted Baseball Glove was approximately $37.
CONSTRAINT INDUCED MOVEMENT THERAPY DEVICE

Designers: Kyle Smith and Lynn Wang
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INTRODUCTION
The goal of Constraint Induced Movement Therapy (CIMT) is to encourage clients with hemiplegia to use their affected arms by restraining their healthy arms. This therapy has been shown to provide significant improvements in some clients. Currently, patients undergoing CIMT at a client facility wear a device for three weeks, 24 hours a day, in an outpatient treatment. The Delta-Cast is a polyurethane resin cast with Velcro straps that is formed around the patient’s elbow, forearm, and hand. This device has two major shortcomings. First, Delta-Casts do not cover the fingertips, so some patients use their unaffected arm and negate benefits of the therapy. Second, Delta-Casts must be custom made for each patient.

A novel device for CIMT in children with hemiplegia was developed. The device immobilizes the fingers, hand, wrist, and elbow of the child’s unaffected arm, forcing use of the affected arm. It easily adapts to children with different sized arms, and is re-useable. The device is relatively inexpensive, comfortable, attractive, and easily constructed from commercially available products.

SUMMARY OF IMPACT
The CIMT device meets its functional objectives while being inexpensive, easily reproducible, adaptable to a wide range of potential clients, and easy for parents and clients to use. Therapists do not need to be specially trained to use this device, and customizations made to the device can occur during client fitting and client/parent education. Once constructed, the device easily adjusts to fit a range of different arm sizes. The hospital can purchase two or three hand splints for both the right and left hands, allowing CIMT devices to fit a wide age and size range. This device should reduce the cost of CIMT therapy because it can be re-used, and requires less therapist time to assemble and fit.

TECHNICAL DESCRIPTION
The three components of the CIMT device are: 1) elbow brace with elbow flexion/extension restraint, commercially purchased and modified with a small aluminum stay to fix its angle at 135 degrees, 2) commercially purchased hand splint made of a malleable aluminum frame with a removable lining, and added Velcro supination/pronation straps, and 3) stretchable sleeves to enclose the device for aesthetics. Each component is durable and easy to put on; straps used with the hand splint are color coded to ensure correct strap direction.

The device uses an adjustable commercial hand splint to increase the range of clients’ fit and to provide the ability to order additional sizes to fit different ranges. The orientation of the straps on the commercial hand splint allows the supination/pronation restraint and the hand restraint to be merged into one unit. The supination/pronation straps are two-inch wide
Velcro extensions of the hand splint straps that wrap around the forearm in opposite directions and attach to the Velcro-sensitive elbow brace. Neoplush placed between the Velcro straps and forearm prevents abrasion.

The sleeve of the device is adapted from arm warmers used by bicyclists in cool weather. One of the sleeves is made of CoolMax, which is available in a range of sizes and colors; children may also decorate their own sleeves because of its low cost.

Cords threaded through the seams on both ends act as drawstrings. The lower drawstring is permanently cinched and tied to prevent its opening. A cord lock on the upper drawstring holds the drawstring tight, preventing the patient from removing the sleeve and thereby potentially removing the device. A knot can be tied for further restraint as necessary.

The cost of parts and material is approximately $120.

Figure 7.4. CIMT Device Components. Hand Splint (top), Elbow Brace (bottom) and Two Sleeves.
HEAD AND NECK SUPPORT

Designers: Diana Hsu and Elizabeth Strautin
Client Coordinators: Mark Pennington, Claudius Parker and Cassandra Rooke
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INTRODUCTION
An adult client has quadriplegia due to injuries sustained in a car accident. As a result of his injuries and gradual weakening of his neck muscles, his head leans to the right side of his body. This unnatural position of his head has caused much upper back and neck pain. A supporting headpiece was devised that raises the client’s head to an upright position. The headpiece, which attaches to the client’s wheelchair, supports his forehead and provides a wide range of adjustment, so his therapists can move his head to an upright position at a comfortable pace. The device reduces the pain in his upper back and neck, and also allows him to make eye contact when communicating with others.

SUMMARY OF IMPACT
The client said, “After 22 years of not having a brace of any kind, my neck had gotten adjusted to not having one, but my back and shoulders hurt a lot from the pressure of my head leaning severely to one side. Many thanks for such a good brace. Every day I use it more and more. It has really improved my life. I can breathe better and my back does not hurt like it used to.” His case manager, added “The device … continues to serve him well and he is able to operate it on his own even with his limited mobility. Many of his co-workers have commented about how much better he looks with his head in a more upright position instead of falling over to the side.”

TECHNICAL DESCRIPTION
Based on initial meeting with supervisors and occupational therapists, it was determined that the side of the client’s head needed to be supported. This side support would be used in conjunction with an occipital support, which would be attached and adjusted separately. The initial design gave support along the right side of the client’s head, extended under his chin, and allowed him to adjust and move the support himself.

This design was not fully approved by the supervisors because of two concerns. The first concern was that the design of the side headrest might injure him by putting too much pressure on his jaw. The second concern was that the supervisors wanted to monitor and regulate most movement of the headrest, rather than allowing the client to move it independently. In this way, they would determine the change in angle of his head over a period of time. However, they believed that allowing him to move the device into and out of position would be an important feature, so that he could remove it for comfort when necessary.

These additional constraints were incorporated into the final design, which connected a Pro-L9S support (Whitmyer Biomechanix, Inc.) to the client’s wheelchair through a grouping of lock collars seen in Figure 7.6. The Pro-L9S allowed fine positioning adjustments to be made by the therapists, but also for the client to move the headrest in and out of position using a sliding sleeve. A foam-padding
sleeve cover was added to make it easier for him to grasp and slide the sleeve. The rod connected to the ball end of the Pro-L9S was not long enough to reach our client’s head, so an extension tube was added, lengthening the rod by four inches. The angle of the ball end of the Pro-L9S was altered so that the headrest would rest in the correct direction and the side arm would fold in the correct direction when not in use. After testing various headrest shapes and padding, a small headrest that would not interfere with the client’s glasses and a Sunmate 1 open celled foam were chosen. Covers for the headrest were designed from socks for easy removal and cleaning. The Whitmyer Biomechanix Pro-1 head support system was purchased to provide occipital support when the side arm was being used.

The cost of parts and materials was approximately $650.

Figure 7.6. Exploded View of Side Arm and Headrest.
MOBILE FOR CHILDREN IN A HOSPITAL

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INTRODUCTION
A client hospital program was unable to find a safe commercial mobile for use with infants. Several mobiles have been examined, but either the hospital safety department has declared them unsafe or the manufacturer has recalled them due to safety issues. The goal of this project was to design and build a mobile that met hospital requirements. A custom mobile was constructed by modifying a commercial mobile designed for home cribs. This mobile mounts securely on a variety of hospital cribs, and has a removable gooseneck arm with a locking hook on the end, allowing a variety of objects to be attached.

SUMMARY OF IMPACT
The mobile is currently being used at a hospital. Given that no other mobiles are approved, the device is receiving constant use. Hospital staff members are pleased with its features and performance, and have asked for five more units to be constructed. A hospital director stated, “We have used the mobile and it has been great. It is secure … the stand itself was great. Having (only) one has been challenging for us because we want to share it with every infant patient and there are lots of infants in right now.”

TECHNICAL DESCRIPTION
Initial research identified a commercial mobile, made by Tiny Love, which met the hospital staff’s requests for music, and contained a removable fixed arm. The commercial base (Figure 7.8, left panel) was adapted so that it would attach securely to pediatric crib rails by attaching a three-millimeter diameter round aluminum plate to the plastic wingnut, providing a stronger and more extensive rail attachment (Figure 7.8, right panel).

The fixed plastic arm of the commercial mobile was replaced with a flexible metal gooseneck. The mobile base had a round 22 millimeter opening, 50 millimeters deep, to accommodate the plastic arm. A 10-inch straight aluminum rod was machined to insert securely into this opening; the other end of the rod was threaded to attach to a commercial 19-inch microphone stand gooseneck. The length of the fixed rod limited the distance the gooseneck could extend down in the crib, thus ensuring it could not contact a child. A strain relief was designed to prevent the plastic base from breaking due to stress from the cantilevered arm. The strain relief was milled from two aluminum sections that sandwiched the plastic hanging flange (Figure 7.8, left panel). When screwed together, the two sections contained a round opening through which the fixed rod inserted.
To secure the fixed rod, a spring plunger was added to the strain relief (Figure 7.8, left panel). This plunger engaged into a hole in the fixed rod for security, but also allowed the arm to be easily removed.

A spring hook was attached to the gooseneck end of the flexible arm, allowing appropriate commercial toys or mobile ends to be securely attached. For the prototype, a commercial plastic X-shaped hanger was attached to the hook, and washable plastic toys hung from its ends.

Finally, a blue rubber hose with an inside diameter of three-quarter inch slid over the metal gooseneck to provide a slick, colorful covering that was easy to clean. All sharp edges were carefully filed, and all machined components were coated with spray-on protective Plasti-Dip.

The prototype mobile had one large on/off switch, three large musical buttons on the front, a speaker, and volume control that are easily accessible. The buttons and switches can be actuated with very little force. The final product was durable enough to withstand forceful movements of the arm, excessive tightening of the wing nut and heavy items being placed on the arm hook.

The cost of parts was approximately $106, including the commercial mobile base.

Figure 7.8. Left Panel: Mobile Base Showing Strain Relief and Spring Plunger. Right Panel: Wing Nut Attachment to Crib.
PAPER CUTTING DEVICE

Designers: Andrew Reish and Travis McLeod
Client Coordinator: Robbin Newton, Lenox Baker Hospital
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INTRODUCTION
The goal of this project was to design a device to allow a five-year-old client with cerebral palsy to safely and independently cut paper. To meet this need, a paper holding fixture and a pair of electric scissors mounted on a stable base was designed. Both met the design requirements to be safe, aesthetic, durable, and portable. This device will improve the client’s independence at home and school.

SUMMARY OF IMPACT
The Paper Cutting Device's major advantage is the ease of loading and unloading paper in the clamping mechanism by the client. The electric scissors can be turned on easily and remain on as she cuts. The client's occupational therapist said, “She is using the paper cutting device at school and at home to cut..."
independently. This device has made a remarkable difference in her independence and she gives the device “a total thumbs up” for helping her achieve this independence.” The client’s mother commented, “The device is great and she enjoys the freedom that she has in using her paper cutting device. She is able to load and unload her paper and cut without assistance. Her teachers were amazed at the project and she can use it in class with minimal interruptions.”

**TECHNICAL DESCRIPTION**

In initial meetings, it was found that the client had only moderate difficulty with smooth vertical motions and was most comfortable working with her arm extended. She showed no difficulty in gripping objects except when adjusting objects in her hands. The design was for lateral movements and to support her arm for minimal fatigue.

The client tried a pair of battery-operated scissors by Donwei (DW-101). The blades cut in such a small region (one millimeter) that she could not fit her fingers into the cutting zone, making the scissors safe. However, maintaining scissor stability while maneuvering the scissors was difficult for her. To increase stability, the electric scissors were mounted in a computer mouse base (Figure 7.10). A wooden wedge supported the scissors at a convenient angle. The scissors were secured to the base with Velcro, allowing for easy battery replacement. The original momentary on/off switch was difficult for the client to operate and required constant pressure. This switch was replaced with a larger push-on/push-off switch mounted on the mouse base. An extra large button was glued to the surface of the switch. A Dycem non-slip strip was added to the base to improve grip. The computer mouse was spray painted in blue Plasti Dip®, and stickers were added to meet the client’s preferences.

A pair of sheet-metal Vise-Grip pliers was modified to hold paper above the work surface. The pliers were mounted in a blue plastic case, with only the handle and clamp surfaces protruding. Alternating rubber bumper teeth were added to create a corrugated effect, suspending the paper one centimeter over the surface (Figure 7.10).

Rubber feet were attached for stability, and a wide polypropylene grip extension piece was bolted to the vise-grip release lever, making it easy to actuate by our client.

The cost of parts for the Paper Cutting Device was approximately $111.
POURING PALACE

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INTRODUCTION
The client is a six-year-old boy exhibiting symptoms of autism and manic depression. These symptoms manifest in his desire to constantly pour liquids and granular objects. He will pour for as many hours as allowed, but the mess produced, lack of supervision, and inclement weather when he pours outdoors, among other restrictions, prevent him from engaging in this activity as often as would be ideal. The Pouring Palace is a large structure that incorporates different activities involving pouring granular objects such as rice or beans. These activities include a cranking and lifting mechanism that hoists the material above the structure and pours it over objects that the client can configure on a pegboard, a magnetic board on which he can affix objects into which he can then pour, and various bins to hold the material for him to create pouring activities with his own imagination.

SUMMARY OF IMPACT
The Pouring Palace provides the client with an environment to occupy himself with his favorite activity safely and independently. The client’s occupational therapist said, “The pouring palace has made a big difference in his life. It provides his family with something to have him do when his behavior is becoming out of control.”

TECHNICAL DESCRIPTION
The Pouring Palace frame is constructed from PVC tubing and connectors for rigidity and light weight. A truncated-pyramid shape provides a stable structure due to the low center of gravity compared to a rectangular structure. The pyramid consists of a five-foot square bottom, four-foot square middle, and three-foot square top, each separated by three feet vertically.

Components affixed to the PVC frame allow different pouring activities. The first, shown in Figure 7.12, is the lifting and cranking mechanism that scoops the rice or other granular material in the following manner. A wooden frame supports three half-inch diameter axles mounted with self-aligning flange bearings. Nine-inch diameter wheels are affixed to each of the axles. The bottom axle extends beyond the width of the frame and has a bicycle crank-arm and rubber handle attached. Cranking this handle rotates a belt attached to the wheels. The belt consists of two one-inch wide, eight-foot long woven nylon straps attached together using metal loop-through buckles. Eight colorful plastic cups, bolted to the belt, scoop into a bin filled with rice as the handle is turned. The rice is lifted the length of the frame and as it reaches the top, drops into an...
elevated bin that directs the rice to the pegboard, as described below.

Two mechanisms help eliminate derailment and twisting. First, wooden guides affixed to the frame direct the cup and belt directly over the wheels to prevent derailment. Second, Velcro strips sewn onto the belt ends prevent it from loosening due to vibration, and allow a high tension to be applied to the belt, preventing twisting.

The second component of the device is the pegboard. The client can easily attach toys or other objects to this pegboard with standard hooks. The cranking and lifting mechanism pours the rice over the objects affixed to the pegboard. A shallow bin below the pegboard collects the falling rice. A tub connected to one end of the bin dumps rice to another bin that hangs below the magnetic board, the next component. The magnetic board allows the client to configure tubing and funnels (with magnets attached) freely, to make pathways for rice to flow. The bin below the magnetic board hangs lower than the one beneath the pegboard, providing him with alternate levels on which to play. Fabric strung from the rungs of the frame surrounds the entire structure, reducing the amount of rice that leaves the frame area, and creating a tent-like playing area.

The cost of parts for the Pouring Palace is approximately $880.
SHOULDER-STEERED TRICYCLE

Designers: Derek Juang and Irene Tseng
Client Coordinator: Barbara Howard
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INTRODUCTION
The client is a five year old boy with TAR syndrome, which is characterized by the absence of radii bones in the forearms, leading to shortness in arm length. He has limited arm movement and rotation as well as minimal strength in his fingers. Both legs exhibit restricted bend (15-degree bend in right leg, 90-degrees in the left leg) and strength. The aim of this project was to modify his commercial tricycle to allow for independent use. The completed design includes a four-bar linkage for steering, telescoping arms to facilitate mounting and dismounting, and a weighted front wheel and unequal crank arm lengths to help compensate for leg differences.

SUMMARY OF IMPACT
Prior to design modification, the client was unable to use a tricycle. The client’s mother said, “It is incredible to see our son do something that other children, including his siblings, can do and up until this project he was unable to do. Most of the activities he does differently from other kids, and doing something the same way others do is really helping him to realize he can do anything he wants.” The client said, “I like my tricycle because they cut the handle bars off, and now I can ride it with (my brother and sister). I also like the basket, so I can put stuff in it, like flowers and rocks, and bring them home to my mommy.”

TECHNICAL DESCRIPTION
The steering system uses a four-bar linkage, which allows the client to steer the tricycle using his hands, which are near his shoulders. The four-bar linkage consists of four solid aluminum bars connected at four pivot points (Figure 7.14, left). Since the four-bar linkage steering system must stay parallel to the ground on which the tricycle is sitting, a universal joint translates parallel motion of the steering system into angled motion of the wheel (Figure 7.14, center). Pushing with the right shoulder causes the right side of the four-bar linkage to shift forward and the wheel to turn to the left. Similarly, pushing with the left shoulder causes the tricycle to turn to the right. This design capitalizes on the torso strength and flexibility of the client, and does not require using his limited arm and finger strength.

Telescoping handlebars make it easier for the client to mount and dismount the tricycle (Figure 7.14, right). A paddle bar locking mechanism secures the handlebars in place during tricycle use. The paddle bars attach to the top surface of the solid telescoping bars via a hinge and spring. Two pins on the other end of the paddle bars fit into a series of holes in the top surface of the hollow aluminum tube. To dismount the tricycle, the client applies a small force on the paddles to raise the pins and push the handlebars forward. To begin cycling, the client pulls the handlebars toward himself until the pins drop into a comfortable position.

Two modifications address the flexibility and strength limitations in the client’s right leg. To address the restricted range of motion for the right leg, the crank shaft of the right pedal was shortened,
decreasing the range through which this foot moves on each pedal stroke. A weighted wheel, consisting of five large fishing weights, assists the power stroke of the right leg. These weights mount at roughly two o’clock when the right foot is beginning its downstroke.

The cost of parts for the project is approximately $130.

INTRODUCTION
An adult client has paralysis in his right arm and leg, and aphasia, which limits his language abilities and his ability to understand visually complex layouts. He wanted to return to his former hobby of photography, which he had not participated in since his stroke. A camera mount and control system was designed that stabilizes a digital camera on his wheelchair and allows full function selection and aim using only his left hand. This system includes a simple remote control and a height adjustable, locking swing arm that allows him to independently move the camera into place.

SUMMARY OF IMPACT
The client can independently use the Camera Mount and Control System to take accurate, quality pictures. The client’s wife relates, “This will help him re-integrate into the community. Photography is something that he has enjoyed and he hasn’t been able to do it much since his stroke.”

TECHNICAL DESCRIPTION
The Camera Mount and Control System components include a remote control, which attaches to the monopod and also provides a handle for aiming. A monopod attaches to the upper arm, which connects to the lower arm. The black pipe to the left is the base clamp, which clamps to the client’s wheelchair. Each component is described in more detail below.

The first step in the design was to help the client select a digital camera. Based on our recommendation, he purchased a Sony Mavica CD-250, which has a 2.5 inch LCD. This large LCD allows him to view the image from a distance, rather than having to use the viewfinder.

A Sony Tripod with Remote Control (model # VCT-D680RM) is modified by removing the tripod legs, leaving a monopod mount that can attach to the...
camera, and allow the client to pan and tilt. The remote control is a wired, ambidextrous control with five large buttons: power, shutter release, video, and zoom in/out. Two minor problems made its use more difficult were: the video button had no function with this model camera, and the separation between the zoom and shutter release buttons required the user to slide his hand up or down to use one or the other. Adding a lever that covers the video button and presses the shutter release button when operated with the client’s thumb solves these problems.

The mounting arm assembly is constructed by modifying a shower head attachment. The lower arm includes a twisting barrel lock, which allows it to telescope and rotate. This rod is covered with rubber (not shown) to aid the client’s grip. The bottom of the lower arm is machined to 7/8 inch outer diameter to fit tightly into the base. A notch is also machined in this end to rest on a pin in the base, allowing the mounting arm to be lifted, rotated 180 degrees, and then lowered back into a locked position. The upper part of the lower arm has a 90 degree bend before connecting to the upper arm. The upper arm contains twist locks at both ends, allowing easy adjustments to the camera’s height.

The base is designed to contain the lower arm securely in a locked position either in front of the client or to the side of his wheelchair. A quick release pin can be inserted through one of two holes, setting the height of the mounting arm assembly. The base is attached to the lower frame of the wheelchair using a pair of framesaver clamps (Bodypoint, Seattle).

The cost of parts for the Camera Mount and Control System is about $200.

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Figure 7.16. Components of the Camera Mount and Control System.
INTRODUCTION
A lap tray was built to allow a high school student with cerebral palsy to have more interaction with his classmates. The lap tray rests lower than the commercially available trays, enabling him to better access his range of motion. A dynamic box holds paper and then releases it at the movement of a lever, assisting him in his job collecting papers from the rest of the class. A large crate attaches to the tray, allowing him more involvement in the recycling and drama clubs. Finally, a storage bag allows all components to rest securely behind the wheelchair when not in use.

SUMMARY OF IMPACT
The lower position of the lap tray compared to previous trays has already helped the client. His mother said, “I’ve noticed how much more motion he has with his arms positioned lower than the armrests.” The dynamic paper box will allow him to have some independence in his daily routine at school, since he currently relies on a caregiver. His mother commented, “I can really see that it’s going to make it more fun and he’s going to have more independence in doing activities with other kids. I’m looking ahead to clubs or after school activities and the volunteer work for socialization – for more
natural forms of socialization opportunities.”

TECHNICAL DESCRIPTION
The lap tray surface is 3/8 inch polycarbonate, cut in a shape similar to his previous tray, with edges carefully smoothed for safety. Telescoping steel tubing (Figure 7.17) provides a secure method for attaching and removing the tray. Two nine-inch long, one-inch diameter hollow stainless steel tubes were clamped to the wheelchair frame. These tubes contain a series of holes, through which lock pins are inserted to set the lap tray height. Two slightly smaller tubes attach to the tray using commercial brackets. These tray tubes include a welded angle that matches the angle of the wheelchair-mounted tubes. A series of holes in the lap tray, and corresponding pegs in the attachments, secure them to the lap tray.

A commercial multicolored collapsible crate attaches to the lap tray using two bolts added to its bottom surface. The dynamic paper box (Figure 7.18) is constructed from 3/8 inch polycarbonate. It consists of a three-sided box, hinged to a base plate on the open end, which faces outward from the client. Springs mounted between the base plate and box tilt the box upward away from the student. A polycarbonate lever, mounted to the lap tray with a locking pin, secures the box in the lowered position when the end of the lever rests on the lip of the paper box. When the large paddle on the end of the lever is moved to the side, the paper box is released and its contents dump off the lap tray. Re-arming the dynamic paper box involves holding it down and moving the lever back into position. Two bolts protruding from the bottom of the base plate mate with holes in the lap tray surface.

A storage bag, consisting of two pockets of royal blue canvas, secures to the rear of the wheelchair. One pocket holds the dynamic paper tray and the other the collapsible crate, in its collapsed position. The bag is covered with a dust flap that falls over the pockets and ties at the bottom of the bag.

The cost of the custom lap tray and attachments is approximately $650, including $350 for machining.
INTRODUCTION
The client is a young man who attends a day program for people with autism. Approximately every 30 minutes, the participants switch to a different activity; however, the client requires repeated verbal and visual prompting from the staff to make these transitions. A device was built to hold a schedule of tasks and to prompt the client to perform those tasks. Activated by a radio frequency remote control, the device uses a BASIC stamp and an ISD voice-recording chip to provide an audio command to check a schedule. Several lights illuminate a visual prompt for the next activity. These cues help the client transition to his next activity with less prompting from the staff.

SUMMARY OF IMPACT
The task prompter was designed to help the client to transition smoothly from task to task, with less assistance from staff members, thereby increasing his independence. The director of the facility that the client attends during the day said, “The prompter device has the potential to greatly increase (the client’s) independence in getting through his day. It uses his strengths of understanding picture and object cues, while compensating for his need in the area of initiation.”

TECHNICAL DESCRIPTION
The overall approach to this design was to provide a visual prompt, a voice prompt, and a notebook of Boardmaker (Mayer-Johnson, Inc., Solana Beach CA) prompting cards that he was already using at his day program.

The visual prompt was created using ten LEDs, controlled with a BASIC stamp microprocessor and driven by NPN transistors, as shown in Figure 7.20. The LEDs were mounted around a sign that said “Check Schedule” in the notebook (Figure 7.19). With each activation, the LEDs remained on for 10 seconds.

The voice prompt was constructed using an ISD4002 ChipCorder® (Fig. 7.21). A nine to 3V regulator provided the supply voltage for the ISD chip from a 9V battery, which also powered the BASIC stamp. The voice prompts were generated in the following way: First, a sound file of the voice prompt was produced through a computer microphone and stored as a WAV file. Next, two wires were soldered to a headphone plug, which was plugged into the headphone jack of the computer. Finally, the headphone plug wires were connected to the ISD input. As the ISD chip was recording, the WAV file was played on the computer, loading the voice prompt into the ISD. An LM386 audio amplifier connected to the ISD output provided the power necessary to drive a speaker.

The remote control circuitry was modified from a RadioShack wireless doorbell. When the remote was activated, the doorbell’s output went high (5V). This signal was inverted and connected to the BASIC stamp reset pin. Because the reset pin was active low, this caused the Stamp to wake up from “sleep” mode and execute the program that turns on the visual and audio prompts. Then the Stamp went back to “sleep”.

Figure 7.19. Task Prompter.
A LeapPad (LeapFrog Enterprises, Emeryville CA) was used for the notebook. The LeapPad was a learning toy that comes with spiral-bound books. The electronics of the task prompter replaced the LeapFrog’s electronics, and the book was replaced with a notebook made out of laminated construction paper, spiral bound to fit into the device. Plastic sleeves, made to hold baseball cards, were cut and attached to the notebook to hold the two-inch by two-inch Boardmaker picture cards representing the client’s scheduled tasks. Velcro was also mounted to the opposite side of the picture cards so that the staff could attach objects that correspond to each task. For example, a paintbrush could be attached opposite from the picture card for the art station. The staff found that the client could transition more easily when his next task was prompted by both a picture card and a physical object.

Parts for the Task Prompter cost approximately $240.
ARTIST’S EASEL WITH ARM STABILIZING DEVICES

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INTRODUCTION
Individuals with ataxia often have trouble performing certain tasks independently. In this case, the client desired to draw and paint without assistance in controlling her tremors. An easel was designed with various features to help her accomplish this. The two major components for stabilizing her arm are a peg for her left hand to grasp while drawing, and a magnet glove. Both components have adjustable features and, depending on the degree of her tremor on a given day, one or both of the devices may be used.

SUMMARY OF IMPACT
Since the magnet glove and left-hand peg reduce the tremor to a certain degree and stabilize the arm in the event of a tremor, the client will be able to draw or paint without someone’s supervision. The client’s mother commented, “This is going to be really nice because it’ll allow [her] to draw what she wants to draw without someone being there to help her.”

TECHNICAL DESCRIPTION
Several widely varied ideas were considered for reducing the client’s tremor. After numerous trials, it was found that magnets attached to the client’s wrist, combined with a metal drawing surface, provided some resistance to tremor motion, but still allowed her to slide her hand around the drawing surface. The wrist magnet idea was modified into a magnet glove. Magnets were sewn under pieces of cloth onto a form-fitting fingerless glove (Figure 7.23). Thirty 1/8 inch diameter rare earth magnets were sewn into fifteen positions on the glove (two magnets in each position). The positions were determined by observing what areas of the hand/palm the client would rest on the drawing surface while she drew.

During early trials, it was also observed that the client often used her left hand to steady the ataxia in her right arm, either by pressing down hard on the table or by tensing it and pulling it back towards her shoulder. The client was given an object to grasp with her left hand while drawing, and it further alleviated the ataxia. A grasping handle was therefore incorporated (Figure 7.22), with seven positions from which the client can choose.

Commercial table-top easels were considered, but a custom device was built because it appeared difficult to modify a commercially available easel for the arm stabilizing device. To provide adjustable tilt angles, several notches were carved in the base, into which the steel rod attached to the drawing surface would fit. The resulting tilt angles were 0 degrees, 20 degrees, 35 degrees, 46 degrees, 51 degrees, and 53 degrees. The drawing surface measured 17.5 inches by 23.5 inches and consisted of a layer of painted sheet metal on top of a polycarbonate sheet.
for support. These two layers were mounted in a wooden frame with molding around the top edges. The base was constructed as a wood frame, into which the drawing surface would recess to minimize thickness and weight. Large rectangular magnets were provided to hold the paper on the drawing surface, accommodating a wide range of paper sizes.

The cost of parts for the Artist’s Easel was approximately $135.

Figure 7.23. Magnet Glove, Reversed to Show Magnet Positions.
INTRODUCTION
The client is a six-year-old girl with cerebral palsy. Because of her disability, she has difficulty playing board games with her family and friends. The game playing device addresses her main needs: board stability, piece maneuverability, card play, and dice rolling. A frame/well combination provides stability for the board, while a metal surface and magnets mounted on game pieces help her move the pieces without toppling them over. Card shoe and dice poppers are also provided to assist with card play and dice rolling.

SUMMARY OF IMPACT
This device allows the client to participate in board games that have been frustrating to her. The client’s occupational therapist, commented “She is definitely a young girl who likes to be independent. The product is going to have an impact on her life by allowing her to play board games independently and normally as other children her age.”

TECHNICAL DESCRIPTION
There are four main components in the design: stabilizing the board, improving piece maneuverability, card play, and rolling dice.

After considering several options, it was decided that a combination of a well and a frame would provide the best board stabilization and game access. The idea of a well also helped with piece maneuverability, as described below. A square piece
of half-inch thick plywood, 21.5 inch square, was routed to create a seven millimeter deep, 21 inch square well into which any of the client’s favorite games would fit. A commercial 28 inch square picture frame was modified to 22 inch square to fit snugly over the well. Plexiglas was mounted in the frame to make a transparent cover, using metal corner brackets.

To provide stability for game pieces, a sheet metal and game-piece magnet arrangement was devised. A layer of cloth was glued to either side of a piece of sheet metal, and the sheet metal glued inside the well. The layer of cloth on the top of the metal provided friction for the game board. The bottom layer of cloth reduced the distance between the sheet metal and the Plexiglas surface. This improved the function of magnets attached to the underside of game pieces. The Plexiglas provided a smooth surface on which the magnets could slide.

To make the frame and well attach to each other during storage or transport, ten small magnets were attached to the corner brackets of the frame. These magnets held to the sheet metal of the well with a force just strong enough to hold the two parts together during transport.

Figure 7.25. The frame and well.

Plastic sleeves, an electric card dealer, and a coupon dispenser were all considered for card play. A plastic casino card-shoe was purchased and found to work well for the client. For rolling dice, a dice popper was extracted from the game “Trouble”. To make it easier to change dice to accommodate different games, we modified the popper so that the cover bubble was easy to remove and secure with rubber bands.

The cost of parts for the game playing aid was approximately $155.
CHAPTER 8
MICHIGAN TECHNOLOGICAL UNIVERSITY

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EXERCISE DEVICE WITH A PHYSICALLY ACTIVATED SWITCH

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Client Coordinators: Kathy Penegor and Mitzi Marcotte, Copper Country Intermediate School District, Hancock, MI
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INTRODUCTION
A student with multiple physical and cognitive disabilities lacks the motivation and interest to exercise her upper extremities. In order to address this problem, a device has been built that targets the upper extremities and provides motivation by activating a device such as a radio while the student is exercising. Since other students will benefit from this device, it is capable of width and height adjustments and is compatible with both wheelchairs and standard chairs.

SUMMARY OF IMPACT
Exercise is important to maintain or increase upper extremity strength for independent wheelchair propulsion and transfers. In addition, exercise has positive effects on other health considerations, including weight control, cardiovascular health and circulation. It is a challenge, however, to motivate this student to actively participate in any exercise program without direct supervision and continual verbal prompts. The new device will motivate the client to improve her upper extremity strength and have significant positive effects on her health and independence.

TECHNICAL DESCRIPTION
The device is pictured in Fig. 8.1. It is fabricated primarily from aluminum and weighs approximately 50 pounds. The overall length is 38 inches with variable width and height. The device can be split into two pieces and collapsed, making it easy to store and transport between locations. The exercise device has three major sub-systems: 1) the frame, 2) air cylinder and arm levers, and 3) the physically activated switch. The frame consists of two base channels and cross-channels. As shown in Figure 1, the wheelchair (or a standard chair) is placed on the base channels. The width can be adjusted to a maximum of 30 inches by sliding the base channels to the desired width and inserting a locking pin in the cross channels. The bottom of the base channel is coated with a double layer of neoprene (rubber) in order to provide stability.

The second sub-system consists of the air cylinders and arm levers. Each arm lever is adjustable to a maximum height of 31 inches. Handgrips from ski poles are placed on the end of each arm lever and the straps that help maintain the student’s grip even if the student loses control of the lever. A plate and
a bracket are welded to the base channel. The lever pivots on the pin of the bracket. An air cylinder (Bimba Manufacturing Company, MRS-50-12-DxP) is attached to the base channel and arm lever with pin joints. The air cylinder is used as a source of resistance. The resistance can be modified by adjusting the flow valve (Bimba, FQP4K) on the cylinder. The motion of the arm levers targets the biceps, triceps and the deltoids and provides the same motion as required to push a wheelchair. These exercises were recommended by the physical therapist involved with the student.

The third sub-system is the physically activated switch. A circuit diagram is shown in Fig. 8.2. When the switch is activated by physical activity, it will provide power to any standard electrical device, such as a radio, blinking lights or a popcorn machine. A magnetic reed switch (Bimba, MRS-0.087-PBL-50) is mounted to each air cylinder and detects the movement of a magnet on the piston of the cylinder. When the reed switch detects the magnet the timer (IDEC, GT3A-6AF20) is activated and power is provided to the motivational device.

The timer allows the user to set a delay between 0.1 seconds and 180 hours. If the reed switch detects the magnet before the set time is complete, the timer is reset for the same delay. This allows for continuous operation of the motivational device as long as the student exercises.

The magnetic reed switches (MRS-1 and MRS-2) are attached to each air cylinder and sense when the piston is extended. They are wired to the timer so that if either one is activated, the timer will activate the device(s) that receive power through the power outlet. The numbers on the timer circuit refer to the pins on the IDEC timer model GT3A-6AF20. The power supply is connected to a standard household outlet.

The actual cost of the parts for the device is approximately $800.
HANDS-FREE WALKER AS A BASKETBALL ASSIST DEVICE

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INTRODUCTION
A device was designed for a 16-year-old male with cerebral palsy, to allow him to stand upright and shoot a basketball. The student uses a Reverse Kaye Walker for mobility and shoots basketballs while seated in a chair in the gym. He cannot completely support himself to stand on his own, but has good mobility and use of his arms and legs. He primarily needs support to prevent tipping and falling due to poor balance control. A hands-free walker device was designed to solve the problem as it provides independent mobility, safety and a durable, effective apparatus. Hands-free walkers currently available are not suitable for this application. It is difficult for the student to get into and out of these walkers, and there are comfort issues when using them for extended periods of time. This student has a Baclofen™ pump implanted on the right side of his abdomen, which transports medicine to his spine for his spastic diplegia. Pressure from standard hands free walkers irritates this area. The design developed is shown in Fig. 8.3. It avoids any heavy fastenings in the abdominal area, and utilizes a padded harness rather than a bike seat for comfort. The adjustable walker supports his weight, does not hamper his gait, and allows him to comfortably stand shooting baskets with adequate arm clearances.

SUMMARY OF IMPACT
This design allows the client to participate in sports and gym class. Other types of everyday activities can also be maintained, such as walking, doing the dishes, and refereeing sporting events. These activities were not possible with existing devices. This student, in particular, also has a fear of falling or being off balance. He was comfortable and at ease the first time he used the walker. The walker allows him to have use of his hands in an upright position and will allow him to be involved with more activities and learn to use more muscles for a healthier life. This design can also be useful for other people, as it is not designed specifically for those with cerebral palsy. It can be used for other individuals who have some mobility of their legs, but need support to stand and use their hands at the same time.

TECHNICAL DESCRIPTION
The frame of the walker is fabricated from Aluminum 6061T6 for its lightweight characteristic.
and strength. The front legs are designed with two 1.5-inch diameter, 1/8-inch thick tubes bolted to a 45 degree solid aluminum elbow for a total vertical height of 39 inches, and a horizontal depth of 18 inches. The bottom of each leg has four-inch diameter swivel wheels. Fig. 8.4 illustrates the bottom of the back legs. They are manufactured from 1.5 inch diameter aluminum tubing with a custom-milled aluminum fork (9.75 inches tall and 3.5 inches wide) connected to the bottom of the tubing. A six-inch diameter wheel is connected to the fork, and a custom steel brake lever activated with hand brake levers allows the student to lock the back wheels. The horizontal component of the entire back leg is 18 inches and reaches 39 inches in vertical height.

Both the front and back legs are attached to a shoulder joint shown in detail in Fig. 8.5. The back leg is connected to the shoulder joint by a four-inch stainless steel tube that has been bolted to the leg. A similar solid aluminum piece connects the front legs to the shoulder joint. Two steel pushpins inserted through the joint and back leg and one steel pushpin inserted into the joint and front leg provide a stable connection for the attachment. The shoulder joints on the right and left side are connected with a two-inch square crossbar. The crossbar is bolted twice on each side to the joint for redundant stability. The crossbar has two vertically cut 1.25 inch square holes and two one-inch tubes attached vertically to it by screws, one foot apart. The square holes allow L-pieces to slide in and are held in place with steel pushpins. The L-pieces connect the harness near the hip of the student. The L-piece has multiple holes one-inch apart for adjustment for growth. The one-inch tube (14 inch length) is covered in plastic and connects the harness’ carabineers to the device. The brake handles also attach at the end of the one-inch tubes. The brake levers can be locked so that the student can remain in place while shooting basketballs. A harness for the student’s upper torso attaches to one-inch vertical tubes that can be adjusted in one-inch height increments.

The lower harness is a standard climbing harness connected with two carabineers to the horizontal arms. This harness is modified by sewing the connection loops for the carabineers closer to the hip. The upper harness is a plastic molding covered with a padded fabric slipcover that can be easily removed and washed. Two seat belt straps are bolted to the bottom of the L-pieces to prevent the student from slouching backwards and swinging in the harness.

The cost of the materials in this project is $676.
DESIGN OF A MODIFIED, RECUMBENT EXERCISE BIKE FOR A STUDENT WITH DISABILITIES

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INTRODUCTION
A student in a local elementary school classroom has severe physical, visual and cognitive disabilities. The student’s primary form of exercise is walking in the school hallways with a classroom instructor. This method is inefficient because it removes one of the two instructors from the classroom and leaves only one instructor to supervise the classroom. The physical therapist requested a device to allow the student to perform exercise while in the classroom. The device must: 1) operate easily with minimal supervision, 2) motivate the student to perform the exercise activity, 3) be safe for the student and classmates, and 4) conform to the classroom. To meet the objectives, an exercise bike is modified to compensate for the student’s disabilities. The design is shown in Fig. 8.6.

SUMMARY OF IMPACT
The development of the bike with a motivational device will significantly enhance the student’s learning and development in the classroom as well as improve his health. The strengthening that he gains through exercise will help to maintain his general health and level of ambulatory skills, especially as he continues to grow. This student also demonstrates a number of disruptive physical and vocal behaviors. The physical behaviors include aggressive movements of his head or falling to the ground intentionally and often without much warning. Exercise helps to modify these behaviors and calm the student, and the bike will allow him to exercise on his own while in the classroom. Since he can also now exercise more frequently and consistently, it is a hope that he will be able to participate in more appropriate social interactions in the school environment.

Figure 8.6. Modified Recumbent Bike.

Testing and utilization of the bike to-date, has been limited. New activities with this particular student are introduced gradually into his daily routine. Preliminary response to the modified bike is good, however. The instructors set a goal of 10 to 20 minutes of bike usage, but during the first week the student felt comfortable enough to sit on the bike for 30 minutes.

TECHNICAL DESCRIPTION
The modified exercise bike consists of five distinct modules that were designed for the student’s specific needs: 1) modified bike pedals, 2) four-point harness system for the seat, 3) swivel seat, 4)
motivational device actuator, and 5) motivational device.

The pedal straps and four-point harness provide for the safe operation of the bike by the student. The original pedals on the exercise bike had a single adjustable toe strap. The modified pedals have a three-strap system to more firmly hold the student’s feet in place. These straps are easily adjustable for any student, and fasten with Velcro. A harness system is integrated into the high-backed seat to allow the student to be completely supported along the back. The harness system is the same one used to transport the student on the school bus. It connects at the shoulders and hips to a vest worn by the student. Since the student and instructors are familiar with this harness system, it is easy to use.

The seat is modified to swivel 360 degrees and lock at 90-degree intervals. This mechanism provides easy access to the seat for the student and teacher. It is difficult to place the student in the seat and position his feet in both pedals at the same time. The swivel allows for the student to first be positioned in the seat and then rotated so his feet can be placed in the pedals. This creates an easier procedure for the student and instructors and less stress for the student.

A motivational device activator is also incorporated into the bike. This activator is a circuit consisting of a magnetic proximity sensor, timer, and outlet. The magnetic sensor detects motion in the wheel of the bike. When the motion is detected, a signal is sent to a timer that closes the circuit supplying power to an outlet embedded in the bike. The timer is adjustable from 0.1s to 180 hours. The motivational device will remain powered as long as the proximity sensor senses motion during the set time. If the set time expires before motion is detected, the timer circuit will open and cut off power to the motivational device.

Finally, a motivational device is on the bike’s console so that it can be easily viewed by a student sitting in the bike’s seat. The motivational device is powered by the circuit described above. Although a simple light box was chosen as the standard motivation, any electrical device could be used. Several devices could also be powered by the same outlet to provide a combination of motivational effects. The motivational device activator and motivational device in tandem promote the use of this exercise device by the student.

The approximate cost of the parts needed to manufacture the bike is $575.
INTRODUCTION
Water play allows students with spasticity of lower arm and hand muscles to relax and improve motor and sensory skills. Students in one school currently use a tub of water placed on top of a table to assist in physical therapy activities. The primary weakness with this method is that the height of the table is not adjustable. The students’ wheelchairs range in height from 25 inches to 35 inches causing some students to reach farther to gain access to the water. A second weakness is that the tub is not stable and can be pulled off of the table. This type of activity requires several aides, creating an unnecessarily chaotic environment. Finally, it is time consuming to remove water from the bin.

To remedy these problems, a new water play therapy table was designed. There are products on the market made for sand and water play, but these tables are only 24 inches high and are not adjustable. The design was broken into two sub-systems: a surface to incorporate water play (tabletop), and a system for height adjustment (table legs). The final design, pictured in Fig. 8.7, utilizes a custom made tabletop with fiberglass bin and a hydraulic lift system to adjust the height. The tabletop has a semi-circular cut out to facilitate student access to the water.

SUMMARY OF IMPACT
All of the students in the classroom have had the opportunity to use the water play table. The semicircular cutout and height adjustability are key factors in allowing all of the students to easily reach the water play area. The sloping bin allows the aides to control the depth of water for different students, which aids in its therapeutic use. Students who use this table for relaxation of arm contractures need deeper water while those who enjoy splashing need very little water. The table will be used in both play and therapy, and the new device allows all of the students to fully participate in water activities.

TECHNICAL DESCRIPTION
The finished device has a custom made tabletop with a fiberglass bin. A four inch wide piece of three-quarter inch thick industrial grade plywood creates the surface area of the tabletop water play table. The plywood has a semi-circular cut-out and is shaped to surround the fiberglass bin. The plywood is coated with a high-pressure laminate for water resistance. A quarter-inch thick fiberglass bin is fabricated to fit inside and on top of the plywood tabletop. Since the bin is set into the table, it cannot be pulled off or tipped over. The bin slopes 12 degrees and has a standard 3 ½ inch kitchen drain to easily empty the bin. A hose is attached to the drain, and a nozzle at the end easily controls the water flow while draining the bin. A rubber liner is placed around the outer rim of the fiberglass bin to prevent the fibers from loosening and the students from scratching or pinching themselves when using the table. A larger foam pad is glued to the semi-circular cutout area to increase comfort for the students when playing in the water.

A medium carbon steel frame supports the table top. The four table legs are fabricated from two-inch square tubes 18 inches in length. Angled crossbeams are welded to each of the legs and under the front and rear edge of the tabletop to make the frame. Gussets (3/16 inch thick plates) are welded to the inside of the legs and bottom of the crossbeams to provide additional stability. A hydraulic lift system (SUSPA Movotec Lift System) provides height adjustability within a 12 inch range. The cylinder legs from the lift system are placed inside the steel legs and the hydraulic pump is secured to the outside of the frame on the right side. The table height is adjusted by turning a crank attached to the pump. To increase mobility in the
classroom, four casters are added to the legs. Two of them have a locking mechanism to keep the table from moving when in use (McMaster-Carr #2834T37).

The cost of the parts for the device is approximately $1100.

Figure 8.7. Water Play Table and Design Team.
CHAPTER 9
NORTH CAROLINA STATE UNIVERSITY

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INTRODUCTION
The Keyboard Adjustment System was designed for a client whose physical disabilities prevented normal reach to the keys on a standard keyboard. This project addressed the client’s desire to be able to reach the keyboard without leaning forward in the computer chair, which caused stress on the back after long periods of time. Visual constraints were also accounted for in the design.

Since the intended user had very limited reach and strength, an adjustable keyboard device that required manual operation was not adequate to serve the client’s needs. The Keyboard Adjustment System operated on a set of two electric actuators that were propelled by a foot switch, which the client could easily maneuver. One of the actuators...
moved the apparatus horizontally on a track system that was mounted to the desk. The other actuator was responsible for moving the keyboard vertically to a desired height. A pivot joint located between the vertical actuator and an aluminum plate attached to the back of the keyboard allowed tilt adjustment. The Keyboard Adjustment System was designed to attach to the computer desk rather than replace the desk completely, and it was also designed to be movable if the person decided to change desks or locations.

**SUMMARY OF IMPACT**
The Keyboard Adjustment System was intended to provide a more comfortable working environment for the client. The electrical controls for the device allowed the client to be self-sufficient. The ability to adjust the location of the keyboard horizontally, vertically, and rotationally provided freedom for change whenever necessary.

**TECHNICAL DESCRIPTION**
The Keyboard Adjustment System used a standard computer keyboard attached to a 12.5 by 18 inch aluminum plate. A pin joint welded to the back of the plate attached the keyboard to a vertical actuator to allow height adjustment of the keyboard. A steel cart, cut to fit the base of the actuator, held the vertical actuator tightly in place. Two 18 inch steel axles (3/8-inch diameter) were welded to the front and back of the cart so that the actuator sat centered on the axles. The axles rolled along two 18-inch steel tracks on four plastic wheels. Front and back steel bars were welded to the ends of the tracks that prevented the cart and actuator from rolling off the tracks.

The cart was pushed along the tracks by a horizontal actuator. The horizontal actuator attached on one end to the back bar that connected the ends of the tracks and at the other end to a pin joint welded to the metal cart that held the vertical actuator that allowed it to push along the tracks and move closer to the client for better reach. The entire apparatus was attached at the back of the desk with a set of clamps that were bolted into the ends of each track.

Because the vertical actuator tended to rotate as it moved up and down, a collar was developed that fit around the stationary part of the actuator. This collar prevented the rotational movement and allowed the keyboard to travel up and down without spinning. It remained facing the client as it was operated (See Fig. 9.1).

Rather than having to reposition the body to reach the keyboard, the Keyboard Adjustment System easily moved the keyboard to a comfortable location. It allowed the client to sit comfortably in her chair and move the keyboard toward her with very little effort. The optimal goal for the design was to create a comfortable working environment and to allow adjustability for various individuals if needed.

The cost of parts and materials was approximately $550.
MODIFIED EXERCISE BICYCLE FOR ELDERLY ADULTS

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INTRODUCTION
An exercise bicycle was designed to facilitate rotational motion for elderly adults. During exercise, the clients attempted to move their arms and legs as if they were on a bicycle by using their own strength to suspend their limbs in the air. This proved to be difficult because they were only able to support the weight of their extended limbs for a very short period of time, which resulted in very little exercise. The designed exercise bicycle was intended to provide a comfortable and safe means for exercise with the emphasis placed on simple motion that promoted circulation rather than cardiovascular or strength training.

An original design was created to incorporate various aspects. An oversized chair with padding and side guards was used to promote safety as well as allow comfort. Foot and arm rotational devices were designed to be in use either simultaneously or separately. The foot pedals and arm handles were also designed to be adjustable in horizontal and vertical directions so they could fit different adult sizes.

SUMMARY OF IMPACT
The main goal of the project was to design a structure that would provide an effective and safe means of guiding the arms and legs through a full range of rotational motion to provide movement and increased circulation for elderly adults. The designed stationary bicycle met all of these criteria, and the bicycle also adjusted to allow for the size differences in users.

TECHNICAL DESCRIPTION
A majority of the design used aluminum to decrease the overall weight of the structure. A rectangular aluminum plate lay on two pieces of square aluminum channel to form the base. Extending straight up from the base was the frame of the leg apparatus of the exercise bicycle. In order for the pedals of the bicycle to be adjusted, four rollers were affixed to a piece of rectangular aluminum channel and placed within two more pieces of aluminum channel that served as tracks for the rollers. Welded onto the rectangular channel were two aluminum plates that adjusted to allow the channel to roll or hold it in place. Through compression and friction, the plates held the leg apparatus securely to prevent moving backwards, forwards, or side to side. Extending upward from the piece of channel with the rollers was the frame for the wheel and foot pedals (See Fig. 9.2). An open square shape was created with single extensions from the top and bottom of the rectangle by welding aluminum tubing together. The single bottom extension was welded onto the rectangular channel, which contained the rollers. Gussets welded on the sides of the extension provided increased support to the upright. The center rectangular opening contained two bearings bolted into each side to attach the wheel and pedals. The wheel was held in place by a single steel rod, welded to the frame of the wheel and placed through two pillow block bearings. The steel rod was welded onto the steel arms that hold the pedals on each side. The pedals contained Velcro straps to hold the foot securely while in use.

The top single extension of the square shape contained a quarter circle head with drilled holes in a three-inch radius. A long piece of aluminum tubing was attached to the quarter circle with a steel bolt. The quarter circle of holes provided a means of height adjustment for the arm apparatus. It was held in place with a steel pin through holes drilled in the quarter circle and the aluminum tubing of the arm apparatus. The tubing extended outward from the top of the square frame with an additional piece of aluminum tubing placed inside. The two pieces of tubing contained drilled holes through their
lengths. The length of the tubing was adjustable by sliding the tubing in and out and holds in place with another steel pin.

Attached to the end of the arm apparatus was a wheel with standard bicycle handles to allow rotational movement of the arms. Two ten-inch diameter wooden circles were attached to the end of the aluminum tubing of the arm apparatus. A center handmade bearing held a steel rod that connected the wooden circles attached at the ends. One plastic bicycle handle was drilled and bolted into each wooden wheel. The handles were offset at 180 degrees to allow the arms to move in opposite directions simultaneously. The wooden wheels were adjustable to offset the handles at any desired angle by simply loosening and retightening the bolts that held the wheels to the steel rod.

The chair used for the device was an oversized, padded chair with solid arm rests on both sides. It was mounted onto the base plate of the exercise bicycle. The front legs were bolted into raised, aluminum pieces so that the front of the chair was elevated at a 20-degree angle. The original base of the chair was removed. A new base was created using a rectangular piece of plywood and the aluminum frame from a different chair. The new base created a stronger base at the degree of elevation used.

The exercise bicycle was designed to meet each requirement of the client. It allowed the user to gain a full range of rotational motion in both the arms and the legs in an assisted and safe manner (See Fig. 9.2).

The cost of the parts and materials was approximately $600.
PINGKO: AN UPPER BODY WEIGHT TRAINING SYSTEM WITH MOTIVATION MECHANISM

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Client Coordinator: Sue Powell, The Charlie Gaddy Center
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INTRODUCTION
A weight training system was designed to develop the upper body muscles for children with developmental disabilities. The device, named “Pingko”, made it possible for the occupational therapist to adjust the resistance to accommodate the different strengths and gradual improvement for each individual child. This system helped motivate children by incorporating a fun and entertaining “ping pong plinko” game that would capture attention while performing the exercise.

The client facility did not have a weight system designed to handle the needs of young children with developmental disabilities. Pingko was developed to strengthen and improve coordination in the upper body by using a pull down motion with only a two to five pound equivalent resistance. These children used a wheelchair to help them with their strengthening; therefore, Pingko was designed for wheelchair access. A game that provided stimulation was essential to captivate the children and encourage them to perform the intended exercise.

SUMMARY OF IMPACT
Pingko provides an exercise that strengthens the upper body muscles that children with developmental disabilities need to perform basic activities of daily life. Pingko satisfies the intended purpose of strengthening the biceps, triceps, and latissimus dorsi muscles in a goal-oriented setting that captures the child’s attention.

TECHNICAL DESCRIPTION
Pingko was made from a five-by-three-by-two-foot frame created out of one-inch square aluminum tubing (See Fig. 9.3). The frame acted as the support for the entire system. The frame had casters placed on the bottom, which allowed the system to be easily moved by one person. The casters contained locks to prevent the system from moving while in use.

Rubber tubing pulled around a pulley and a sheave created the downward pulling motion. The pulley attached to the bearing located at the bottom of the system was responsible for guiding the rubber tubing. The pulling of the rubber tubing created a torque in the axle, which was translated 90 degrees through the gearbox to another axle. This axle had a conveyor belt attached to it that rotated in the direction of the applied torque. The conveyor belt was slanted with three buckets sewed onto it.

As the buckets rotated along the conveyor belt, they came around the lower bend of the conveyor belt system and scooped up a ping-pong ball. Each bucket then rose to the top and crossed over the top bend of the conveyor belt system. As the bucket crossed the top bend, it released the ping-pong ball onto the pegboard, and the ball fell into randomized patterns of motion down the pegboard into one of four sections.

A strap was connected to a sheave around the top axle in order to provide the adjustable resistance. As the strap tightened, the axle required a strong torque for rotation, requiring the child to use more force in pulling the rubber tubing. The more force used to pull down the rubber tubing, the more strength the child would build in the upper body.

The cost of parts and material was approximately $200.
INTRODUCTION
The client was a 50-year-old man who had mental retardation and cerebral palsy. This condition had inhibited the pursuit of several athletic interests, primarily baseball, due to the client’s poor balance. As a solution, our design team created a balance aid in the form of shoe fittings that attached to the instep, out-step, and heel of each shoe.

Because this solution was intended for athletics, a traditional walker-type balance aid would limit freedom of movement. Shoe fittings, however, ensured full range of motion and offered an improvement in stability for the client. Molded from clay replicas, the fittings consisted of urethane 80 A (liquid rubber), which was both lightweight and durable. The fittings attached to the shoes through screws, which were tightened into plastic anchors secured into the soles of the client’s shoes.

Figure 9.4. Molded Rubber Shoes.
**SUMMARY OF IMPACT**

The solution was designed to meet the specific balance needs of the client while remaining compact and easy to use. The intent was to provide shoe fittings that sufficiently improved the client’s balance so that he could safely participate in athletics.

**TECHNICAL DESCRIPTION**

An extrusion die was designed by the team and created in the Biological and Agricultural Engineering Research Shop. The die consisted of a 2.015-inch metal pipe with a metal plate attached at one end. The cross-section design for the shoe fittings was removed from the plate and served as a template for the shoe fittings. Modeling clay was then extruded through the die by a two-inch metal rod.

Once the clay replicas had been extruded, they were molded to the specific shape of the client’s shoes. The replicas were then oven dried and coated with a thin layer of polyurethane. Polyurethane kept the clay replicas from sticking to the molding medium and deforming the mold. The clay replicas were then placed in a molding medium and allowed to set. The clay pieces were then removed and the molds filled with urethane 80A. Finally, the urethane was allowed to cure overnight.

The molded rubber shoe fittings described above were created through a process that required repeated trials and tested a variety of products. Using water based modeling clay and Memory Mold powder/water mixture produced the most workable products and was chosen for the final process.

Once the fittings had been created they were attached to the client’s shoes (See Fig. 9.4). Anchors were securely locked into the soles of the client’s shoes and holes drilled into the fittings at matching locations. Screws were then used to tighten the fittings to the shoes.

The cost for this project including materials and labor was $330.
MODIFIED BOWLING RAMP

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Client Coordinator: Douglas Gill, ARC of Wake County
Supervising Professor: Dr. Michael D. Boyette
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INTRODUCTION
A modified bowling ramp was designed for individuals with various disabilities, including wheelchair users, individuals with low strength, coordination, and vision. This project addressed the desire to have an improved bowling ramp that better suited the specific needs of persons with various disabilities.

SUMMARY OF IMPACT
This design made bowling easier and more accessible for people of various abilities. The intended users desired a device that provided therapy, enjoyment, and improved technique over the original ramp. This ramp met the needs described by the client.

TECHNICAL DESCRIPTION
The original bowling ramp was difficult for people of various abilities to use and was structurally weak at the ramp-frame interface. The modified ramp addressed these problems through various design components. Telescoping legs, a jack, and flexible connectors were added to make the ramp adjustable in height. A ball holder was included to keep the ball stationary while making adjustments to the ramp. Two legs were added to the original ramp design to improve overall stability. In order to make the ramp more accessible to wheelchair users, the frame width was increased. The framework and ramp were painted red to help make the ramp more distinguishable for persons with low visibility.

Retractable wheels allowed easier movement and storage of the ramp. When the ramp was in use, the wheels were retracted to expose rubber stoppers that kept the ramp in place. If necessary for storage purposes, the ramp could be separated from the frame.

The modified ramp utilized a 30-inch wide frame to accommodate wheelchair users (See Fig. 9.5). Four legs and added support framework increased the stability of the ramp during use. A ball holder was created by slightly curving the tubing between its connection to the framework and the descending portion of the ramp. Four telescoping legs and a jack allowed the height of the ramp to be adjusted. Flexible tubing was used in two locations along the ramp to connect the ramp to the framework and allow for the movement necessary to keep the “feet” of the ramp on the ground at all times. Vertical supports helped maintain the proper curvature needed to minimize the y-component of velocity as the ball exited the ramp.

The ramp could be adjusted to a maximum height of 40.5 inches, whereas the minimum height of the ramp was 28.5 inches. The velocity of the ball upon exiting the ramp was similar to the velocity of a ball bowled by hand.

The cost of parts, material, and labor was approximately $405.
Figure 9.5. Silver and Red Adjustable Height Wheelchair Accessible Ramp Design.
INTRODUCTION
Modifications were made to a Reverse Gator Walker™ for a three-year-old girl with cerebral palsy, a disorder that affects motor control. The Gator Walker helps children with cerebral palsy walk independently, however the intended user did not have the upper body control to use the walker without assistance. The project addressed the needs of the child with quadriplegia in order to help her utilize the Gator Walker to its fullest potential.

Since the intended user was weak in her upper body and lacked fine muscle control, she tended to lean
forward making it impossible to walk in her Gator Walker without being held upright by her therapist. A neoprene harness was created to provide chest support to maintain her vertical standing position. A wooden back support was constructed and mounted to the frame of the Gator Walker to improve trunk and back support and provide an attachment for the harness. The client also had difficulty keeping her arms in the current armrests and her hands on the handgrips. New armrests were made that were deeper and with elbow backings to hold her arms in the armrest. Dowels were also customized for her hand size.

**SUMMARY OF IMPACT**

The goals of the project were defined by the abilities of the client. The additions to the Gator Walker (See Fig. 9.6) were customized to allow the intended user to utilize her Gator Walker independently so that she could develop her walking skills. New pieces were also designed to adjust to the user’s growth.

**TECHNICAL DESCRIPTION**

The Gator Walker’s armrests were constructed to better secure and support the client’s arms. The armrests were formed using aquaplast, a thermal setting hard plastic material. The new armrests were cylindrical, with a four-inch radius and an eight-inch length. The armrests included a 90 degree bend at the elbow and provided support from the upper arm to the wrist. The formed aquaplast had a series of screws that fastened it to the frame of the walker. To provide comfort, the armrests were upholstered with neoprene.

A quarter-inch plywood back was assembled to provide added support for the trunk and back and counter support for the harness. The back support was a nine by eight-inch rectangular piece of wood that had threaded screw mounts and four two by quarter-inch rectangular slits cut into the back support for attachment of the harness. The plywood support was cushioned using three-quarter inch foam padding and upholstered with 3/16-inch thick neoprene. The back support was attached to the frame of the Gator Walker by means of four screws and the mount for the existing trunk support.

The existing walker did not account for the client’s limited muscle control in the upper body. For this reason, a harness was constructed from neoprene to provide chest support to keep her upright without assistance. The harness was made of two members: each one included a chest flap, a shoulder strap, and a side strap. Each strap of the harness passed through a slit in the back support and was folded back on top of it. To ensure adjustability, the flaps and straps of the harness were secured using Velcro.

The client had trouble gripping and holding the existing dowels because they were too large for her hands. New hand dowels were sized to the hands of the client and cut from half-inch diameter wood. This diameter provided sufficient support to bear the user’s weight and made the dowels easier to grip. The dowels were covered in aquaplast to add diameter and texture. The new dowels were secured using two steel screws on either end that attach to the existing mount.

The total cost of the project was approximately $269.
MODIFIED REMOTE CONTROLLED DOOR OPENING AND LOCKING SYSTEM

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Client Coordinator: Kimberly Stewart, North Carolina Independent Living Rehab
Supervising Professor: Dr. Michael Boyette
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INTRODUCTION
A system for opening and locking/unlocking a residential front door was designed for a 60-year-old woman with muscular dystrophy. She used a wheelchair and lacked the strength, dexterity, and tactile sensation in her hands necessary to close and lock her front door when she wished to leave her house. This project provided an alternate means for her to operate her door while meeting restrictions of cost and homeowner and insurance policies and maintaining the usefulness of the device.

The problem involved designing a device that would open and securely close a standard residential door. Although automatic door openers are commercially available, they usually cost upwards of $1500 plus a sum for installation. An unknown source donated a commercial automatic door opener to the client. The device was modified by physically converting it from right-handed, outward-swinging operation to left-handed, inward-swinging operation. The device was then outfitted with a radio frequency receiver and remote control. Furthermore, an infrared remote controlled deadbolt was purchased to address the issue of locking the door. The remote control unit for the deadbolt was modified to make it a suitable size to be manipulated by the subject.

SUMMARY OF IMPACT
The woman had extreme difficulty with her front door until the time of this project. The door and deadbolt lock required too much effort and range of motion for the client to use them effectively. She desired a device to aid her in these tasks that was compatible with her abilities. She is now able to independently operate the entrance to her home.

TECHNICAL DESCRIPTION
The main effort in this project was modifying the existing right-handed, outward-opening automatic door opener for left-handed, inward-opening operation. This was accomplished by rotating the mechanical components inside the device’s casing 180 degrees and redesigning the swing arm. The case contained a number of holes for the protrusion of the motor axle, etc. These holes were mirrored to the opposite side of the case, so that the components could be reinstalled according to the modification. The motor was located on the left side of the device with a clockwise-turning torque. Such an arrangement was ideal for pulling open a door hinged on the left side.

The swing arm also required modification so as to work in cooperation with the new layout of the device and the space in which it was installed. Two parts were designed and manufactured to fit onto the proximal segment of the existing swing arm. One was an aluminum bar that extended the reach of the arm and connected it to the door. The other was a piece of steel square tubing used to constrain both the new and old arm segments. The arm assembly attached to the door via a Teflon slider, which was housed inside a brass slide track fashioned out of a piece of square tubing. The result was a functional and practical swing arm that fit the specifications of the client’s door (See Fig. 9.7).

The deadbolt remote control was a keychain-sized device. Placing it inside a wooden box and constraining it with sculpted Styrofoam enlarged it. A button was fashioned out of PMMA, which was a readily available material. The controller, along with the door opener remote control, was outfitted with adhesive Velcro. Corresponding Velcro strips were applied to the sides of the client’s wheelchair, to a wall plaque near the door, and to a pair of
gloves that she wore to aid her in handling the devices.

The cost of parts, material, and labor was approximately $500.

Figure 9.7. Door Opener with Modifications.
PORTABLE DIGITAL COMMUNICATIONS ASSISTANT

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Client Coordinator: Beth Wolf, MS, CCC-SLP
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INTRODUCTION
The digital communications assistant helps persons with speech disabilities communicate with others. The device is designed to be: 1) portable, 2) programmable, 3) easy to use, and 4) reasonably priced. Eight interchangeable overlay cards each allow selection of eight phrases, which gives a total storage capacity of 64 phrases. Cards are easily customized and are typically organized by situation or context, such as “work” or “food”. In this way, the user simply inserts the situation-appropriate card and then touches a picture corresponding to a desired phrase. With interchangeable cards, unit size is kept small and complicated menus are unnecessary.

Although several commercially available communications devices are available, these products are typically expensive, complicated to operate, and too large for portable use. Thus, the new design offers significant advantages over many existing devices.

SUMMARY OF IMPACT
By helping clients communicate, the digital communications assistant improves a user’s independence and quality of life. The device is small enough to be truly portable; device dimensions are approximately 7.5 inches by 3.5 inches by one inch, or roughly the size of an engineering calculator. With a very simple interface, clients with a broad range of abilities are able to successfully operate the device. Simplicity and portability promote device usage. Additionally, the device is easily programmed with new phrases, which ensures that the device adapts to the changing needs of the user. With moderate production, the designed system costs roughly $120 per unit, a price significantly lower than most commercial devices.

A completed device, shown in Fig. 10.1, is currently in use by the client coordinator. She has expressed her satisfaction with the product on several occasions, and plans are underway to demonstrate the device to a wider audience of professionals who serve clients with speech and language disabilities.

TECHNICAL DESCRIPTION
As shown in Fig. 10.2, the digital communications assistant is composed of four component blocks: 1) a pair of optical readers, 2) a user interface, 3) a controller, and 4) a record and playback unit.

The digital communications assistant supports multiple, eight-phrase cards. To discern between cards, a pair of optical sensors is used to read a special bar code printed on the backside of each inserted card. The bar code, a sample of which is shown if Fig. 10.3, serves two functions: 1) it provides a three-bit code that identifies the particular card inserted, and 2) it identifies whether the card is inserted forwards or backwards. Card identification is necessary to associate more than one phrase with a particular touch sensor. Insertion direction is necessary to ensure buttons are
associated with the proper picture. If a card is inserted backwards, the control unit compensates for the rotation in software.

When a card is inserted into the device, the user selects a desired phrase by touching one of the eight displayed pictures. Beneath these pictures lies a touch sensor matrix created on a printed circuit board.

When a finger contacts a picture, two four-button touch-sensing chips made by QProx (QT60040) interpret the resulting signals on the underlying touch sensor matrix. The QT60040 digital outputs are inverted and then encoded using an eight-to-three line priority encoder before being sent to the micro-controller.

Based on signals sent from the encoder, the micro-controller determines which button is being pressed and initiates a play or record operation at the correct address in the ISD5116. Additionally, the micro-controller monitors signal lines from the optical sensors to determine when a card is inserted, what card is inserted, and what direction the card is inserted.

Recording and playback are achieved using a specialized audio storage chip - the Winbond Electronics ISD5116. By choosing a sampling rate of eight kilohertz, this chip is capable of storing approximately eight minutes and 45 seconds of audio. Equal memory is allocated for each of the eight cards, which allows approximately nine seconds of audio for each button on each card. Audio input is accomplished using the biased electret microphone circuit suggested in the data sheet for the ISD5116. The audio output is fed through an LM 386 audio amplifier prior to being routed to an eight-ohm speaker. Playback and recording operations are controlled by the PIC micro-controller using an I2C interface.

A nine-volt rechargeable battery powers the entire system. When the system is not in use, a switch is available to turn the unit off. Finally, a small switch is located in the battery compartment to switch between the record and playback modes. A more complete device schematic is presented in Fig. 10.4.
INTRODUCTION
This system is designed to automatically open the personal lockers of three individuals to improve their independence at work. Due to cerebral palsy and rheumatoid arthritis, these individuals lack the finger dexterity and strength required to grip and open their lockers. Assistance is required, and an automatic apparatus directly controlled by each individual is preferred.

The automatic locker opener operates wirelessly. When pressed, a button transmits a unique code to open its matching locker, much like a garage door opener. A motor and cam lift the locker’s latch, allowing a compressed spring to gently open the locker door.

While some devices exist that assist opening various doors, custom devices are often required to properly interface with a particular door or latching mechanism. The current system is designed to integrate with the existing locker arrangement at the Developmental Work Activities Center (DWAC) in Fargo, North Dakota.

SUMMARY OF IMPACT
The automatic locker opener improves the independence of clients at DWAC. The users no longer need to wait for assistance to open their lockers. By simply pressing a button, their locker opens automatically. Clients have improved access to personal belongings throughout the day.

TECHNICAL DESCRIPTION
Fig. 10.5 illustrates the main components of the system. The switch, encoder, and transmitter are enclosed in a portable button. The remaining blocks are enclosed and mounted within the locker itself.

By requirement, a large and easy to operate button is required. As shown in Fig. 10.6, a commercially available touch light casing functions as the button. The case also contains a three-volt coin battery, an encoding chip, a transmitter, and a trace antenna. When the button is pressed, an eight-bit identification code is created by the encoder and serially transmitted three times at 434 MHz by the radio frequency transmitter. The eight-bit identification code allows up to 256 locker openers to operate in the same vicinity. The button is portable; it can be carried, mounted on a wheelchair, or mounted to the locker itself.
A 434 MHz receiver is located inside a control box that also contains the rest of the system components. Received identification codes are passed to the decoder for validation. If valid, the decoder sets the $V_T$ pin high to indicate successful reception.

When activated, the $V_T$ pin signals an interrupt routine on a PIC micro-controller. By checking a user-adjustable potentiometer, the micro-controller inserts a proportional delay prior to activating the locker opening mechanism. The delay feature allows an individual to back a wheelchair away from the locker once the button is pushed. After the delay, the micro-controller activates a motor driver to power the motor.

When powered, the geared motor shaft turns. A sea-shell cam capable of three-eighths inch lift is fixed to the end of the motor shaft. The increasing radius of the sea-shell cam is ideally suited to gradually lifting the locker latch as the motor turns. The latch releases once the maximum radius is reached, and compressed springs open the locker door. Afterwards, the cam radius drops back to the initial state, which returns the locker latch to the closed position. A bearing is used to reduce friction between the cam and the locker latch.

The micro-controller monitors the output of an optical sensor. As the locker latch is raised, an object passes an optical sensor indicating the opening sequence has started. After the peak of the sea-shell cam is reached, the latch falls and the object passes the optical sensor again. This event indicates the locker is open, and the micro-controller halts the motor.

By request, buttons for DWAC are mounted on the locker itself. The remaining hardware is mounted inside the locker and powered by a wall transformer. Tests indicate that the transmitter and receiver pair has a range of approximately 15 meters. A completed unit is shown in Fig. 10.6. Although the geared motor and cam combination provides ample force to open the locker, it takes about two seconds for the locker to open. Follow-up designs could improve this speed, implement additional code security, and reduce the size of the units. The final cost of one unit is approximately $215.
INTRODUCTION
The crossbow system is designed to assist an individual with paraplegia to participate in archery and hunting activities. The new system, which is shown in Fig. 10.7, is customized for the client, who has movement in his right arm and upper torso. Motorized pan and tilt movement is possible using a joystick interface, and a solenoid trigger mechanism fires the crossbow at the push of a button. The entire crossbow assembly conveniently mounts to the client’s wheelchair and is located to allow line-of-sight aiming.

SUMMARY OF IMPACT
The new crossbow system offers dramatic improvements over the client’s previous crossbow system. The previous system uses a fixed plywood mount, offers no aiming control, and fires using a somewhat awkward trigger extension. The new system offers improved mounting, aiming, and firing.

By providing the client with an improved crossbow system, he is able to more actively participate in a sport that he enjoys.

TECHNICAL DESCRIPTION
The new design meets the client’s special requirements for a crossbow system. The crossbow is directly mounted to the wheelchair, which ensures portability and strength. Additionally, the wheelchair and user provide sufficient mass to withstand crossbow recoil and to improve system stability. The crossbow is placed near shoulder level so that the crossbow can be aimed with the crossbow sight or added scope.

All system controls are designed and located for easy client access and operation. Wires are carefully routed to avoid potential entanglements. Linear actuators provide precise pan and tilt control over a wide target range. The joystick interface provides an intuitive and simple method of aiming. The joystick control is programmed to allow variable speed of operation, which promotes rapid and precise aiming. The solenoid trigger mechanism allows the crossbow to be fired with the push of a button. Built-in safety mechanisms are included to prevent the accidental discharge of the crossbow.

The system block diagram is shown in Fig. 10.8. System power is drawn from a battery. Five-amp voltage regulators provide five and 12-volt supplies. The five-volt source is used for the joystick and logic control while the 12-volt supply is used to power the motors and the solenoid.

Crossbow system functions are controlled by a PIC 16F876 micro-controller. The PIC’s analog-to-digital converters monitor movement of an inductive joystick. The crossbow pans with left or right joystick movement and tilts with forward or backward joystick movement. The further the joystick is displaced from the center position, the faster the crossbow moves.
The speed of the pan and tilt motors is controlled using two pulse width modulation (PWM) outputs available on the micro-controller. The PWM duty cycle is set according the digital values converted from the joystick position, and motor direction is controlled using additional digital output lines from the PIC.

Two H-bridge circuits, each comprised on N-channel power MOSFETs, convert the five-volt PWM signals into 12-volt PWM signals appropriate to drive the pan and tilt motors, which are connected to linear actuators that actually move the crossbow. Each linear actuator is equipped with limit switches to limit motion to an appropriate range.

The arming and firing mechanism is controlled by two illuminated push buttons. The yellow button arms or disarms the solenoid. If the red button is pressed within eight seconds of solenoid arming, the crossbow fires.

The approximate total cost for the entire crossbow project is approximately $750.
CROSSBOW SYSTEM FOR A PERSON WITH QUADRIPLEGIA

Designers: Erwin Lesmana, Craig Schaler, and Travis Shaw
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Supervising Professor: Jeff Wandler
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INTRODUCTION
The crossbow system is designed to assist an individual with (C-2,3) quadriplegia to participate in the sport of archery. The new system, which is shown in Fig. 10.9, controls crossbow aiming and firing and is customized for the client. The system is divided into two parts: the Control Panel (CP) and the Motor Controller (MC). A Jelly Bean (JB) button is placed next to the client’s cheek as an interface to the CP. The crossbow and MC are mounted together on a separate, freestanding tripod. By client request, the system is accurate up to 30 yards, allows variable control speeds, and exposes a minimal number of wires.

SUMMARY OF IMPACT
The new crossbow system offers many improvements over the client’s old system. First, communication between the CP and the MC is performed wirelessly. This simplifies set-up and eliminates wire tangles. Three motor speeds (fast, slow, and pulse) improve crossbow aim accuracy. Menu sequences are chosen to eliminate unnecessary JB clicks. Several safety features are incorporated into the design to ensure safe operation. Finally, crossbow mounts are improved.
The new crossbow system allows the client to continue participation in a sport that she enjoys. Although CK requires assistance in crossbow set-up and loading, she enjoys complete control of crossbow aiming and firing.

**TECHNICAL DESCRIPTION**

The Control Panel (CP), powered by four AA batteries, is a ten by five by two inch plastic enclosure that contains a single PIC micro-controller and a LINX RF transceiver that operates in the 900MHz range. Eleven Light Emitting Diodes (LEDs) are mounted on the CP faceplate, and each LED corresponds to a particular menu item. LEDs are grouped by function: three for basic operations (aim, safety, fire), five for aim control (up, down, left, right, exit), and three for motor speed (fast, slow, pulse). By utilizing careful LED sequencing, the crossbow is operated with parsimonious button use. To select a menu item, the JB input is clicked when the corresponding LED is illuminated. The PIC micro-controller monitors these selections and sends the proper command code to the RF transmitter for transmission to the MC unit. The final CP unit is shown in Fig. 10.9.

Housed in an aluminum box, the Motor Controller (MC) contains: 1) power supply circuitry, 2) a PIC micro-controller, and 3) a transceiver unit. Commands received by the RF receiver are passed to the micro-controller for decoding. Following decoding, the micro-controller supplies control signals to drive the appropriate hardware (pan motor, tilt motor, or firing solenoid). Fig. 10.10 shows the motor controller connected to the crossbow assembly.

The pan stepper motor is rated at 200 steps per revolution or 1.8 degree of rotation per step. With added gears, the crossbow’s horizontal resolution at 100 feet is approximately one inch per step. Tilt is accomplished using a linear stepper motor that has a six-inch screw shaft. Using a Hall-Effect position sensor, crossbow pan movement is limited to 45 degrees in either direction from center. Tilt movement is restricted to plus or minus 20 degrees. These safety features ensure the crossbow does not target an improper area.

A solenoid is directly connected to the trigger on the crossbow. When energized, the solenoid develops the seven pounds of force required to depress the trigger and fire the crossbow.

An in-system rechargeable 12-volt battery powers all the electronics in the MC. Voltage regulators are used to reduce voltages to the appropriate values for each electronic component located in the MC.

Including parts, materials, and machining, the crossbow system costs approximately $1350.
INTRODUCTION
This project explores the use of optical sensors for the control of a prosthetic device. Common red (660nm) light emitting diodes (LEDs) and low-power phototransistors are used to characterize and detect non-fatigue skeletal muscle contractions.

Other methods exist to control prosthetic devices, including electromyography (EMG) and near-infrared spectroscopy (NIRS). EMG is most common but suffers from poor signal transmission due to perspiration between prosthesis and limb. NIRS remains minimally explored and has yet to be implemented into a device [1,2]. Low-power LEDs and phototransistors offer a low-cost alternative.

SUMMARY OF IMPACT
A low-cost, reliable method to control prosthetic devices is desirable. Individuals with appropriate prosthetic devices would gain improved reliability and independence.

TECHNICAL DESCRIPTION
When a muscle contracts, muscle blood volume is reduced. Thus, detection of blood volume changes indicates muscle contraction [3]. Additionally, oxygen is required to fuel the contraction, so changes in available oxygen can also indicate muscle contraction. Oxygen is primarily carried by hemoglobin, which absorbs light differently with oxygenated or deoxygenated [4]. Therefore, changes in reflected light can indicate changes in blood oxygenation or changes in local blood perfusion.

In this study, short-duration skeletal muscle contractions are simultaneously measured on the extensor (carpi ulnaris) and the flexor (carpi radialis) muscles of the forearm. Baseline EMG recordings are also taken. Light from two red LEDs is transmitted to body using separate 1000 μm-core plastic optical fibers, which are secured perpendicularly to the skin. Reflected light is collected using a single optical fiber coupled to a phototransistor. The reflected optical signal is then amplified, converted to digital, acquired with LabView, and post-processed using MATLAB. Fig. 10.11 shows the system block diagram.

Two experimental protocols are presented. The first protocol is used to determine whether the optical signals qualitatively correspond to simultaneous EMG recordings. A second protocol attempts to characterize different types of contractions. Two male and two female subjects perform each protocol four or more times. In each case, the subjects are seated with the instrumented arm resting on a table.

In the first protocol, measurements are only taken from the extensor muscle and contractions are grouped into one of three categories: soft, medium, and hard.
or hard. Fig. 10.12 presents a typical result. As muscle contraction increases, the received optical and EMG signals also increase. Although the baseline of the optical signal shifts after each contraction, the optical signal is capable of indicating muscle contractions.

In the second protocol, both the extensor and flexor muscles are optically instrumented. EMG signals are also collected from the extensor muscle. The protocol consists of three different movements: 1) extending the hand palm out, 2) clenching the fist, and 3) flexing the hand palm in. Fig. 10.13 presents a typical result.

For the first two contractions (palm out), extensor muscle signals are dominant. During the next two contractions (clenching), signals from extensors and flexors are both pronounced. For the last two contractions (palm in), flexor muscle signals are dominant. Although shifting baselines are again present, contraction type is differentiable using the received optical signals.

It is concluded that optical signals from low-cost, low-power LED’s are a potential alternative to current methods of controlling a prosthetic device. Optical components cost just a few dollars. Application-specific data acquisition hardware needs to be designed in order to perform a final cost analysis.


ADAPTIVE CONTROL SYSTEM FOR AN ELECTRIC CAR

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INTRODUCTION
General Electric Motor (GEM) produces electric cars with a top speed of 25 miles per hour. These cars are street legal on most streets with a posted speed limit of 35 miles per hour or less. Current GEM production models are not equipped for hands-only operation. The goal of this project is to research and develop a prototype system that allows hands-only operation of a GEM electric car. The new system is designed to install with minimal modifications to the GEM vehicle and is consistent with features found on other types of adaptive vehicles.

A drive-by-wire system is presented. For this system, a handlebar control replaces the steering wheel. The accelerator and brake are placed motorcycle fashion on the handlebar. A handlebar control possesses several advantages. First, it is a proven and accepted method for motor vehicle control that is familiar to most people. For drivers not accustomed to a handlebar control, it is relatively simple to learn. Second, a handlebar interface allows the driver to control the vehicle with both hands while braking or accelerating.

The drive-by-wire approach reduces the number of mechanical modifications necessary to implement the system on the GEM vehicle.

SUMMARY OF IMPACT
A hands-only electric vehicle is appropriate for individuals with limited use of their legs. An adapted car provides its owner with improved mobility and independence. Unlike a wheelchair, an electric car offers passenger and cargo capacity as well. Furthermore, the proposed controls require few vehicle modifications, which help keep the system affordable.

TECHNICAL DESCRIPTION
A system schematic is presented in Fig. 10.14. This system requires adaptation of three fundamental components: 1) the accelerator, 2) the brake, and 3) the steering wheel.

The change to the vehicle accelerator is purely cosmetic. The GEM car utilizes a potentiometer attached to the accelerator pedal to vary the field current to the electric motor, thereby controlling vehicle speed. The new system relocates the potentiometer to a grip throttle. As the throttle is twisted, the potentiometer turns and controls vehicle speed.

It is more challenging to adapt the steering control. The GEM car uses rack and pinion steering. To replace the steering wheel directly with a handlebar requires a greater gear ratio than currently exists in the vehicle. Thus, a drive-by-wire steering mechanism is implemented. The drive-by-wire steering system eliminates the mechanical connection between the steering control and the rack and pinion. A signal is sent from the handlebar to a motor that moves the rack. To do this, the handlebar shaft is equipped with a potentiometer that outputs a voltage between zero and five volts. The system is calibrated so that an output of 2.5 volts indicates that the handlebar is centered. The DC motor that moves the rack is also equipped with a potentiometer as a means to encode rack position. A PIC micro-controller compares the signals from the two potentiometers and outputs an appropriate control signal for the motor. Additionally, the potentiometer attached to the motor is used to prevent over-steering; the micro-controller stops the steering motor when the wheels are at their fixed maximum angle.

Similar to the steering system, a motor is used to actuate the car’s brakes. A brake lever is placed on the handlebar in a configuration similar to a
motorcycle or bicycle brake lever. A potentiometer is turned as the brake lever is pulled, and this action creates a voltage signal that is proportional to the desired degree of braking. A micro-controller monitors this signal and creates the appropriate control signal for the brake motor. Forward motor rotation presses the existing car brake pedal down, which increases braking, while reverse motor rotation allows the brake pedal to return upward, which decreases braking. When the brake lever is released, springs return the lever and potentiometer to a neutral state.

A drive-by-wire approach has the added benefit that it supports other input mechanisms, such as joysticks, that allow a client to customize the system for their particular needs. Although the system illustrates hands-only drive-by-wire control of an electric vehicle, the system is not yet ready for actual use by a client. Better control algorithms are needed to ensure stable system operation given a car’s particular dynamics. Redundancy is also critical for steering and braking in case failure occurs in any of the drive-by-wire components.

The total cost of this system is just under $500.

Figure 10.14. Circuit Schematic of Adaptive Control System.
VOICE ACTIVATED RADIO CONTROLLED VEHICLE

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INTRODUCTION
The Voice Activated Radio Controlled vehicle (VARC) is a tracked RC vehicle that is controlled by spoken commands. Voice commands also direct the pan and tilt movements of a top-mounted camera, which transmits images to a receiving monitor. Taken together, the VARC permits an individual to explore remote locations using simple voice commands. The VARC is constructed using off-the-shelf components, which helps ensure availability and affordability of system components.

SUMMARY OF IMPACT
The VARC is well suited for use by individuals with limited mobility. A person is able to explore nearby surroundings without having to move. The VARC

Figure 10.15. Completed VARC Vehicle with X10 Camera.
traverses most areas navigable by wheelchairs, and it typically does so with much less effort. The VARC is also suited to certain law enforcement and SWAT situations.

**TECHNICAL DESCRIPTION**

The VARC is a modified Blizzard 2EV tracked RC vehicle manufactured by Kyosho. The vehicle’s wide base and low center of gravity permit it to operate in relatively rough and diverse terrain. Mounted at the top of the vehicle are an X10 Tiny Wireless camera and camera mount. Camera images are transmitted to a monitor and allow an operator to observe the terrain surrounding the vehicle. Independent of vehicle motion, voice commands also position the camera using a motorized pan and tilt assembly. The vehicle and camera possess separate RF receivers to control their operation. The completed vehicle, which weighs a little over five pounds, is shown in Fig. 10.15.

A total of 11 voice commands are used to provide hands-free control the VARC. Six commands are associated with vehicle motion: 1) move forward slowly, 2) move forward quickly, 3) turn right, 4) turn left, 5) move in reverse, and 6) stop. Five commands are used to move the camera: 1) tilt up, 2) tilt down, 3) pan right, 4) pan left, and 5) stop. The VARC is easily programmed to recognize 11 user-chosen keywords corresponding to these 11 desired actions.

Voice commands are spoken into a microphone that is attached to an HM2007 Voice Recognition Kit. When trained, the HM2007 best recognizes words or phrases spoken by a particular speaker. To avoid voice recognition errors, each keyword needs to be unique and phonetically distinguishable. The HM2007 has sufficient storage to accommodate multiple VARC users. When a word is programmed, the HM2007 assigns the word to a binary code. During operation, the HM2007 attempts to associate the microphone input with one of the stored words. When a word is recognized, the HM2007 outputs the corresponding binary code assigned to the word.

Two PIC 16F876 micro-controllers decode the outputs of the HM2007 and send suitable commands to either the camera or the vehicle. The first PIC is dedicated to communicating with the vehicle’s control transmitter. Digital-to-analog converters are used to convert output from the first PIC into the analog form required by the vehicle’s remote control unit. The second PIC is dedicated to controlling camera motion. Output from the second PIC controls a set of four relays that properly activate the camera’s remote control unit.

The VARC control unit utilizes two wireless transmitters, one for control of the vehicle movements and the other for camera movements. The former is a modified Futaba Attack 2er FM wireless controller operating at 74.5 MHz, or Channel 65, and measuring approximately six by seven inches. The latter is a modified X10 camera remote working at 2.4GHz and measuring approximately three by four inches. The controller for the VCRC is designed to be small enough to hang from the operator’s neck or lay on the operator’s lap. Fig. 10.16 displays the block diagram of the VARC control unit.
CHAPTER 11
STATE UNIVERSITY OF NEW YORK AT
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POWER LIFT CHAIR TO ASSIST WITH TRANSFERS FROM WHEELCHAIR TO BED

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INTRODUCTION
The Power Lift Chair (Fig. 11.1) assists such individuals with lower body paralysis in transferring from a wheelchair to a bed, as well as reaching high places. Since devices throughout the house sit at different heights, a device able to accommodate such height changes will have a wide variety of uses.

SUMMARY OF IMPACT
An assistive device was successfully constructed to assist an individual with transferring from a wheelchair to a bed. Although the primary use is to help in the transition to a bed, this device can help accomplish different tasks. It can assist individuals with disabilities to reach objects out of range such as on top of refrigerators or cabinets. Furthermore, people with disabilities can use this device when washing the dishes or cleaning the stove.

TECHNICAL DESCRIPTION
The Power Lift Chair is a device for assisting those individuals paralyzed from the waist down. This device consists of: 1) a table, 2) a 24 V-DC power supply, 3) an electrical actuator, 4) an executive chair, and 5) a remote control. When assembled together they comprise a suitable transferring device (Fig. 11.2).

A hydraulic table used by mechanical shops to move heavy objects such as transmissions and engines was selected. The table originally used a pneumatic cylinder, which used a manual pump to compress the air and increase the table’s height. It also contained an air release valve to decrease the air pressure inside the cylinder and lower the table altitude.

A manual pump cylinder would not meet the requirements of the project. Therefore, the cylinder uses a 24-volt electrical actuator with remote control to drive the chair up and down. The actuator consists of a gear system that rotates and drives the table. The purpose of the project is to assist people with physical disabilities by providing an electronic device capable of adjusting to height differences.

The remote controls the actuator draws 14 amps from the power supply to raise the chair to the height of the objects. The use of an executive chair makes the device comfortable as well as marketable.
The lifting device will be placed in a location where the user will utilize it frequently. The user will transfer from the wheelchair into the lifting device and then will use the remote to raise the chair to a higher altitude.

The total cost of this project was $286.
ULTRASONIC OBJECT DETECTION DEVICE TO WARN OF OBJECTS IN THE PATH OF A BACKING AUTOMOBILE

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INTRODUCTION
This device’s design will help people avoid property damage, vehicle damage, and injury to people and animals. The device also helps those individuals with limited flexibility and peripheral vision giving motor vehicle operators an extra set of eyes to see objects that lie out of their field of vision.

SUMMARY OF IMPACT
The main purpose of this device is to prevent the minor incidents that occur frequently in driveways and parking lots by improving driver confidence and expanding the driver’s rearward visibility. The detection device will also assist drivers who have limited flexibility and less than perfect vision. Some automobile manufacturers provide a similar device on expensive models. The reported device will be inexpensive and accessible to those who cannot afford to own a luxury vehicle.

TECHNICAL DESCRIPTION
Three components work together to assist the driver (Fig. 11.3). The first device is an off-the-shelf ranging kit that uses sound waves to determine the distance to an object. The circuit board creates an output voltage, 0-5 Vdc, proportional to the distance of the object detected. The device operates on 12 Vdc power, which is standard for automotive electronics. This device will switch on when the gear selector is in reverse. The circuit board generates an output frequency from 39-52 kHz and receives the return echo from an object up to 35 feet away. An aluminum enclosure, mounted under the seat or in the trunk of a vehicle, encapsulates the circuit board.

The second device is another circuit board designed to work with the ranging kit. This board takes the output voltage from the ranging kit and gives a warning noise. An LED indicator lets the driver know how close the object is. The lower the output voltage from the ranging board the closer the object is to the sensor and vehicle. This board provides four warning indicators: 1) a warning buzz, 2) a red LED if the object is very close, 3) a yellow LED if it is at a mid range distance, and 4) a green LED if the object is at a maximum distance. This circuit board, enclosed in a plastic container, mounts to the rearview mirror or the dash board.

The third device is the Ultrasonic sensor that sends and receives the Ultrasonic sound waves used to detect an object. The sensor is constructed of stainless steel and is environmentally tested to withstand dirt and water, but must be cleaned periodically to operate consistently. The sensor is mounted in a plastic enclosure and is sealed around the sensor. In order for the sensor to operate properly, this case must be vented. This device mounts to the rear of the vehicle and connects to the ranging board via shielded wire.

The total cost of the project is $347.
Figure 11.3. Ranging Kit, LED Indicator Box, and Ultrasonic Sensor.
INTRODUCTION
The objective of this project was to design and build a device that would allow for easy removal of juice from tuna or other food product cans. This product would assist individuals with little or no strength or mobility in their arms or hands due to arthritis, injury, or some other affliction. The need for improvement over existing devices results from the large amount of leftover juice that remains even after the device drains the food product can. The remaining juice must be discarded manually by the individual. This product provides the user complete control over the amount of juice removed and allows for quick and easy disposal of the unwanted juice.

SUMMARY OF IMPACT
In an otherwise overlooked aspect of kitchen appliances, this product allows individuals with disabilities the freedom to choose how they want to enjoy canned food. This product’s advantages focus on, but are not limited to, assisting people with...
disabilities. The Can-Tastic Juice remover would also assist an athlete who eats tuna often but does not want to lose any tuna from manually pushing the lid down. In addition, restaurants who use large quantities of tuna may find this product helpful.

**TECHNICAL DESCRIPTION**

The project’s design considered many aspects, including ease of use, light weight, and aesthetics. The project itself consists of three main parts. These parts include: 1) the main structure which holds the can and contains a manually driven turn screw, 2) the compression/drainer plates, and 3) a hook that connects the device to a sink (Figure 11.4).

To begin removing juice from a can, the user places the hook on the side of a sink, with the actual device sitting within sink. Then, the user places a pre-sized drain plate onto a can that has already had the top removed. The drain plates come in two sizes, which fit on cans of 2.75 inch and 3.4375 inch diameters. The can is then placed onto the main structure which consists of two different size cuts that fit the previously described can sizes, each fitted with a non-slip surface (Figure 11.5). The user manually turns the acme threaded screw rod down onto the can. As it turns down, the plate attaches itself to the rod by means of a ratchet and socket system which presses the juice out. This design further allows the user to dump the unwanted juice into the sink since the device is hinged to the hook (Figure 11.6). Velcro holds the device onto the hook while pressing the juice out. Once the user has finished dumping the juice, he can pull the device back to its beginning position, loosen the screw, and remove the can with the juice completely removed.

To achieve a light-weight product while still incorporating an aesthetically pleasing appearance, Corian®, was used. Corian can also withstand a high compression rate, approximately 18,000 psi, which gives the user the peace of mind of knowing that continual use will not ruin the product. In addition, felt padding, and non-slip surfaces ensure that this product will not scratch or in any other way destroy the existing sink or countertop.

The total cost of the project was $450.
INTRODUCTION
People who use wheelchairs have trouble reaching kitchen cabinets or fully taking advantage of their capacity. Thus, the goal of this project was to make wall cabinets accessible to individuals who use wheelchairs.

The Adjustable Kitchen Cabinet was designed for universally recommended kitchen design constraints. When not being accessed it looks just like a normal kitchen cabinet (Figure 11.7). To access the cabinet, the user operates a remote control that operates a winch. The winch allows the cabinet to move down and out from its normal position, allowing full access to the user. After the user is done accessing the cabinet, the winch retracts it to its normal position.

SUMMARY OF IMPACT
The adjustable kitchen cabinet, by extending out and down from its normal position, allows wheelchair users to fully access wall cabinets. The most important advantages of the device are its normal appearance and adaptability to most kitchens. The adjustable kitchen cabinet is also simple, safe, durable, and inexpensive.

TECHNICAL DESCRIPTION
The adjustable kitchen cabinet was designed to accommodate universal kitchen design standards. These standards are as follows:

- Cabinet dimensions – 30 inch H x 12 inch D (width varies)
- Countertop height from ground – 36 inches
- Countertop to bottom of cabinet gap – 18 inches minimum
- Countertop depth (front to wall) – 24 inches

The foundation of the design is a four bar mechanism (applied to both sides of the cabinet) that guides the path of the cabinet (Figures 11.8 and 11.9). The parallelogram design ensures that the coupler link is always parallel to the ground link. Thus, when the ground link is the wall and the cabinet is the coupler, the cabinet remains level at all times, ensuring that its contents do not fall out. The ground link is provided by two steel support arms that are each welded to 2 inch x 2½ inch x ¼ inch steel plates. Steel was chosen for its strength and weldability. These arms are then bolted to a wood plate screwed into the wall studs, which has the strength to support the cabinet in all its positions. The crank links are aluminum bars that have a 5/8 inch bend in them to bridge the gap between the cabinet wall and the support arms. This gap allows
room for the ends and heads of the bolts that fasten the crank links to the cabinet and support arms. The distance between fasteners on the aluminum bars depends on the gap between the countertop and bottom of the cabinet; the bars on the prototype bars feature holes 13 ¾ inch apart. Aluminum was chosen because it was strong enough, light, and easy to shape. Shoulder bolts (one-inch long, 3/8 inch diameter) connect the crank links to the support arms so they can rotate smoothly with minimal side-to-side motion. Normal hex head bolts (one-inch long, 5/16 inch diameter) connect the crank links to the cabinet. All bolts fasten with lock nuts to prevent the nut from loosening due to the rotation occurring about the bolt during cabinet movement.

Gravity and an electric winch drive the cabinet’s movement. When the cabinet is in the normal, retracted position the aluminum crank links are at an angle of 75 degrees since it is fastened to the support arm three inches from the wall and fastened to the cabinet six inches from the wall. Thus, the weight of the cabinet is not centered over the rotation point and the cabinet wants to rotate down. However, it is held in the retracted position by the winch. When the user pushes the down button on the remote control, the motion of the cabinet is maintained by the speed of the winch feed. The prototype has a generic winch that required pulleys to reduce its speed and adjust the position where the forces acted on the cabinet. However, for actual applications of this device, a winch specifically designed for this application would be valuable. The winch is contained in the soffit above the cabinet.

The final component of the design is the fake walls that hide the mechanism links. The two fake sides are each made up of two pieces of wood three inches wide that run along the front and bottom of the cabinet. A sheet of plywood the same dimensions as the side of the cabinet is tacked into these two pieces, thus concealing the mechanism when it is in the retracted position. In consumer applications the type of wood used should match the rest of the cabinet for aesthetic reasons. For demonstration purposes, a transportable wall was built that was fixed to the prototype.

The total cost of the project was $200.
INTRODUCTION
Disabilities prevent many individuals from participating in sporting and outdoor activities. Although this product was designed for an individual with limited hand strength who uses a wheelchair, individuals with amputations and arthritic joints can also benefit from the fishing pole holder (Figure 11.10). The motorized fishing pole holder attaches to the arm of a wheelchair and controls the pole’s movement via a switch.

SUMMARY OF IMPACT
Many devices have already been developed to assist with everyday activities such as door opening. The next task for designers is to develop products that allow more freedom and active participation in activities previously deemed difficult for people with disabilities.

After reeling in the fish, the user can raise the pole to ensure the catch is within reach of a net. The unit may be fully disassembled for repairs or battery replacement by removing five screws from the side panel.

Figure 11.10. Fishing pole holder with fishing pole.
TECHNICAL DESCRIPTION
One of the largest concerns of this project was securing the fishing pole to the wheelchair arm. The fishing pole easily inserts into the holder by simply placing it in the plastic pipe and turning the pole. The pole essentially falls into place without any assistance; there are no clamps or screws. Once the fishing pole is secured in place, it cannot be removed from the holder unless lifted straight up; therefore, a fish could not pull the pole into the water. This feature eliminates the need to hold the pole while fishing, thus allowing the user to use their strength to reel the catch in or activate the switch to raise the pole. The holder is non-destructive to the fishing pole, eliminating the need for a special fishing pole.

Light pressure activates the switch to move the pole. When the switch is released, the motor stops. This important feature permits the user to easily control the unit.

The desired range of motion for the motor to move is approximately 90 degrees. Rather than adding limit switches to a motor and reversing the polarity, the unit uses a power window motor from an automobile. The pole is then attached to the existing arm of the motor (Figure 11.11).

Brackets allow the unit to be set onto the arm of a wheelchair. Friction between the brackets and the arm hold the unit in place without risk of being pulled off.

Drainage holes are added to the bottom of the unit along with a protective rubber coating inside the holder to protect the pole from scratches. A nine-volt battery, residing behind the removable side panel, powers the motor.

The total cost of the project was $58.
INTRODUCTION
Many individuals who use wheelchairs face challenges everyday when traveling in cars, trains, planes, etc. Today, wheelchairs exist that collapse into smaller sizes to aid in storage and ease of transportation. However, the wheel of a collapsible wheelchair does not decrease in size; it simply detaches from the wheelchair. In many cases, the wheel is the largest part in the collapsible wheelchair assembly. A wheel that collapses down into smaller pieces will further decrease the storage space needed for the wheelchair. The body of the wheelchair has been sufficiently designed to collapse, so the aim of this project was to focus on only the wheel. This wheel will provide the same amount of versatility and strength as present wheels with the added option to collapse down into small pieces for easy storage. Figure 11.12 shows the assembled version of the collapsible wheel.

SUMMARY OF IMPACT
A collapsible wheel will have a significant impact on the portability of wheelchairs in general. The wheel is designed for use with a standard wheelchair, therefore not limiting the applicability on most wheelchairs. The intent of the wheel’s collapsibility is to encourage individuals with disabilities to participate more actively in traveling. The
wheelchair users will feel more at ease when they need to stow away their wheelchair and not need a lot of storage space. The smaller collapsed size would also reduce the necessary size of designated wheelchair storage spaces.

**TECHNICAL DESCRIPTION**

The wheel is comprised of essentially nine parts: 1) four spokes, 2) four outer rims, and 3) one center hub (Figure 11.13). The hub is constructed from two circular pieces of aluminum that clamp together and encapsulate the ends of the spokes to hold them in place. Two quick release ball bearing pushpins hold the clamping pieces of the hub together. Inside the hub are two springs connected to each half of the hub that force the hub open when the pushpins are released.

The full outer rim separates into four quarter pieces that attach to each other with round pins. These pins are at one end of each section and fit into the open end of the sections counterpart to hold the rim together. There are 1/8 inch holes in each round pin and rim section at each collapse point in which the spoke pins are inserted and lock the rim together.

Each of the four spokes has a 1/8 inch pin press fitted into the end of it. These pins will hold each rim section together with the corresponding section. The four spokes of the wheel perform dual roles to hold the rim sections together and attach the hub to the outer rim.

The device pictured is a prototype of the actual collapsible wheel assembly. This prototype passed manually testing and proves the proof-of-concept. The prototype must undergo further testing to determine the long term durability. However, the results obtained show potential for the success of the concept.

The total cost of the project was $45.

Figure 11.13. Disassembled Components; Spokes[middle left]; Rim Sections[lower middle]; Center Hub[upper middle].
MECHANICAL JAR OPENER

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INTRODUCTION
One hundred people living in a retirement community were surveyed to ascertain what daily tasks they found most difficult to perform. Over 90 percent of those surveyed identified opening jars as their most strenuous task. As indicated by the survey, opening jars is often a painful task for people with diminished use of their hands due to conditions such as weak joints, arthritis, carpal tunnel syndrome, or amputation of an upper limb. This project addresses the need for a mechanical device that will help people with disabilities open jars with little physical exertion.

Initial torque tests revealed that jars require up to 64 pounds/inch of torque to loosen the lid. This significant amount of torque can be detrimental to people who have debilitating diseases such as rheumatoid arthritis. Jar openers on the market today have manual operation, requiring the user to grip the base of the jar while applying a torque to the lid. The Mechanical Jar Opener is a motor-driven device that loosens jar lids. Unlike other jar openers, the Mechanical Jar Opener does not require the user to hold the jar or apply the necessary torque to the jar lid. Instead, a conical shell attached to the output shaft of the AC induction motor lowers to engage the jar lid. Natural latex rubber bonded to the inside of the conical shell and the base plate provides the friction surface needed to grip the jar. The vertical position of the motor is adjusted using a rack and pinion assembly. The downward force of the floating base plate activates a switch beneath it. The user needs to apply only five pounds of force to the hand wheel to activate the switch.

SUMMARY OF IMPACT
The Mechanical Jar Opener will allow people with disabilities to regain a greater sense of independence. Even a child whose hands are too small to open larger jars can easily use this device. The device will allow those with only the use of one hand to open jars. Additionally, this device may be implemented into commercial use. An example lies in the culinary arts industry, where it may be used to prevent repetitive injuries such as carpal tunnel syndrome. Finally, this device’s inherent safety features allow for confident and virtually carefree operation.

TECHNICAL DESCRIPTION
The device consists of a user-operated section and an automatic section resulting from the user input (Figure 11.14). The device will be described starting at the input, and the description will flow through the devices’ major components, finally reaching the switch that activates when the motor is energized. This progression is exactly how the device operates.

The user begins by placing the jar in the device and centering it on the floating-base. By unlocking the hand-wheel from its uppermost position, the gearbox, motor housing and cone will drop down onto the jar. At this point the user applies five pounds of force onto the hand-wheel. This force produces 30 pounds/inch of torque to the input shaft, which translates to a 120 pound downward force on the jar-lid. The shaft is supported by a cantilever beam and bearing assembly. This beam protects the relatively small shaft (0.25 inches) from the bending moment force created by the five pound user input.

The next integral component is the slip-device. The slip-device will allow 34.7 pounds/inch of torque to be supplied to the input shaft. Any more torque and the device will allow the shaft to turn in relation to the hand-wheel. Whereas before the limiting amount of torque was applied, the shaft was ‘rigidly’ connected to the hand-wheel and every time the hand-wheel rotated, the shaft would rotate as well. The slip-device is used for safety reasons; it will not allow the user to supply too much force on any sensitive components, namely the jar itself, the shaft or the gear-teeth. The safety factor of the slip is S.F. =1.15, which will allow a maximum of 138 pounds of force on jar-lid.
The slider allows the smooth translation of the motor housing and cone onto the jar. It resists torsion around the tower horizontally, and the moment introduced against the tower face in the upward direction by the resisting force of the springs that is translated through the cone and motor housing.

The motor operates at six RPM and provides 100 inches/ pound of torque. This torque provides 1.5 times the maximum tested torque at an RPM slow enough for the user to easily release the handle when the lid is removed without worry of overturning the lid. The cone is the self-adjusting feature that actually translates the 120 pounds of downward force and the 100 in\(^\text{lb}\) of torque to the jar-lid. The floating base is rubber coated so that the base of the jar does not slip when the torque is applied to the top. Four springs are centered by rods that allow the base to translate vertically. This vertical translation results in the 120 pound force that squeezes the jar in between the cone and floating-base. When the springs are deflected 0.75 inches, the 120 pound force is generated, and a momentary position SPST switch is activated, energizing the motor.

At this point the cone should spin in between one-half and one full turn to insure the lid is loosened. Finally, the user raises the cone off of the jar, locks the hand-wheel in the uppermost position, and removes the opened jar from the device.

Figure 11.14. Mechanical Jar Opener.
ADAPTIVE BABY SWING

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INTRODUCTION
Traditionally, parents and children cradle a baby to sleep; however, a parent with physical disabilities may avoid endangering the baby by simulating this natural rocking using a baby swing (Figure 11.15). This product’s audience includes, but is not limited to, people who have seizures, arthritis, muscular dystrophy, as well as other mental or physical handicaps. Busy parents may also take advantage of this device to free up extra time.

In addition to helping parents, the baby swing also offers benefits to certain babies born with handicaps. In particular, babies born addicted to drugs receive treatment to stay calm by placing them in swings.

SUMMARY OF IMPACT
The baby swing is an assistive device meant to aid both parents and children with physical and or mental disabilities. This product features an improvement over comparable priced existing designs in the marketplace by combining the simplicity and reliability of traditional inexpensive winder models with the safety and stability features seen in more expensive electronic-motor controlled models. This baby swing accomplishes the best attributes seen in many swings today, namely inexpensive cost and safety.

TECHNICAL DESCRIPTION
The baby swing’s design maximizes certain desirable attributes desirable such as inexpensive cost, stability and lightweight design. The baby swing design maximizes the use of inexpensive materials, solid construction and light structural material available without sacrificing strength.

A winder mechanism keeps the cost of the swing low. This winder mechanism consists of two collinear springs and two cog gears with rocker arms extending from the plastic housing. The springs compress by turning the winder crank. This design provides the potential energy needed to power the device. The arms then oscillate repetitively as the swing is brought to a 30-degree angle with respect to a horizontal frame of reference. The device rocks back and forth with cog gears, with each spring providing energy for its respective forward or backward stroke. As the springs release energy, the position of the cog gears change. This is visible by the white line in the red background on the right side of the swing. The top position represents about 30 minutes of slow swinging. The speed of the swing’s stroke is determined by the spring’s energy release. Altering the position of the
control knob on the right can change the speed of the stroke.

Tubular aluminum provides the device with stability and lightweight (Figure 11.16). Two legs on each side of the slider fit into grooves located in the winder. The resulting motion of the swing imparts forces acting along these legs. A low profile and cross bar connecting each pair of legs stabilizes the system. Four bolts provide the seat’s stability, with high shear stress limits connecting to the rocker arms originating from the winder. These arms are bent steel tubing attached to the winder via a connecting pin. This configuration proves to be stable. The swing successfully survived 30 pound tests, which exceeds more than most babies weigh.

Figure 11.16. Tubular Aluminum Adds Stability and Minimizes Weight.
**REMOTE LIGHT SWITCH ACTUATOR**

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**INTRODUCTION**
The objective of this project was to create a device to control a wall mounted light switch via wireless remote. The unit should require no modification to the switch itself or its wiring, and should also provide operation of the light switch by those entering a room without the remote control unit.

**SUMMARY OF IMPACT**
The device installs directly to the switch plate on a wall and operates by remote control (Figure 11.17). To install, the user first connects the mechanical linkage to the wall switch finger with a customized rubber band and then the device is screwed on to the switch plate using the plate’s existing screws. Since the design does not involve any contact with wiring in the walls, an electrician is not required for installation.

The user operates the wall switch with the remote control unit by pressing the “up” directional button (for both “on” and “off” light switch operations.) The user holds the button until the switch has been flipped, noted by an indicator light turning on or off. The push button on the device cover allows someone entering the room to operate the wall switch without the remote. The device avoids any damage to the wall switch plate or finger.

**TECHNICAL DESCRIPTION**
The casing for the device is milled from aluminum bar stock, as two-cavity housing was required to contain the linkage on one side and the batteries and motor on the other. The dimensions of the housing are constrained to allow mounting the device to a wall switch.
switch plate with multiple switches and offer unimpeded access to any of these switches not controlled by the device.

A remote controlled toy car provides the radio control electronics which operate at a frequency of 27 MHz. Two AA batteries power the actuator portion of the device, and a nine-volt cell powers the remote control unit.

A worm-gear motor system provides mechanical control, operating at three volts, which translates power to a rotating lever in the linkage side of the housing. This lever connects to a pivoting arm, thus creating the linear motion required to flip a conventional light switch (Figure 11.18). This arm connects to the switch with the rubber band mentioned earlier.

An exposed wire antenna attaches to the circuit board to improve the range of the device. The range is approximately 15 feet. More importantly, line-of-sight is not required. This is especially important in dwellings or residences where a switch to control a light may be down a hallway or where furniture may impair line-of-sight.

The total cost of this project was $120.

Figure 11.18. Back of Light Switch Actuator and Remote Control.
REVOLVING CAR SEAT TO HELP A PERSON IN A WHEELCHAIR GET INTO A CAR

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INTRODUCTION
The purpose of this project is to create an easier and safer technique to move a person from a wheelchair into a passenger vehicle. This task can be very challenging, and there is the possibility of injury to both the passenger and the person assisting.

This device serves as a simpler and less expensive alternative than wheelchair vans. This device does not require a specially made vehicle because it can be installed in any passenger vehicle. This design uses a rotating arm that attaches to the wheelchair seat itself and slides on top of the car seat (Figure 11.19). Therefore, this device eliminates the need for the passenger to leave his wheelchair seat or be lifted.

SUMMARY OF IMPACT
This method is a much safer and convenient method to move people who use wheelchairs into vehicles. The device requires little strength and little use of tools, so it is simple to operate. Since the person never has to leave his wheelchair seat, he or she is not at risk for injury or accidents that can occur from manually lifting the passenger.

This design is intended for anyone who needs assistance moving a person into a car, but specifically for the elderly. There is no strength requirement on this design, and the individual providing assistance uses simple manual fasteners to connect the wheelchair seat to the arm and push the passenger into the car. The arm rotates on a flange bearing, so there is little friction or resistance to the push.

TECHNICAL DESCRIPTION
This design utilizes a wheelchair with a detachable hard seat. The seat detaches from the wheelchair via four hand-operated fasteners.

Figure 11.19. Wheelchair Secured to Car Seat.
A vertical steel bar adjusted to the current height of the vehicle seat mounts adjacent to the seat. The bar fits into a flange bearing at the base of the vehicle to provide rotation and the mounting of the device. The bearing bolts into the floor with four bolts to secure the device.

The arm is welded to the vertical beam at the appropriate height of the car seat, providing support for a pair of heavy duty drawer slides. These slides attach with simple screws and nuts. At this point,
the vertical beam secures to the base and a pair of drawer slides extends outwards from the car to connect to the wheelchair seat.

Mounted on top of the drawer slides is a piece of plywood that slides flush underneath the hard wheelchair seat. The plywood slides into place when the drawer slides are extended and is guided into position with sleeves at both ends under the wheelchair seat. Once in position, the drawer slides and plywood fixtures fasten to the bottom of the wheelchair seat with four simple fasteners positioned at the four corners of the wheelchair seat for convenience. Once the seat is fastened to the drawer slides, the seat itself can be detaches from the wheelchair.

With everything in position, the wheelchair slides out backwards, leaving the passenger suspended on his seat solely by the device. With a simple push, the drawer slides retract and the device rotates on top of the passenger seat (Fig. 11.20). This whole process takes place with the passenger still in his wheelchair seat at all times. This process can reverse for when the passenger disembarks from the vehicle.

The Revolving Car Seat addresses the problem in a very simple and effective way. This is a proof-of-concept model and though fully functional, some of the materials would be changed for increased comfort and aesthetics for commercializing this device.

The overall cost of this project was $260.
HANDS-FREE INTERIOR DOOR OPENER

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INTRODUCTION
Most homes are equipped with doors that latch when closed. These doors can be found leading to bedrooms, closets, bathrooms, and laundry rooms, but some individuals have limited ability to use these doors that lead to multiple rooms throughout a home.

The new design is a mechanism that allows persons with limited or no use of their hands to unlatch a closed door within the home. It opens the desired door by simply stepping on a foot pedal that protrudes from the wall adjacent to the door (Figure 11.21).

The mechanism also allows the door to function normally as it is intentionally designed. This feature allows those who do not need assistance to open doors using the still functional door knob. Also, the mechanism has limited modifications to the external appearance of the doorway, drawing little attention to the installed assistive device.

SUMMARY OF IMPACT
The intent of the Hands-Free Door Opener is to allow persons with limited use of their hands to move freely about their home, while maintaining the traditional functionality of the standard home interior door.

The Hands-Free Door Opener also has a minimal effect upon the aesthetics of the doorway because most of the functioning parts of the mechanism hide within the wall adjacent to the door.

The Hands-Free Door Opener can also prove useful to others. People who may have their hands full with a load of laundry can now open doors without having to put down what they're carrying. Also, pets can be trained to activate the mechanism by stepping on the pedal, allowing the pet to move about the home freely.

TECHNICAL DESCRIPTION
The hands-free door opening device was designed using a three dimensional computer aided drafting software; this helps ensure that the multiple components of the final assembly work properly in unison. The implementation of the 3-D CAD software also allows the designer to make revisions to a working computer generated model of the assembly. These revisions using the software limit the modifications once the building process begins and reduces the time necessary to manufacture components.

Depressing the foot pedal causes four linkages pinned to one another in two places to operate much like a scissors jack found in a car. This action creates a vertical linear motion that is transferred through a vertical link. The vertical link then transfers this vertical motion into a horizontal motion via a third
set of linkages that connect across an angle to the pushrod. Machined guides and channels constrain both horizontal and vertical motions. This horizontal motion of the system is within the pushrod component of the assembly. The pushrod is a piece of round bar stock that travels within a custom bored bar that acts as a bearing and a main support to the system. As the pushrod moves from the initial starting position of the system, it travels within a hole drilled through the doorjamb. Once the rod is through the doorjamb, it makes contact with the rack and spur gear assembly. The pushrod moves the rack across the spur gear initiating a rotation. The spur gear is rigidly attached to the neck of the door knob, and as the spur gear rotates, it also rotates the door knob. As the door knob rotates, it unlatches the door from the frame, and the door can now swing open. A spring loaded plunger located in the top corner of the door jamb assists the door in swinging open. The plunger pushes the door open the first few inches so that it will not become re-latched once the foot pedal is released (Fig. 11.22).

Each of the above steps describing the operation of this mechanism occurs simultaneously, allowing the door to open almost instantaneously when depressing the pedal. The Hands Free Door Opener also resets itself after each use via a tension spring within the mechanism that retracts the mechanism back to its initial starting position so that it doesn’t interfere with the door closing.

Adjustability of the mechanism was also a concern when creating this design. To allow for variations in doors, the supporting guide rails also include adjustable mounting flanges at each mounting location. The flanges allow the user to install the mechanism between wall studs of varying distances. Also, the adjustable flanges allow the mechanism to be installed at varying heights to accommodate multiple door knob heights. These flanges therefore allow for the minor dimensional differences found in every home application.

Another design concern was the aesthetics of the doorway. To prevent the mechanism from being noticed, the linkages, support rails, guide pieces and pushrod are hidden within the wall adjacent to the door. Since all the moving parts hide within the wall this prevents the mechanism from detracting from the aesthetics of the doorway and the rest of the room. The only noticeable feature of the Hands Free Door Opener is the foot pedal that protrudes from the wall near to the floor, out of the ordinary line of sight.

Materials chosen for the assembly’s components assure the longevity and smooth operation of the mechanism.

The linkages, pedals, guide rails, rack and spur gear were designed using mild steel because the strength of steel is required, and steel is an inexpensive material to purchase for the manufacturing.

The push rod is manufactured using brass because the pushrod rides within a steel cylinder and through the studs of the door frame. The brass will not gall with the other materials and will provide a good bearing surface.

All the pieces that are designed to be guides, intending to ride within the guide rails, are made from nylon. Nylon is a good bearing material for moving parts because it is a self lubricating. Also nylon is an inexpensive material and is easily machined. The total cost for this project was $900.
INTRODUCTION
Anyone who has ever had an arm or wrist injury on their dominant side knows the difficulties that exist when performing any activity that involves gripping motions of the hand, especially when writing and typing. The use of a cast to brace the injured limb, or the inability to completely close the hand entirely, prevents the individual’s ability to write and type with ease. This device addresses both of these issues.

SUMMARY OF IMPACT
Many products on the market assist individuals to write and type. However, almost all of these products are designed only for persons with arthritis or some other injury in which the subject does have limited use of a hand. They use the hand to push or pull the assisting device. The reported design is unique in that it targets individuals who have no use of their dominant hand. The device will permit cast-wearing individuals to write and type freely and easily, without sacrificing handwriting legibility and typing error.

TECHNICAL DESCRIPTION
The device consists of a quarter-inch inch thick, 12 inch long piece of polycarbonate machined to fit comfortably to the round shape of the arm. A 1/16 inch layer of latex coats the “sleeve” for added comfort providing a non-slip surface.

Attached to the end of the sleeve is an original design of a clamping mechanism composed of aluminum. At the end of an angled arm, two thumbscrews tighten and loosen the clamp to hold writing devices of variable sizes.

Two hook and loop adjustable Velcro straps secure the entire device to the side of the cast-bearing or injured arm. The individual will use his “good” hand to hold the device on its side, then slip the injured arm underneath the strap loops, and finally tighten the straps to a desired holding fit.

With the device now held onto the arm, the individual places the writing tool in between the two v-shaped notches of the clamping mechanism, then tightening the thumbscrews until the writing tool is held firmly in place. The individual will move his or her arm with the attached device in order to write.

To type, the individual again places the device on the side of the injured arm, but will rotate the arm downwards as if to type normally. The typing tool, made from acrylic tubing with hard rubber inserts, is then placed in the clamping mechanism, which is then tightened to a firm hold by the thumbscrews. The typing tool will act as a finger on the injured hand, and in conjunction with the use of the “good” hand, will allow for multiple keys to be pressed at one time.

A number of people, using an Ace Bandage to simulate a totally disabled hand, tested the device. The tests resulted in legible handwriting and easy, accurate typing (Figures 11.23 and 11.24).

The total cost of the project was $48.
Figure 11.23. Cast Attachment for Typing.

Figure 11.24. Cast Attachment for Writing.
UNIVERSAL ADJUSTABLE SUPPORT
WHEELCHAIR ATTACHMENT

Student Designer: Nicholas Larratta
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Client Coordinator: Dr. T. J. Mountziaris
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INTRODUCTION
The objective of this project was to design and build a collapsible attachment that would provide head, neck, and chest support for individuals who use wheelchairs. Similar existing devices only serve electric wheelchairs and can rarely attach to collapsing wheelchairs.

The design must possess the following characteristics: 1) easy to assemble, 2) user friendly, and 3) providing upper body and head support. The Universal Adjustable Support was designed specifically for and will be used by an individual with Multiple Sclerosis.

SUMMARY OF IMPACT
This device was not designed for one particular model of wheelchair, but rather most collapsing and non-collapsing wheelchairs models available (Figure 11.25). This device is unique because the user can collapse the wheelchair without removing the head support.

TECHNICAL DESCRIPTION
This design utilizes the wheelchair’s existing bars, meant for back support, for easy attachment by four U-bolts that fasten to the lower parts of the wheelchair’s handlebars. Two U-bolts attach above the back support and two attach below the back support of the wheelchair (Figure 11.26).

Two vertical telescoping poles extend in length and hold the chin rest-supports at the top. Custom brackets, attached to the U-bolts and the two telescoping poles, allow the vertical poles to be placed between the handlebars. This design eliminates any contact between the two poles as well as any contact with a user’s hands pushing the wheelchair.

Two aluminum bars, mounted perpendicularly to the vertical poles, provide support for the headrest mount and also provide stability for the two horizontal poles (Figure 11.27). A horizontal bar, located on the lower part of the device, provides additional support by connecting the two vertical poles to minimize movement. The headrest-mount
attaches with clamps, adding adjustability to accommodate each individual’s head position.

The swing-away chin rest utilizes the swivel motion of the telescoping poles so the chin rest can be moved out of the individual’s way when not in use. The chin rest itself is a strap that loops around the two support bars and connects with Velcro.

The head support mounts between the chin rest support bars. The head support can provide a variety of head support heights preferred by the individual due to telescoping capability.

A strap provides support to the chest by wrapping behind the wheelchair and then across the chest of the person. It is secured tight by Velcro.

The device is connected by a variety of bolts, lock washers, and locknuts so that the parts are very secure to one another. For safety, rubber caps are used on the ends of the poles so no sharp or rough edges are present. Bolt ends face inward so they are out of the way of the user and also allow easy adjustment if needed.

The total cost of this project was $520.
INTRODUCTION
The PDA Magnifier is an attachment designed for most personal digital assistants to help visually impaired individuals read on-screen text (Figure 11.28). It is composed of a magnifying glass and a line reader to help amplify and isolate a line of text making it easier to read. The PDA Magnifier detaches to maintain the size and convenience of a standard personal digital assistant.

SUMMARY OF IMPACT
An estimated 7.9 million persons (age six and older) have difficulty seeing words and letters in ordinary newspaper print, even when wearing glasses or contact lenses.

People with vision impairments have difficulty seeing small lines of text. The PDA Magnifier has the ability to magnify and isolate individual lines of text, making it easier for the visually impaired to use a personal digital assistant. While other PDA magnifiers exist in the marketplace, no magnifier is equipped with a device to isolate a line being read.

TECHNICAL DESCRIPTION
The PDA Magnifier was designed to amplify and
isolate the text displayed on a PDA screen while maintaining its size and convenience. Key features are described here.

**Magnifier.** The lens has 4x-magnification to help those with more severe vision impairments. The lens can slide in all directions and does not have to be adjusted for focus. The magnifier mounts to the device using a 4-40 x ¾ inch screw so that positional adjustments can be made if needed.

**Line Isolator.** The line isolator is a thin slider made out of lightweight polycarbonate that can move along the face of the PDA to help the user read one line at a time.

**Overlay.** Provides a central location for the magnifier and line isolator to be mounted. This feature also allows the device to be detached easily.

**Easy Attachment/Detachment.** The PDA Magnifier attaches to a PDA using Velcro for easy attachment and removal. Each individual piece (magnifier, line isolator, and overlay) can also detach separately.

**Lightweight Materials.** Lexan and similar polycarbonate materials are used because they are light and durable, helping to maintain the convenience of the PDA.

**Aesthetically Pleasing.** The PDA Magnifier blends well with the device and does not draw unwanted attention to the user.

**Compatibility.** Can be used with most PDAs. The magnifier’s position can be altered to create more room whether an individual is left-handed or right-handed.

The total cost was $50.
PATIENT TRANSFER DEVICE

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INTRODUCTION
A device which ensures safe patient transfer for not only the patient, but the caretaker as well, is needed. This project is a proof-of-concept prototype of such a device.

SUMMARY OF IMPACT
This device ensures patient transfer of two types 1) from an ambulance stretcher or cot to a bed, and 2) from bed to bed.

Bed-to-bed transfer is the most common transfer technique for patients. This requires caretakers to lift the patient via a bed sheet or backboard. When a backboard is used, where the patient is rolled over on his side, then the backboard is placed under the patient and after rolling the patient back on, lifting is still necessary to transfer the patient to the next bed.

The device’s design essentially removes the lifting from patient transfer by introducing a sliding mechanism (Figure 11.29). Two heavy duty drawer slides are the muscle in this device, attached to a polycarbonate board and strapped to the cot or stretcher. The device works similar to the backboard, and looks similar with its handles on the sides and top. Once the patient is rolled over on his side, the device is slid under. Once the patient is on the device, he or she is slid over safely and swiftly.

Lifting has been removed from patient transfer making it safer and easier. Other similar devices exist, such as a low friction cloth where the patient is slid from an adjacent bed. Though the cloth eliminates some lifting, it must be completely placed under the patient before sliding can take place.

TECHNICAL DESCRIPTION
Simplicity is an essential part of this design. It consists of three major parts. The backboard is made of polycarbonate, a plastic just as strong as steel. The board measures 24 inches x 48 inches x 0.5 inch, which fits most stretchers, hospital beds and cots. These dimensions also make up the major dimensions of the device. Holes are cut for handles to decrease the weight of the total structure.

The drawer slides are standard heavy duty steel slides. They have a 450 pound load limit at an 18 inch spread. This design has the slides about 24 inches apart, but the load is also distributed into the backboard. Screws attach the drawer slides to the board.
Nylon straps add stability to the structure. The device is not meant to be in its open position by itself; this would cause the whole stretcher to tip over due to an imbalance in moment. The straps are held on by an epoxy adhesive.

The device itself weighs more than expected; a production model should be lighter and therefore easier to store. The cost of this device was $260.
INTRODUCTION
The goal of this project was to design a device that could hold a coat steady for its user so he or she would only have to guide his or her arms into each sleeve.

This design consists of a slider and track assembly that attaches to most coat racks (Figure 11.30). Two adjustable arms, each fitted with two spring clips, attach to this slider. Once moved into place, a coat may clip on in an “open” position to help its wearer get each arm into the sleeves with minimal twisting and movement (Figure 11.31). After the coat is on, the user has only to reach to the neck and unclip the coat.

SUMMARY OF IMPACT
The two 12 inch arms meant to hold the coat in place are each fitted with a pair of small clips, one at their far end and one at their midpoint. These arms rotate horizontally around pin joints used to fasten them to the slider extension. Each clip passes a test to ensure they are strong enough to hold a coat of approximately three pounds. This ensures that there is more than one way to clip a coat into place. In addition, the slider-track assembly provides approximately 20 inches of height adjustability. The combination of these successfully-completed design goals ensures that any type of coat may be held steady and “open” over a wide range of heights. There are no such similar devices on the market.
today in terms of function or design.

**TECHNICAL DESCRIPTION**

The first design challenge was to construct a device to mount on common coat racks and still have adjustable height for different users. This feature was achieved by modifying a steel bar clamp so that only its steel track and sliding head were present. The sliding head of this clamp could be adjusted by two disc clutches that, when released, held it rigid on the track. The rest of the device could be built off of this slider. The steel track is attached to the coat rack vertically by a pair of pipe clamps at its top and bottom. These were fitted with several layers of rubber gripping for increased strength.

The second design challenge was to create an arm holder that could attach to the slider-track assembly and hold two aluminum arms steady. This was accomplished by creating a horizontal surface atop the slider with a vertical wall at its front that extended down to the slider. Two hinges were mounted on this aluminum surface so that they extended to either side of the coat rack neck. A pair of small steel plates was then attached to the extended ends of each hinge. Each pair of steel plates sandwiched the end of a 12 inch arm. In this way, each arm holder could flip up into a vertical position that allows its arm to hang down and out of the way when not in use. In a horizontal position, the arm holders allowed the arms to be adjusted horizontally and are supported by the vertical wall portion of the horizontal extension to the slider.

The device worked well in holding several different coats and was used successfully by the five senior citizens who helped us test it.

The final cost of the design was approximately $75.

Figure 11.31. Coat Rack in Use.
PROSTHETIC HAND FOR MANIPULATION OF FOREIGN OBJECTS

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INTRODUCTION
Amputations and birth defects that result in a missing hand can limit an individual’s daily functioning. A partial hand is still limiting, but is much more useful for accomplishing tasks than most prostheses. The purpose of this project was to develop a mechanical prosthetic that could function as a hand. This prosthetic has three fingers to allow simple grasping of objects (Figure 11.32).

To save weight, the motor unit, gearbox and electrical power supply are stored on a location off the prosthetic to minimize muscle fatigue in the user.

SUMMARY OF IMPACT
This device should provide a relatively simple, lightweight and cost effective prosthetic hand for use in simple tasks. Electro-mechanical actuation of the device eliminates cumbersome body movements to power the device. A bicycle brake cable transfers motion mechanical energy without adding to the weight of the hand.

Figure 11.32. Prosthetic Hand with Straps.
TECHNICAL DESCRIPTION
The prosthesis consists of three connected units (Figure 11.33). The control unit mounts around the user’s chest and consists of two sets of two switches located under each arm. The operator presses the left or right arm into the switches to send electrical current to the motor unit.

The motor unit consists of a nine-volt motor connected through a series of gears to an elastic belt that runs from the gearbox to an aluminum spool. This spool collects or expels nylon string as it rotates. Finally, the string connects to a bicycle brake cable that then connects to the hand unit.

The hand unit consists of a base that connects to the artificial fingers. Through the hand unit and the fingers, nylon cords swing to provide tension and curl the appropriate fingers.

The artificial fingers in this device mimic the articulation of human fingers. Nylon strings act as tendons to flex the aluminum digits and allow the power supply and the motor to be located off of the arm to minimize muscle fatigue.

The direction of finger movement is controlled by the polarity of the current running through the motor. The control unit consists of a simple circuit to send one of two current polarities through the motor depending on which set of switches is activated.

The total cost of the device came to $71.
REMOTE VISION RETRIEVER FOR LOCATING AND RETRIEVING OBJECTS IN AWKWARD PLACES

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INTRODUCTION
Many elderly people and individuals with disabilities find it difficult to pick up objects that have fallen beneath household furniture or appliances. Therefore, a device was created to aid individuals with the strenuous task of bending over to retrieve objects (Figure 11.34). This design is particularly useful for individuals who use a wheelchair.

SUMMARY OF IMPACT
This design idea differs from conventional mechanical grabbing devices because it utilizes a flexible hose between the handle and the mechanical hand which grasps the desired object. A visual system is implemented to allow the operator to see what will be grabbed without actually having to see the object. Therefore, this device can locate lost objects in confined spaces.

TECHNICAL DESCRIPTION
The design is composed of three basic systems. These are the structural, visual, and mechanical hand.

The structural system consists of the handle junction box, mechanical hand bracket, and a flexible hose, which connects the first two components. The handle junction box consists of two handles for possible two-handed usage while also supporting the liquid crystal display screen. A flexible, but rigid hose allows the mechanical hand component to enter confined spaces at any desired angle or length. Also, another advantage of the flexible hose is the ability to place the video and brake cable through the hose, making the device aesthetically pleasing. The mechanical grabber bracket serves a duel purpose to support the mechanical hand as well as the pinhole camera.

The second system is the visual system (Figure 11.35). A pinhole camera, video cable, video adaptor, and liquid crystal display screen make it possible to see images of the lost object. The size of the camera allows it to fit into confined spaces. The LCD screen size is convenient because of its low weight and small size.

The mechanical hand system is created from a set of bicycle brakes (Figure 11.36). Though the design is slightly modified for attachment purposes, it operates the same as it would on a bicycle. Squeezing the handle causes the brake pads to pinch together, grasping the desired object.
Overall, the proof-of-concept adequately satisfied the design criteria. The total cost of the project was $410.

Figure 11.35. Visual System.

Figure 11.36. Mechanical Hand System.
INTRODUCTION
The objective of this project was to design and produce a one-handed earring fastener. The need for this device was simply to ease the insertion and removal of earrings from the ear lobe. The main audience for this product was individuals with the use of only one hand, the elderly, and/or those who do not have finite control over manipulating small objects.

SUMMARY OF IMPACT
The product was designed as a simple clamping device similar to a single hole punch, though requiring much less strength. The product was designed only for existing earring holes, not for creating new ones. The user no longer needs to rely on assistance in inserting or removing earrings.

TECHNICAL DESCRIPTION
The E-Z Earring is a single-hinged (with a brass pin) clamping device constructed from lightweight aluminum. The product consists of two “arms” (Figure 11.37).

The narrower arm has a small notch for the earring post with a small plastic flap acting as a cover to hold the earring post in place. The wider arm has a wider notch as well as a thin notch running perpendicular to it. This end holds the back of the earring. Obviously, not all earring types are able to fit in this device, there is room for the further adaptation on the product, but it is set up for the most basic earring types.

The concept of the product is that the earring post inserts into the narrow arm and the back of the earring into the wide arm (Figure 11.38).

The earring post then gets gently inserted into the existing earring hole in the ear lobe. Once the post is inserted, the two clamping arms bring the back of the earring forward, sliding it on to the post. Once the back is in place, the device is gently pulled downward to release the earring and back from their respective notches. The user reverses the process to remove the earring.

The E-Z Earring created does not meet the requirements to perform its objective. Due to machining and tool limitations the proper alignment could not be achieved. The process is difficult for even two-handed manipulation. It is, however, easier to take off an earring rather than inserting and clasping an earring. The design could work if the original design concept could be fully realized.

Total cost of this project was $11.
Figure 11.37. E-Z Earring.

Figure 11.38. Arms with Earring Inserted into Notches.
INTRODUCTION
As individuals age, loss of strength and balance can make operations that require bending and lifting both difficult and dangerous. For many elderly individuals, a fall will result in the need for medical attention. This project’s objective was to enable an individual in a health care facility to access the contents of a bottom dresser drawer without bending over.

This goal is accomplished by elevating the bottom drawer (Figure 11.39). Importantly, any modified dresser design must retain the original storage capacity and utilize the same physical space as a traditional dresser. Assistive device implementation often draws embarrassing attention to the user’s disability. For this reason the finished product should not draw attention to the user’s disability.

SUMMARY OF IMPACT
This device makes it possible to place items in and retrieve items from the bottom drawer of a dresser without bending over. Although this device was specifically designed to assist elderly individuals in a health care environment, other groups can equally benefit from this design. Such groups include individuals with back problems restricting their bending motion and individuals who use wheelchairs.

The automatic dresser design completely conceals its nature as an assistive device when not in use. In a health care environment, this device will often be used by individuals without any disability, such as nursing staff or family members. For these individuals, the time required to raise and lower the drawer may be undesirable. To account for these situations the dresser can operate both manually as well as automatically. During manual operation the drawer will slide in and out, but will not have the capability of raising and lowering.

TECHNICAL DESCRIPTION
A pair of double scissor jacks elevates the bottom drawer (Figure 11.40). Scissor jacks were chosen because of their ability to extend to several times the collapsed height. An ACME screw driven linear actuator raises and lowers the scissor jacks. This type of actuator is chosen because of its load carrying characteristics. While spinning, the screw will move the jacks. An individual cannot cause the screw to spin by attempting to move the jack.
Therefore, the load placed on the jacks will never affect the drawer’s height.

An electric motor powers the device to minimize noise and to work with standard wall outlets. A power supply is built to convert the AC power from the wall outlet to DC power, required by the motor.

A design objective for this device is that the drawer should elevate with up to a 60 pound loading. Because the anticipated actual load that the drawer will experience is 30 pounds, this gives a factor safety of two. Calculations based on this design parameter and the physical dimensions of the dresser, jacks, and linear actuators available resulted in an asymmetrical jack design where the top halves of the jacks are slightly shorter than the lower halves. This is required because the extended length of the linear actuator (attached to the base of the jack) is greater than the length of the drawer (which attaches to the top of the jacks). The asymmetrical jack design also results in a requirement of a linear actuator capable of applying 300 pounds of pulling force at the base of the jack to support a 60 pound load. The linear actuator used is capable of providing 1350 pounds of pulling force at a rate of 9.4 inches per minute (under full load). Because the actuator does not operate under full load, it is able to travel at a rate of over 100 inches per minute. This allows the drawer to elevate the 20 inches required to reach its full height in 11 seconds.

While the drawer is raised and lowered automatically, the prototype does not offer a means of pulling out the drawer automatically. To accomplish this task bending, one must use a short rod with a hooked end to pull on the drawer handle. One other feature not incorporated in the prototype but is essential in a production model is switches attached to the upper drawers that allow the drawer to elevate if the drawers directly above are shut. This prevents the bottom drawer from elevating into the drawers above potentially causing damage.

The jacks for the prototype mount on the inside of the bottom drawer, avoiding excessive modifications to the original dresser. The jacks are constructed from aluminum channel to allow the jacks to be lightweight, strong (under a bending, torsion, or axial load), and thin enough to fit inside of the drawer without removing a significant amount of storage space from the drawer. A single actuator ensures that both of the jacks raise and lower at the same rate. The actuator mounts to two cross-members that connect the bases of the two jacks. Attaching the cross-members at right angles to the two jacks eliminates their ability to move independently of each other. Therefore, the left and right sides of the drawer are always the same height (system has one degree of freedom).

The total cost of this device is $550. Of this cost, $300 resulted from the cost of the original dresser.
DETACHABLE BATHTUB GRAB BAR

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INTRODUCTION
This project addresses a problem that affects individuals with disabilities or elderly people while bathing alone. Standard bathtubs do not have a hand rail on the exterior side to provide leverage to lift oneself out of a bathtub.

The objective of this project was to design and build a device to clamp on the exterior wall of a bathtub. Because the aesthetics of the home should be maintained, the device must detach and not mar the bathtub surface.

SUMMARY OF IMPACT
A device was successfully designed, built and tested that attaches to the exterior wall of a bathtub. This detachable bathtub grab bar device will now assist the elderly and people with disabilities by providing leverage to lift oneself out of a bathtub (Figure 11.41).

TECHNICAL DESCRIPTION
The device has adjustability and will mount on an exterior bathtub wall as narrow as two inches and as wide as seven inches. To provide leverage, the handle sits twelve inches above the surface of the exterior bathtub wall. The person installing the device needs a 5/8 inch socket or wrench to secure the device onto the bathtub.

Because the device will come in contact with water and humidity, it is constructed out of aluminum and stainless steel to prevent corrosion. The low weight of aluminum reduces the overall weight of the device. A lighter product will be easier to maneuver when attaching and detaching from a bathtub, making it more marketable.

The contacting surfaces of the device on the bathtub are a non-slip material manufactured by Dycem. The non-slip material does not damage the bathtub surface. This material is durable in water and has an adhesive backing which adheres to the aluminum plates. Dycem’s non-slip material passed a test where a 225 pound person lifted himself out of a bathtub without assistance.
Figure 11.41. Bathtub Grab Bar.
TIRE CHANGING KIT: MAKE IT EASY TO CHANGE SPARE TIRE BY USING BODY WEIGHT

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INTRODUCTION
Many individuals have difficulty changing a flat tire because many factory-installed devices are not well designed. The basic concept of the reported design originates from the Armed Forces. Drivers are trained to change one tire on a four-ton truck within 2.5 minutes. The reason it is possible to change these big tires in a short time using a simple wrench is that the tire changer uses a safety jack to firmly support the wrench. With the wrench secured, the tire changer can jump on the big wrench to create enough torque to unscrew the nuts (Figure 11.42).

The primary advantage of this device is that this supporting process makes it possible to change the tires easier and quicker.

The hardest part of changing tires is unscrewing the nuts when the nuts are rusted or tightened. Using the supporting process, body weight or a kicking motion will create more torque easily and safely. The regular “L shape” or “Cross shape” wrench installed from the factory can buckle easily when trying to unscrew lug nuts by kicking the wrench or jumping on the wrench because there is no support.

Figure 11.42. Tire Changing Kit in Operation.
SUMMARY OF IMPACT
Along with the wrench installed in the car, “tire changing kits” from stores or web sites do exist. However, they are expensive, complicated, heavy, and large. Thus, this assistive device should incorporate two main ideas: 1) Support the wrench to make it safe for kicking or jumping, and 2) Design a compact and multi-functional device.

TECHNICAL DESCRIPTION
As Fig. 11.43 shows, the compacted shape is book-sized and the entire component stores inside of this box for simple storage in the truck. When an individual needs this tool, he or she can simply assemble this device and use it.

Figure 11.44 shows the assembled device. The device’s height adjusts by moving up the teeth and by rotating the top part (there is a screw inside of this part connected to teeth). The range of the height is from seven to seventeen inches from the ground to reach from lowest screw to highest screw when the tire is flat. The telescopic wrench allows torque adjustment by changing the length. In addition, after adjusting the height, this device can quickly unscrew the nut by jumping on the wrench.

Components are: two base plates, teeth, T-shape top part, locker, six screws and nuts, wrench, connector, two supporting wings). Materials include steel for the teeth and teeth locker and aluminum for the base plate and top of the jack.

The total cost of this project is $67.
RADAR OBSTACLE DETECTOR

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INTRODUCTION

Individuals with visual impairments have difficulty detecting stationary obstacles in their surroundings. With moving objects, individuals with visual impairments can detect the object from the direction of the noise made by the moving object, but for stationary objects, there is no way to locate the object unless the person is close enough to touch it. However, some objects are hazardous to touch, such as hot ovens.

Currently, the most common device for individuals with visual impairments to detect stationary obstacles by range is the white stick. The limitation is that the users have to come into close contact with their surrounding to determine the location of the obstacle.

SUMMARY OF IMPACT

The main purpose of this design project was to design a handheld device that is small enough to carry to assist in detecting obstacles in the surroundings. There are some ranging systems on the market, but they are expensive. An objective of this project was to make it as low cost as possible. This device will expand the detection range to the surroundings and reduce the dependency on the white stick.

The handle sends out an ultrasonic signal to detect the obstacles in the surroundings. When the ultrasonic signal hits the obstacle, the device receives the reflected signal. The signal is then transmitted and processed by the ranging module and microprocessor to send out beeps telling the user there is an object in the direction pointed.

TECHNICAL DESCRIPTION

This device has two parts, the handle and the case. The case encapsulates the entire electronics assembly and the handle provides a secure location to hold the device. The handle and the case are connected by wires. (Figures 11.45 and 11.46).
batteries are connected to the 9th Pin of the Module and grounded.

A large capacitor is added between the GND and V+ to avoid voltage drop and to maintain a stable voltage current. The 8th Pin of the Ranging Module Output is grounded to reduce unwanted noise. The INIT-pin connects to the +5V-pin in the Motor Port of the Handy Cricket, and the ECHO-pin connects to the “Sensor Signal Input”-pin in Sensor Port of the Handy Cricket. All of the Ports will be grounded.

After applying power to the Ranging Module, the INIT goes high after a minimum of five milliseconds elapsed. During that time, all internal circuitry in the Ranging Module is reset and the internal oscillator stabilizes. When the INIT is taken high, drive to the Transducer XDCR output occurs. Sixteen pulses at 49.4 kilohertz with a 400-volt amplitude excite the transducer as transmission occurs. The transmitted signal travels at the speed of sound, approximately 343.2m/s. When the transmitted signal hits the object, it reflects back to the transducer. After the transducer receives the returning signal, the ECHO goes high. The microcontroller will process the signal of the ECHO output and signals the user of the object.

Total cost of this project was $300.

Figure 11.46. The Detector's Electronic Design.
NSF 2003 Engineering Senior Design Projects to Aid Persons with Disabilities
CHAPTER 12
STATE UNIVERSITY OF NEW YORK AT STONY BROOK

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HAND-DRIVEN TRICYCLE

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INTRODUCTION
The hand-driven tricycle is a mobile physical therapy device. The goal was to create a device that will encourage young students to participate in physical therapy. It will be a fun toy and allow the student to increase his strength and overall health. The tricycle will also be a device for students with disabilities who want to be active. The vehicle will require the rider to have gross motor skills in the upper body. Students with little or no functionality in the lower body are the target user group.

SUMMARY OF IMPACT
The Hand-driven Tricycle will allow students, capable of using their upper-body, to exercise. The new design differs from many other products that are mainly for adults and/or require the rider to use all of their limbs.

TECHNICAL DESCRIPTION
The Hand-driven Tricycle is a completely mechanical system. It utilizes linkages, sprockets and chain to perform all of its functions. The vehicle is powered when the rider performs a bench press motion that drives a chain ring located at the base of the arm. This chain ring then drives the sprockets at the rear wheel, moving the vehicle forward. The design of the rower arm allows the user to perform turns at any position during the stroke. The outer sleeve of the arm actuates the steering linkage via two links [the rabbit ears]. The steering and power generation systems are incorporated into one unit to facilitate the target users who only have use of their hands and arms.

4130 Chromoly tubing is used to construct the chassis. Some of the tricycle’s features include: 1) Ackerman steering geometry for better vehicle control, 2) center-patch steering to reduce wheel scrub, 3) self-centering steering, 4) six strength settings to accommodate drivers with varying abilities, 5) drum brakes in the front wheels and a seat belt for safety, and 6) an inclined seating area to accommodate drivers of varying heights.

Figure 12.1. (a) The Hand-Driven Tricycle. (b) Tricycle in Use.
Figure 12.2. Model of the Hand-Driven Tricycle.
INTRODUCTION
The goal of this project was to develop a multifunctional wheelchair. It is usually difficult for a wheelchair user to be transported into or out of a chair. This chair will allow its user to stay in the chair for many daily activities that he/she normally has to be transported out of. As a result, there is less physical strain on both the user of the chair and the person providing care.

TECHNICAL DESCRIPTION
The seat, originally from a Saab, has plush leather covers on the back and bottom support surfaces as well as the headrest. The seat and back support of the chair is made up of foam and individual air cells that could be inflated or deflated. A small pump used for medical purposes, powered by a 12 volt-DC battery inflates the air-cells. A single toggle switch controls two solenoids per air-cell, one for intake and the other for exhaust. Since the chair is made up of 10 separate air-cell regions, there are a total of 20 solenoids. When inflating an air-cell, the pump is turned on and the intake solenoid is opened for the corresponding air-cell. When an air-cell is deflated, only the corresponding exhaust solenoid is opened to allow air to vacate. The air cells provide the user with proper positioning and corrective alignment. By alternating air pressure one can counter pressure points and reduce the risk of tissue breaking down.

To optimize the seating further, the chair can recline, tilt and go into a lay-flat position. Two Bloco-lift gas springs will be used to assist in tilting the wheelchair. Each spring is mounted to the inner part of each side of the frame. The springs are connected on an angle to the bottom of the seat base. This setup provides optimum space for the air cell power components. The spring release is mounted to the respective side of the handle bar.

A provisional US patent application has been filed for this design.
Figure 12.4. Solenoid Assembly.
INTRODUCTION
The purpose of this project is to design a portable wheelchair-lifting device for a school. On many occasions, it is necessary to bring a wheelchair onto a stage in the auditorium. At present, the school’s faculty uses a wooden ramp over the main staircase to perform this task. Because of problems with the current lifting device, nearly half of the school’s facilities are inaccessible for a child in a wheelchair. A portable lift could be taken from the location where it is most widely used and easily be adapted to lifting children onto the stage during special occasions.

Operating the lift will need to be simple. The lift will need to be able to lift a maximum of 500 pounds. A vertical distance of approximately 30 inches and a horizontal distance of 40 inches are desired. It will need to be safe to operate. Maintenance required will need to be kept to a minimum.

SUMMARY OF IMPACT
This project assists a person in a wheelchair up a small flight of steps.

TECHNICAL DESCRIPTION
The lift has three major components: A steel main frame, linear bearing system and a control system. The linear bearings connect the platform to the frame while the hydraulic and electric control system raise and lower the lift.

The power unit consists of a DC motor, hydraulic pump, and reservoir. Calculations were performed to determine the type of motor and hydraulic pump. A common pump displacement is used to determine the horsepower and time. The area of the rod multiplied by its stroke length determines the minimum reservoir capacity.

Fig. 12.8 shows an electric schematic of the electrical system. An 110V AC plug is connected to a 110V AC to 12V DC Power Converter. The power converter is connected in series to a 12V DC battery to provide power to the motor and to charge the battery. The battery provides the necessary power
to run the motor when the power converter is not plugged in. The single pole double throw spring center switch is the switch used to raise and lower the platform. When the switch closes the circuit to the start solenoid, the motor is activated and the platform is raised. When the switch closes the circuit to the solenoid dump valve, the dump valve opens and allows the platform to lower. The normally closed switch is placed so that when it is depressed (circuit opens) the platform is at its maximum height and the pump no longer runs.

The total cost for the project was $1490. All the steel used for this project was donated and not calculated in the total cost.
INTRODUCTION
The purpose of this design project was to redesign the Pedalo, a pedaling device, in which the user pedals against his or her own weight. This device is purely mechanical with no steering capability. Redesign goals were to add steering capability and make it electrically powered and electronically controlled. Use of the original device requires that a supervisor have the user get off the machine in order to turn it around. Users of this device have little leg strength, so having them come off the machine every time it needs to turn around is difficult for both the user and the supervisor. The addition of a steering system eliminates this need. Through the use of a controller, the supervisor is able to turn the device around with the user on the machine.

SUMMARY OF IMPACT
This project develops an electronically controlled steering system to turn a rehabilitation pedaling device.

TECHNICAL DESCRIPTION
The LRD is supported by a chassis made of aluminum square tubing. To this chassis three subsystems, pedaling, steering, and driving, are attached. The pedaling subsystem consists of the pedals and the mechanism by which they are supported. The support mechanism includes pedal bars that rotate through bearings. These bars are similar to that which is used in a pedal boat. Attached to the pedaling subsystem is an activation motor (Fig. 12.12). Turning the pedals activates this motor which in turn activates the drive motors turning the wheels forward. The steering is determined by the controller seen in Fig. 12.11. The cylinder in the center controls the steering. The trigger allows pedal activation of the motors. The two buttons allow the supervisor to move the device forward and back without pedaling.
Signals from the controller go to a BASIC Stamp microcontroller seen in Fig. 12.11. The program written for the stamp includes safety commands. For example, the wheels are prevented from turning more than 45 degrees when the motors are active to prevent the user from tipping over. The wheels can be turned 90 degrees when the motors are off. Once they are turned, the motors can be activated again allowing the device to turn around. The LRD automatically stops when there is no input from the controller or the pedals.

The LRD is powered by two six volt batteries mounted on each side of the chassis. The batteries are rechargeable through the use of a typical power cord that can be plugged into the wall. The supervisor simply allows the machine to charge, flips the power switch, and it is ready for use.

All electronic and steering components are covered with a sheet metal exterior to protect the components as well as the user. Handlebars made from aluminum circular tubing are added to support the user. Fig. 12.9 shows the LRD ready for use.
MICROWAVE HOT WATER HEATER WITH TOUCHPAD INTERFACE

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INTRODUCTION
The objective of this project was to design and manufacture a working prototype of a digitally controlled faucet to assist individuals with physical disabilities. The requirements were: 1) variable flow capability, 2) enough power to increase the water temperature up to 100 degrees Fahrenheit, 3) a temperature range from 60 degrees Fahrenheit to approximately 100 degrees Fahrenheit, and 4) an accuracy of plus or minus one degree Fahrenheit. The user interface would have a touchpad small enough to be mounted anywhere on the unit.

The unit was designed to integrate an electromagnetic energy source, such as a microwave oven, and hydraulic components, such as poly flexible tubing and plumbing fixtures, and electronic equipment, such as PLC controllers, thermocouples, solenoid valves, relays, a voltage adapter, and a user-friendly interface module.

SUMMARY OF IMPACT
The user will input the desired temperature into the operator interface/controller. The controller will open a valve for the cold water pipe only, and allow for a constant flow rate. At the same time, the microwave’s magnetron will provide a sufficient amount of energy to heat the water passing through the microwave in order to achieve the user-defined temperature. This temperature change will be
limited to 15-30°F. The thermocouple will read the output temperature and change the power provided by the microwave to achieve the desired temperature.

**TECHNICAL DESCRIPTION**

The operator interface chosen was a Unitronics Operator Panel & PLC Controller, MN: M-90. The teams choose this device for multiple reasons. The first reason was affordability. The second reason was the number of inputs and outputs. The team did not want a large and bulky controller.

This unit was very small, having only 12 I/Os, which was more than adequate. The controller was powered with 12VDC, and drew 140mA. Two inputs can be converted into two analog thermocouple inputs. One thermocouple input was used for the outlet temperature reading as a feedback sensor. This established the power consumption and high temperature limit.

The water heater cavity chosen was a 1300W Panasonic Microwave oven, MN: NN-SS42BF. As an initial prototype, the team preferred to use a pre-designed cavity for safety reasons as well as the complexity in designing a cavity. The team was not qualified to perform such a task because of the lack of education and experience in that field. The microwave is 94.8 percent efficient, consuming 1370W and outputting 1300W. The microwave had two holes in the cavity to allow for an inlet and outlet. Microwave safe tubing was spiraled horizontally inside the cavity in a conical formation for complete microwave absorption and to eliminate interference from other coils. The team experimented with several spiral designs for the tube system.

The electrical control box was required to transfer power from the controller to the microwave and the solenoid valve. Figure 12.15 illustrates the electrical box layout. 120VAC entered through the bottom. The high end (brown) was fused to protect the microwave, and then sent to the terminal block and the low end (blue) was sent to the terminal block. The ground (green/yellow) was sent to chassis ground. 120VAC was sent to the 12VDC power supply, the 120-24VAC Transformer and the 24VAC relay. The output 12VDC (black/white, white) from the power supply (black/white, white) and the 24VAC from the transformer (red, green) then returned to the terminal block. 24VAC was sent to Ry1, which powered a 24VAC Solenoid Valve, and to Ry2, which powered Ry3, in turn powering the magnetron. Ry1 and Ry2 were energized with the 12VDC output from the PLC. Ry4 – Ry8 and 12VDC relays were soldered to the PCB inside the microwave. When energized, the relays short out switches on the control panel which are required to power the microwave.

This device cost $300, including all operating software.
INTRODUCTION
A wheelchair that reclines allows the user to be moved into a different position while remaining in the wheelchair, improving comfort, increasing circulation, reducing the risk of sores, and transferring the center of mass to another location on the body.

SUMMARY OF IMPACT
This project develops a slider mechanism and guide rail system that permits a reclining range of motion for the user. This wheelchair is simple to use and inexpensive to build.

TECHNICAL DESCRIPTION
This wheelchair is composed of four systems. The slider and guide rail mechanism, leg support, back support and head and neck extension. The main feature of this wheelchair is the slider and guide rail mechanism (Fig. 12.17).

The slider is capable of sliding along the guide rail and rotating for the reclining motion of the back support (Fig. 12.18). Leg and back supports are attached to the slider using T-tubing. The leg support can rotate independently while the back support is designed to rotate as the slider shifts forward. Once the slider shifts to the end position rotation will occur. Fig. 12.19 shows the 3D model of the reclining wheelchair.

Figure 12.16. The Reclining Wheelchair.

Figure 12.17. Slider and Guide Rail Mechanism.
Figure 12.18: Back Support Mechanism.

Figure 12.19: 3D Model of Wheelchair.
MOTORIZED WHEELCHAIR WITH OPTICAL GUIDANCE SENSOR SYSTEM

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INTRODUCTION
The purpose of this project was to construct a mechanism to aid in the mobility of individuals with physical disabilities and their caretakers. The device incorporates a sensory system and a remote control. It is designed for indoor use.

SUMMARY OF IMPACT
This project is a wheelchair that can be controlled by guided sensors, a joystick and remote control. The operator will be capable of traveling without requiring a great deal of physical strength. The sensory system will alarm the operator to deviations from a predetermined track and stop if the deviation persists. The accompanying remote will allow the supervisor to control the wheelchair if desired. In a school for children with disabilities, the ratio of children to teachers creates an environment difficult for supervision.

TECHNICAL DESCRIPTION
The chair will have seating that suits the child’s needs and will be covered with rubber to eliminate sharp edges that may cause injury. The electrical components and batteries will also be covered to eliminate injury or contact with elements such as dust and rain. The sensor will be placed under the chair and when activated, it will guide the chair throughout a room or building. The joystick will be placed on one of the arm rests and will also be used as a controlling device for the chair. The remote control is an optional safety device that will be used to override whatever command is give by the joystick. The remote is intended to be used by a supervisor or guardian of the child.

All the electrical components will be controlled by a BASIC Stamp. This component will receive all the inputs from the respective controlling device and output the commands. The electrical schematic of the motor circuit is shown in Figure 12.22.

The total cost for the project is $546.00.
Radio Control of 2 Motors
Complete System

Using a Standard RC receiver, Basic Stamp, Interface pcb, Two Motor Controls

Figure 12.22. Electrical Schematic of Motor Circuit.
PERSONAL WORKSTATION

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INTRODUCTION
The goal of this project is to design a personal workstation for an individual who uses a wheelchair, specifically a child at a school. The disability of the user can range from being unable to move the lower half of their body to not having normal coordination and use of all limbs. The user of the workstation should require no additional assistance to use the device. The advantages of the workstation include being able to modify the work area as well as other components. The workstation should be able to change to meet the needs of many users on a frequent basis.

SUMMARY OF IMPACT
This device should be judged on the success of the user when they interact with it. Aesthetics should also be addressed, but the true measure of the workstation should come from the satisfaction of the user and their production in using a safe and advantageous device. The overriding goal is to design a device that will satisfy individuals with disabilities.
TECHNICAL DESCRIPTION

The chosen design incorporates three subsystems to generate its automation. The first moves the desktop vertically. The second system rotates the back half of the desktop to create a rest area for a book. The third system lowers and raises a shelf to the user to store materials for work. The electrical components of the system are minimal. All working systems are controlled by two simple three-position switches.

The total cost for the project is $527. Some of the components, such as scrap metal, were donated.

Figure 12.24. Electric Diagram.
INTRODUCTION
The purpose of this design project was to design a lifting system that will allow an individual to be removed from a wheelchair to a height of one and a half meters or lower. This system will greatly reduce the physical strains placed on caretakers since the mechanisms will not require much physical strength or effort. Also, since this system is going to provide a reliable and safe means of transporting the person, the efficiency of transporting people from a wheelchair will increase for individuals who work with a large number of patients.

SUMMARY OF IMPACT
This project develops a lifting mechanism to lift an individual with disabilities out of a wheelchair.

TECHNICAL DESCRIPTION
As shown in Figure 12.25, the mechanical design of the hoist is composed of a lifting arm, a hydraulic jack, a base, an arm support and a body support. The lifting arm can be rotated in 360 degrees, it is 3.5 feet long and can be raised to a height of 8.5 feet. The base is composed of three 4.8 long steel plates and a 22 by 22 inch square plate. The hoist is used by assuring the lifting arm is set within the desired dismounting position. The lifting arm is placed in Figure 12.25. The Wheelchair Hoist.
the horizontal position and the wheelchair is then locked. The individual’s legs are then placed in the leg support (under knee caps) and attach the arm support to the main lifting arm of the swivel arm. Once the arm support is placed comfortably under the client’s underarms, the hydraulic jack is pumped, supportive for three tons or less, until the client is lifted to approximately one to one and a half inches above the wheelchair. The wheelchair must be unlocked and removed to a secure place. The deluxe hanging chair is placed on the swivel arm’s end hook. The deluxe hanging chair is adjusted securely under the client. The deluxe chair can support a weight up to 350 pounds. The sling is removed from the end hook of the swivel arm support. The hydraulic jack is pumped until the client is lifted to approximately two inches above the dismounting position. The client is slowly lowered onto the platform.

The total cost of this project was $460, including the cost of shipping.
BUILT-IN WHEELCHAIR RAMP

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INTRODUCTION
The goal of this design was to produce a ramp mechanism, which allowed the average adult wheelchair user to attain access to elevated areas when a handicap ramp is in absence. The ramp is to be entirely enclosed by the wheelchair and not prohibit regular usage of the wheelchair. It would be self projecting as incorporated into the design and permit easy retraction by the wheelchair occupant. This design does not require additional assistance to put the ramp down or retract the ramp. This allows the occupant ease of mind by not needing to find a handicap entrance ramp to gain access to an elevated surface such as a sidewalk. By permitting the occupant the ability to sooner enter an area, such as a sidewalk, may remove that person from a dangerous situation early. Also this relieves much unnecessary anxiety and associated stress from an already stressful situation. This ramp mechanism is being constructed as a fully mechanical device in its prototype phase. The addition of electronic controls and actuators will further enhance this device as an everyday asset. The ramp is also designed such that it may be rigged to any other wheelchair without gross adaptations.

TECHNICAL DESCRIPTION
The Wheelchair Ramp is to be a self contained mechanism that mounts to a preexisting wheelchair. This ramp does not require a special wheelchair to be built will have limitations as the length and height of the wheelchairs undercarriage. The ramp is mounted to the wheelchair as shown in Fig. 12.26. The ramping mechanism consists of two component systems. The first system is the self-projecting linkage. The second is a ratchet actuated cable retraction system. The self-projecting linkage is made up of gas charged struts that produce a linear force over a specific distance. A series of these links were used to produce the necessary path generation of the ramps.

The wheelchair’s occupant actuates the ramp on demand by releasing the retraction system ratchet. Once the ramps are in place the wheelchair may be rolled over the ramps and onto the elevated surface. At this point the cable ratcheting system then retracts the ramps, which are now behind the wheelchair but still connected. The cable ratchet system utilizes one cable to connect the ratchet to the connecting cable spool and one cable per ramp to connect to the connecting spool. The ramps are first folded from the horizontal position to the vertical position through the use of least resistive forces and leverage. Next, the ramp assembly in the vertical position is pulled up and under the wheelchair. The occupant stops the ratcheting motion when the ramp is fully under the wheelchair as identified by the inability to further ratchet the cable. This position is in a design position which allows the links to project forward when the cable tension is released.

The Portable Wheelchair Ramp is adaptive to most wheelchairs and weighs very little. It does not hinder the occupant’s ability to function the wheelchair and is composed of common materials. The total cost for the design is $488.
Figure 12.26. Ramp In Home and Projected Positions.
CHAPTER 13
UNIVERSITY OF ALABAMA AT
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THE CHILDREN’S STAIR TRAINER

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INTRODUCTION

A physical therapist requested a piece of playground-like equipment that could be used to teach stair climbing to children up to age five with disabilities. The product would be placed in an indoor gym-like playroom, but would need to be portable and small for storage in an area approximately five by 10 feet. Other requirements included: 1) the product should have two sets of stairs, preferably one set that is less steep than standard and one set that is standard stair height, 2) the product should be freestanding in the center of the play area, and 3) individual pieces must be light enough for two men to carry. Safety considerations were primarily for prevention of head or limbs being entrapped and to have no sharp edges on the product. The product needed a reward at the top of the stairs, and it was decided that a slide, safe for children with disabilities, would be ideal.

CPSC guidelines were as follows. Stair railings must be approximately 22 inches – 26 inches in height. Handrails must be 0.95 inch – 1.55 inches in diameter. All open spaces, cracks, or crevices must be less than 3.5 inches or greater than nine inches. The stairs were to be greater than 12 inches in width, depth must be greater than seven inches, and vertical rise must be less than nine inches, with slope less than 35 degrees to the horizontal. The slide must be less than a 30 degree slope with the horizontal, the height-to-length ratio must be less than 0.577, and must have sides of at least four inches for safety. The exit platform must be at least 11 inches. The top platform must be greater than 22 inches square, and have guard rails greater than 29 inches.

SUMMARY OF IMPACT

The physical therapist reported that the children use the trainer daily during playground hours. Children of various levels of ability are able to practice stair climbing, and receive direct reinforcement – a ride down the slide. The staff commented that the concentration of children playing on the stair trainer allowed for easier supervision of larger numbers of children.

TECHNICAL DESCRIPTION

In order to meet CPSC guidelines and customer requests, a tripod assemblage was designed comprising of two sets of stairs and a slide separated 120 degrees from each other connected by a central base. A composite made out of high density polyurethane foam laminated with carbon fiber were selected. The PUR foam with 6K tow plain-woven carbon face-sheet sandwich composites were produced using the hand lay up method. A four-foot by five-foot sheet of glass was used as the lay up surface. The PUR foam was cut to the appropriate shapes (stairs, risers, side panels, and platform) using a band saw. For each piece of PUR foam, a piece of carbon fiber was cut that would wrap around the edges and come together on the other side. Corner pieces of carbon fiber were cut to cover exposed corners.

The resin system used was F-82 resin and TP-41 hardener having a mixing ratio by weight of five to one, respectively. Resin was mixed and the carbon fiber was wetted out using rubber squeegees. The fiber was then transferred to the lay up surface. Microballon was mixed another batch of resin and was used to wet the surfaces of the PUR foam. Once wetted the PUR foam was placed on top of the wetted out fiber. The fiber was wrapped around the foam piece. A vacuum bag of appropriate size was used to cover the laid up sandwich composite, and was sealed to the glass sheet by the tacky tape. The part was then placed under vacuum for 24 hours. The part was removed from the lay up surface after 24 hours. The part was then grinded at the edges to remove any pooled resin. The glass surface was cleaned again and the processing continued until all pieces were completed. The pieces were fitted
together and FM-73, an adhesive film, was used to bond the components together.

Holes were drilled for placement of the hand railings and connection of the pieces. Bondo was used to fill in any gaps between the components. The exposed surfaces were sanded to obtain a smooth surface. Two layers of primer were used to coat the structures prior to painting. Several layers of paint were applied. The hand railing and the slide were then attached to the completed PUR foam/carbon fiber structure. The safety nets were then attached to the railings.

The completed project is shown in Fig. 13.1. Total cost was $1,349.

Figure 13.1. Children’s Stair Trainer.
INTRODUCTION
A physical therapist at a children’s daycare center proposed a device that would allow children with cerebral palsy, ages three to five, a means of locomotion by way of a hand powered cart. More specifically, the device would focus on children with insufficient muscle tone to mobilize a wheelchair. The occupant would be in a seated position, with both legs extended in front. The design constraints included: 1) allowance for child height and weight from the 25th percentile three year old to the 75th percentile five year old, 2) weight not to exceed 50 pounds and height not to exceed 47 inches, 3) minimal arm strength required to provide propulsion, 4) the children should have the ability to turn and stop the device with relative ease, and 5) enabling of staff members to manually propel the occupants.

SUMMARY OF IMPACT
The design assists children in coordinating arm movements to move forward and turn...
independently. Since the device incorporates a similar motion to that of wheelchairs, it is used as a training device for children with below average arm strength who use a wheelchair. The mechanical advantage of the device helps to bridge the gap between complete staff assistance and the conventional wheelchair. With this mechanical advantage, children may learn to mobilize themselves, increasing their independence, while relieving staff for attention to other tasks. The device increases endurance, enhances muscle tone, promotes peer interaction, and improves perceptual motor skills.

TECHNICAL DESCRIPTION

For the frame, the team chose to use 3/8 inch carbon ASTM A36 tubular steel, purchased in sections of threaded tubing, along with t-junctions, elbows, and sleeves. A modular frame was developed and welded into place to accommodate the rear bicycle wheels as well as the seat. The device was approximately 25 inches from the seat back to the footrest, and had a 30 degree knee flexion incorporated into it. The height of the seat back was 22 inches, so this will allow variability with children. The width of the frame (15.5 inches) was designed to accommodate the width of the seat, which was 14 inches. A push handle was welded onto the back of the device, approximately three feet high (35 inches), for control and access by the staff. The gear shifters were located on this push handle in such a way as to provide easy access.

The seat consisted of a molded plastic body bolted onto a metal supporting frame, and was taken from a children's stroller. The seat was vertically adjustable from 55 degrees to 125 degrees. A degree of declination was built into the frame by mounting the seat at a constant 15 degree angle. For trunk restraint, a three-point harness was attached to the seat. To restrain movement of the pelvis, another buckle was mounted parallel to the seat. The upholstery consisted of two one-inch thick padded cushions covered with black vinyl. The padding material was attached to the seat by strips of Velcro, which allowed the seat to be removed at the staff's convenience for cleaning. For the front leg/feet support, a diamond-plated sheet of aluminum was bolted in the horizontal plane of the frame. A second plate was added at an angle of approximately 70 degrees from the horizontal, to serve as the footrest.

Two large (one-inch) aluminum caster wheels were purchased, complete with bearings, to serve as the driving wheel. The driving wheels were coated with a red polyurethane surface and were threaded into the existing tubing using a one-inch sleeve. The rear wheels were custom-made 20 inch bicycle wheels, complete with spokes necessary to hold the gearing hubs. Two Shimano Nexus 4-speed internal gearing hubs were selected. A sprocket was mounted on the rear wheels that was approximately half the diameter of the sprocket on the driving wheel, thus decreasing the gear ratio by a factor of two. The final gear ratios were 1-.5, 1-.61, 1-.75, and 1-.92. The coaster brake version of the Nexus hub was chosen for its turning ability and it provided a means to abruptly stop the device. The propulsion system was covered by a sheet of aluminum bent at a 90 degree angle, and bolted to the frame of the seat. The rear wheels and spokes were not covered, similar to many bikes already present at Hand-In-Hand. The output force ratio, F2/F1 = 1.4, gave a 40 percent mechanical advantage. For the front wheels, free-swiveling casters with brake apparatus were attached to the frame. The frame, driving wheels and the footrests were painted with a red Krylon paint. Motion activated beacon lights were added to the rear tires.

While seated, the child turns the “driving wheels”, adjacent to the seat, which independently drive the rear wheels at a mechanical advantage to the child. The rotary gear-shifters are mounted on the rear handle.

The final product is shown in Fig. 13.2. Total cost was $1069.
INTRODUCTION
The purpose of the present design was to create a device which allowed children with cerebral palsy to sit and play in a sandbox. The design constraints were that the device: 1) contain a restraining system (seat belts and straps) capable of being loosened and tightened to keep the child’s torso at a desired angle, 2) not inhibit lateral, horizontal, or vertical motion of their arms, 3) be lightweight and portable, without compromising the structural integrity of the device, and 4) be corrosion resistant to water and detergents for cleaning purposes.

SUMMARY OF IMPACT
Cerebral palsy makes it difficult for many children to perform simple tasks such as sitting on the floor. The present design resulted in a greater number of children being able to participate in a greater number of activities.

TECHNICAL DESCRIPTION
The present project was based on a previous design developed by a senior design team from UAB. It was made of wood and aluminum. The wood was sealed with a non-toxic, dip-coating, which will further prevent warping and bowing associated with environmental conditions such as humidity and temperature. A hinge and lock design mechanism with positive locking pins maintained a backboard structure capable of positions ranging from 20 degrees (folded forward) to 125 degrees (completely extended). The back support rotated by a set of wide-leaf utility hinges, swaged for mounting onto the panels and zinc-plated to provide maximum protection against rust and corrosion. Locking pins were used to secure the back supporting structure at the appropriate angle. These pins were positive locking with ball bearings that lock the pin into its receptacle. The ball, ring, spring, shank, receptacles and spindle were made of stainless steel.

The sandbox sitter was lined with a urethane padding upholstered in washable vinyl. A four-point chest support strap (Bodypoint harness) along the back supporting structure was used to keep the spine and head erect and aligned. The straps were made of a polymeric material called Rubatex. Velcro attached the chest support to the back support and kept the child’s pelvis correctly oriented in the chair, stabilizing the posture and controlling movement in a neutral motion. Metal end-fittings and slides were provided for a strong, adjustable means of attachment. An adjustable footrest, purchased from a supply company, was held in place with a set of plastic dowels. A schematic of the final product is shown in Fig. 13.3.

Total cost was under $400.
Figure 13.3. The Sandbox Sitter.
CHAPTER 14
UNIVERSITY OF CONNECTICUT

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INTRODUCTION
The client is a 44 year-old man with cerebral palsy, dysarthria, moderate cognitive impairment, visual acuity trouble, limited dexterity, and limited upper body movement. He is an avid painter and continues to produce high quality work. Since his conditions limit the range of motion in his upper body, he is limited to smaller paintings. The client desires a devise that provides him with the ability to access larger works of art from a stationary position.

In order to satisfy this request, it determined that a movable easel provides him with a better platform from which to paint. The device is electromechanical in nature and provides the movement of the canvas through linear actuators. A joystick controls the movement. The entire easel is small and light enough to provide easy storage and not be overwhelming to the user. A photograph of the easel is shown in Fig. 14.1.

SUMMARY OF IMPACT
This client relies on painting as a way of expressing himself and his talents. Painting has also provided him with a productive means of income, as his paintings have been selling for increasingly higher sums of money. The design provides the client with an easel that allows him to paint larger works of art.

TECHNICAL DESCRIPTION
While many easels are produced, there are a limited number that adjust to or conform to a person using a wheelchair. Most easels have obstructions regarding the amount of legroom underneath the easel. The most common solution to this problem is a table-top version of the easel, which in this case did little to aid the user in the amount of area desired to be covered and was also insufficient in not having adjustable tilt capability.

The devise moves the canvas horizontally to enable the client to stay in a stationary position. It also tilts the canvas towards and away from him, giving him the ability to paint at any angle that best suits him. The angle of tilt also allows the client to see his canvas from different perspectives, which can be important when creating larger works of art. Sufficient legroom is also supplied.

The easel consists of an electromechanically driven easel mounted onto four detachable legs. A linear actuator with a 12-inch stroke length powers the horizontal movement, while the degree of tilt is driven by a linear actuator with an eight-inch stroke length. All of the operations of the easel are internally controlled by a microcontroller which is
integrated into a design circuit. Tactile user control is provided via joystick mounted in an ergonomically desirable position on the final easel frame.

Certain safety features included are limiting switches that determine maximum tilt or movement. A microcontroller program has the ability to use the limit switch inputs and override the joystick control should it still be actuated.

The joystick controls the horizontal and tilting motions. The signal from the joystick is relayed to a microcontroller that processes a signal and produces output that controls the linear actuators. The joystick requires a minimum of two degrees actuation to produce a sufficient voltage change when in use. The microcontroller is programmed to recognize this voltage change and output the correct action for the linear actuators.

All movements of the easel frame are provided by two linear actuators. A 12 inch horizontal linear actuator provides horizontal movement across two linear rails. A second actuator (eight-inch) controls the angle of tilt of the easel frame. Both linear actuators are able to power loads up to 100 pounds. Operating at 12 volt DC, speed is 0.5 inches per second, which is an acceptable speed for the client. These linear actuators also contain an internal limit switch that recognizes the limit of movement and shuts them down in case of overextension. There is a system of linear rails and bearing/pillow blocks that guide the actual movement of the device itself. These actuators are shown in front and elevation view respectively in Fig. 14.2 and 14.3.

Paintings ranging from eight by eight inches to 30 by 30 inches are accommodated. The frame material is aluminum. The base material is also aluminum, and provides the platform for the rail system as well as the electrical circuit and joystick. The base can be a tabletop element, or with its attachable legs it can be configured as a freestanding easel with 30 inches of ground clearance for the wheelchair. Power supply is standard 120 VAC. Since the actuators operate on 12 Volts DC, proper transformation of power is provided.

The cost of this project is $980
CONTROLLED AND ADJUSTABLE ART TABLE

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INTRODUCTION
Existing models of art tables are not ideal for artists with disabilities. There is not always sufficient space underneath the tables to allow room for a wheelchair and for the artist’s feet. The table is being designed for any person who uses a wheelchair and has limited mobility. People with conditions such as cerebral palsy, multiple sclerosis, or paralysis are examples of those who would benefit from this product.

SUMMARY OF IMPACT
For most people, arts and crafts such as drawing or painting seem like a relatively simple task. For certain artists however, sitting at a table to draw or use an easel to paint is not easy. These certain artists have limited motor skills in such areas as strength, dexterity, and range of motion. Limitations may place them in wheelchairs where a height adjustable art table would be useful. The Art Table is catered to fit various size wheelchairs and allow enough room for the clients' feet. The artist uses an electronically controlled device to adjust the table height.

TECHNICAL DESCRIPTION
In order for the table to be easily adjusted by the artists, it is operated by a momentary rocker switch. Depending on the direction chosen by the artist, the table moves up or down. Several motors powered by a battery move the table vertically. A microprocessor is also used to give the correct commands to the motors. The table reaches a minimum height of 28 inches above the ground and a maximum height of 40 inches. A photograph of the completed table is shown in Fig. 14.4 below.

The adjustable table operates using a 12 Volt battery. A 5 V regulator is utilized to step down the voltage for the microprocessor system- in this case a PIC16F87. A switch operated by the user adjusts the height of the table. The microcontroller interprets this information using an assembly program written in MPLab. Output is amplified and sent to two linear actuators. The actuator on each leg of the table moves the table vertically in the direction desired by the artist.

Most of the table is constructed of aluminum. It provides a sturdy, yet lightweight surface to do artwork. The tabletop is in the shape of a rectangle with a surface area of 180 square inches. Along the outside edge of the table is a strip of rubber to
provide a “softer” table edge. The legs of the table are also fabricated from aluminum. There are two table legs, each six by six inches and about 16 inches high. On top of the legs is a half-inch plate fixed to the linear actuators. Another plate is fixed to the underside of the table and attaches to the other end of the actuators.

Two electromechanical linear actuators that allow 12 inches of movement power the vertical movement of the table. These are Duff-Norton actuators, operate on 12 VDC and can support a load of 100 pounds. They operate at a speed of 30 inches per minute (0.5 inches/second). Included with the actuators are fully adjustable limit switches. The limit switches are set to stop the motion of the actuators at any point providing a safety feature to prevent the table from moving too high or too low. A schematic of the actuator system is shown below in Fig. 14.5.

The total cost of the Adjustable Art Table is $732.

Figure 14.5. A Line Drawing Assembly of the Adjustable Art Table.
INTRODUCTION
Existing models of easels are not ideal for artists with disabilities. Many disabled artists find it difficult to bend over or reach the easels they are using, since most easels are designed to tilt away from the artist. This easel is designed to tilt towards the user. The easel is being designed for anyone who uses a wheelchair and has limited mobility. People who have cerebral palsy, multiple sclerosis, or paralysis are examples of those who would benefit from this product.

SUMMARY OF IMPACT
For most of us, arts and crafts such as drawing or painting seem like a relatively simple task. For certain artists however, sitting at a table to draw or use an easel to paint is not easy. These certain artists have limited motor skills in such areas as strength, dexterity, and range of motion. These limitations make it difficult to do things such as reach out and touch an easel to paint. The easel can project forward and tilt at various angles. This prevents the artist from having to bend over or reach out to the paintings to work.

Figure 14.6. Easel Board.
TECHNICAL DESCRIPTION

The easel projects forward (toward the artist) and vertically tilts from zero to forty-five degrees. It consists of a momentary contact rocker switch to allow the artist to position the easel in the most comfortable position. The switch causes an electromechanical linear actuator attached to the back of the easel to extend, while the bottom of the easel remains fixed to a hinge. This results in the easel tilting forward toward the user. The easel is able to attach to various size canvases and has restrictions based on the angle of tilt and rotation. Its main purpose is to tilt forward or back, so there will not be a need for a wide range of movement in other directions.

The easel consists mainly of an aluminum board on which the canvas rests. This is the part that tilts toward the user. The back of the board is attached to a stand in two places, one at the top edge of the board, and one at the bottom, both centered with respect to the width of the board. A hinge at the bottom acts as the point of rotation.

A linear actuator attached to the stand and the easel board provides the power to adjust tilt. The actuator is powered by 12VDC. The particular electromechanical linear actuator utilized is a Duff-Norton that can move 100 pounds a distance of 12 inches at .5 inches per second. This actuator is seen in Fig. 14.7.

The easel board is big enough to support canvases up to a size of 24 by 30 inches. A small tray will protrude two inches along the length of the board for the canvas to rest on. Rubber edging is applied to the exposed edges of the board for safety. A linear actuator is attached to the top of the easel that in turn is fixed to the stand. Both of the attachment points of the linear actuator are able to pivot. The stand for the easel has three legs in order to give it better balance. The configuration of the legs allow for optimum clearance for a wheelchair.

The total cost of the Adjustable Art Easel is $385.
AN AUTOMATED TABLE TOP SLIDING EASEL

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INTRODUCTION
Introduced is Slide-Art, an automated table-top sliding easel capable of attaching to a wheelchair and accommodating different sized canvases for painting. The intended client has limited use of his extremities due to Cerebral Palsy, so the device is fully automated. The completed device slides (bilaterally) left and right with the use of a large joystick. The joystick is operated by either the client or a third-party. The joystick requires minimal side movement pressure to actuate. The sliding action of the table is appropriately designed to support the weight of both the canvas and arms of the user. Fig. 14.8 shows the completed project.

SUMMARY OF IMPACT
The client is a very prolific painter and this device allows him to contribute to the studio where he is employed. The table slides bilaterally to accommodate the limited movement of the client’s arms.

TECHNICAL DESCRIPTION
This device is separated into two main sub-systems, including the electrical system and the mechanical system. The main control system is microcontroller (PIC16F874) based. The use of a PIC microcontroller allows the device to interpret the user and system inputs and generate the appropriate output response. The responses allow it to move left, move right, or stop. Accordingly, the main function of the microcontroller is to transfer a signal from analog to digital via the manipulation of the joystick.

For the joystick to signal the microcontroller, it must be subjected to an offset in the direction that travel is desired. This offset can be as small as a few degrees to send the required signal to the controller (in this case a five-volt high). The microcontroller recognizes the five-volt signal and an internal program authored in MPLab sends the appropriate command to the motor driver circuit. The motor reacts in accordance with the constructed circuit.

This device utilizes a stepper motor since it is lightweight and the stator/rotor combination is easily programmed to move the device in opposite directions (left and right). The size and frequency of the square wave generated in the microcontroller program controls the speed of the table, which is no faster than about one inch per second. The particular stepper motor in this device has a toothed gear attached to its shaft that in turn moves a rack (thus the gear and rack combination) located on the underside of the tabletop. The range of motion for this table is about twelve inches in each direction. A 12-Volt Battery powers the device itself.

Mechanically speaking, the device contains a few basic sub-assemblies. These are the Motor Drive Assembly, the Table Top, and the enclosure for the electrical components. In general, the table can withstand a weight of 20 pounds and can be adjusted to fit a canvas ranging from eight inches by eleven inches to 24 by 30 inches.

The table-top is primarily constructed using 1/8 inch thick Aluminum Sheet stock. The dimensions
of this table-top are by larger than 24 by 30 inches. A stationary lip is added to one of the long sides of the aluminum table top representing the base from which all canvas sizes rest. Two rails are fastened along the sides of this table-top. A secondary lip that stretches between the two rails is allowed to move, accommodating the varying canvas sizes. Resistance is generated by a spring system. This entire sub-assembly rests on a pair of bearing rails mounted inside an enclosure fashioned to contain the stepper motor and rack assembly that drive the table back and forth. The motor shaft with its simple gear drives the rack, mounted on the underside of the table top with the bearing bars and incorporates use of various pillow blocks acting to relieve binding as the table indexes. The method of fastening the canvas to the device itself is manual and not motor controlled.

Custom designed mounting brackets are fashioned to hold this device to a user’s specific wheelchair. These brackets attach to the main enclosure of the device and areas on the user’s wheelchair to offer the most convenience. Line drawing of the device is shown below in Fig. 14.9.

The cost of this project is $775.

Figure 14.9. Mechanical Schematic of the Sliding Easel.
INTRODUCTION
TAP controls a variety of household items extending the client’s reach and control of daily tasks by the simple press of a single button. The following functions have been implemented in TAP: 1) Two Way Radio with Call and Talk functions, 2) Two X10 light or small appliance controllers utilizing RF signals to control hose current via plug-in control boxes, and 3) A Universal Remote Control capable of controlling a DVD, a VCR, a TV, or a satellite/cable box. A view of the completed TAP project is shown in Fig. 14.10.

SUMMARY OF IMPACT
The client involved communicates to the world by typing on a computer using a head pointer device. His activities are limited to those that require no movement other than the motion of his head. He lives with his parents but spends much of his time in a little clubhouse next to his home. A device containing a two-way radio actuated in a manner conforming to his particular capabilities allows him to communicate between club and home with ease. When in his room, the same device operates his lights and TV as well as other things of interest. TAP, a single touch, large target switching system fulfills these requirements.

TECHNICAL DESCRIPTION
The Control Box is mounted on a transportable table allowing for easy short distance transport. The box may be removed from the table utilizing two latches and carried anywhere using its side handles.

Internal components of TAP are easily accessible by turning the side lock and removing the top of the unit. An internal fused power strip protects the internal modules in case of electric shorts or liquid spills.

Electromechanical solenoids control an Audiovox two-way radio, X10 RF remote control module, a Sanyo universal remote control, and give the signal the ability to go through walls. Two power adapters supply electricity to the unit. The universal remote control is the only module that runs on two AA batteries.

The two-way radio operates with any two-way radio located within a one-mile radius of the control box. Buttons marked Call and Talk are provided. A microphone is mounted at the front center of the control box and is activated when the “talk” button is depressed.

One Infrared to RF cone is included for use. The user must place the cone in front of a TV, DVD, VCR, or satellite box. A system within the control box produces RF signals to control the particular entertainment unit. The RF signal is capable of passing through walls so the device needs not be pointed towards the entertainment system. This control is centered on a Sanyo Starlight universal remote control.
Figure 14.10. Completed TAP Project.
CHAPTER 15
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THREE-WHEELED LIGHTWEIGHT MOTORIZED SCOOTER

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INTRODUCTION
The intent of this project was to design a stable, collapsible, lightweight scooter for a client with Parkinson’s disease. The client currently uses a two-wheeled scooter as a means of transportation around his office building, but the progressive nature of Parkinson’s disease has caused a loss of his ability to balance. The client desired a scooter-like design, which was more stable than his current model but maintained collapsibility and powered operation, while also remaining relatively lightweight. A choice was made to modify an existing two-wheeled design, swapping the single rear drive wheel with two wheels, driven by a shaft. Stability and strength analyses were completed and CES selection software was used to aid in the selection of the best materials and processes for the production of the new and redesigned components.

SUMMARY OF IMPACT
Currently the market for three wheeled scooters consists only of large, heavy, and unattractive models, which are expensive and hard to transport and store. The market for lightweight, fun, and collapsible scooters is better for the two-wheeled variety. The scooter in this design project is small, lightweight, attractive, and collapsible, yet it offers substantially more safety and stability than can be found in a two-wheeled model, and it is relatively inexpensive.

TECHNICAL DESCRIPTION
The design of the three-wheeled scooter is carried out by modifying an existing two-wheeled unit (Figure 15.1) to incorporate two rear wheels in place of the original single wheel.

The current setup consists of a single belt driven wheel that rotates via two ball bearings about a stationary shaft (Figure 15.2).

In the redesign, the original drive train is replaced with a belt driven shaft to which the two rear wheels are attached.

When changing from a stationary shaft to a driven shaft design, a few of the scooter components are modified. The mounting brackets that the original shaft was fixed to needed to be enlarged and fitted with ball bearings for the new shaft to pass through. The original hub from the driven wheel is maintained (the tire is removed) in order to keep the same belt drive and braking functions with minimal cost. A larger hole is drilled in the brake plate to allow the now-larger shaft to pass through it. Further cost savings are achieved by using the original scooter’s front wheel (minus the bearings) for the rear wheels of the new design. This eliminates the need to design a new wheel and hub design for the new rear wheels. The wheels and drive hub are permanently attached to the new shaft to allow power transmission to the wheels. This is achieved by inserting roll pins through the shaft,
which engage slots milled into the drive hub and the two wheels. The result of this modification is that all the components rotate as one unit. Because the existing bore diameter of the hub and wheels exceed the shaft diameter, aluminum collars are fitted and locked to the shaft via setscrews. Correct belt, brake, and bearing alignment are achieved by inserting various sized aluminum spacers between components on the shaft. The prototype of the scooter is shown in Figure 15.3.
ADAPTABLE BICYCLE

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INTRODUCTION
The design of a standard bicycle was modified to have an adjustable mechanical pedaling system as well as a hand restraint. These improvements were intended for individuals with disabilities who lack the muscle strength to ride a conventional bicycle. Areas of consideration in the design of this product were based on maintaining stability, while providing a mechanical assistance to the user’s leg. The mechanical pedaling system provided assistance by allowing adjustment of the crank arms. Wrought Aluminum Alloy (2024) was chosen as the best material. Cold closed die forging and impact extrusion were the optimal manufacturing processes for the crank arm. The restraint prevented the hand from unintentionally slipping off the handle bar. This will be injection molded using ABS plastic.

SUMMARY OF IMPACT
Problems with movement and posture associated with cerebral palsy can cause difficulties in riding a bicycle. Today, there are many existing solutions to overcome the difficulty of riding a bicycle. However, most of these designs are expensive and unconventional. The proposed improvements provide the user with an affordable and reliable solution.

TECHNICAL DESCRIPTION
Design criteria were as follows. The crank arm had to be able to withstand the applied bending forces necessary to keep the bicycle in motion. It also had to be lightweight and easily adjustable. The restraint had to offer enough clearance for the user’s hand and be comfortable against the user’s skin. The modifications had to be inexpensive, aesthetically pleasing, and have a good resistance to corrosion. With these known objectives, Cambridge Engineering Selector (CES) software was used to determine the optimal material and process for manufacturing the parts.

Figure 15.4. Adjustable Crank Arm Fully Extended.
Figure 15.5. Crank and Hub Assembly.
maximum load is determined to be approximately 320N. To achieve a stiff material, the
information, it is possible to determine the most appropriate dimensions and materials to be used. The cost analysis is then used as effective tool in determining the optimal material. Cost analysis, based on 100,000 units, shows that wrought aluminum alloy (2024) is the most appropriate material.

Including a three-speed internal hub to the rear wheel as shown in Figure 15.5 is also recommended. This hub provides the rider with additional variable force requirements. This is an off-the-shelf item, therefore no analysis was carried out.

The restraint prevents the hand from accidentally slipping off the handle bar. Figure 15.7 shows the hand restraint attaches to a 25.4 millimeter handle bar with standard bolts and nuts. A foam pad is included inside where there is contact with the hand.

The maximum impact load upon the restraint is approximately 100N. The material must be somewhat flexible; therefore the maximum deflection was set to 2.54 centimeters. With this information, it is possible to determine the most appropriate dimensions and materials to be used. A cost analysis, based on 100,000 units, shows that injection molded ABS plastic is the optimal material and process.

A prototype adaptable bicycle was constructed as shown in Figure 15.6. The adjustable crank arm assembly is shown in Figure 15.8. In place of a three-speed hub, the standard bicycle gear ratio is reduced from 2.25:1 to 1.5:1.
**INTRODUCTION**

A kayak entry system is designed to allow an individual with paraplegia to return to the proper seating position of a sit-on-top kayak from the water. This system is designed for a Hobie® Pursuit™ kayak, but can be modified to work with other sit-on-top kayaks as well. The design involves a slide that attaches to the side of the kayak. The individual uses the slide as a ramp and pulls his body smoothly up via a pull strap. By using the Cambridge Engineering Selector software, the slide is determined to be manufactured of polypropylene using compression molding. To make the slide buoyant, injection molded ethylene vinyl acetate closed-cell foam is attached to the slide using contact cement. All other parts of this design are purchased from Eastern Mountain Sports®.

**SUMMARY OF IMPACT**

Methods of entering a kayak from the water generally involve the use of one’s legs. This makes the activity of kayaking difficult for individuals with paraplegia. The proposed assistive kayak entry design allows the user to pull him- or herself up an attachable slide using a pull strap. This system also utilizes the existing method of using the paddle with an attached paddle float to stabilize the kayak.

**TECHNICAL DESCRIPTION**

There were several criteria that needed to be considered for this design. First of all, it was necessary that the design be lightweight. The user must be able to move the components around with ease. Also the weight of the components must not inhibit the performance of the kayak. Secondly, the process must be quick and easy to do. The design must minimize the length of time that an individual is in the water for safety purposes. Finally, the design must be easy to carry on the kayak, as well as being easy to access when needed.

The assistive kayak entry design creates a simple and easy to use solution. It focuses on the individual pulling his or her body up a gradual slide to get onto the top of the kayak. The slide is made of polypropylene with ethylene vinyl acetate close-cell foam attached to the bottom of it via contact cement. These materials were chosen using the Cambridge Engineering Selector software. The slide and foam are to be compression molded and injection molded, respectively.

The foam at the top of the slide creates a snug fit to the contour of the kayak. The foam runs along the whole length of the slide, so that the buoyancy force from the water creates a gradual ramp angle. The
lip at the top of the slide hooks onto the gunner of the kayak. The bend at the bottom end of the slide prevents the user’s life jacket from catching the bottom edge of the slide.

The slide attaches to the boat by clipping the slide locking straps from the boat to the slide straps on the slide by the means of side squeeze buckles. The slide locking straps are attached to the boat using carabineers, which are in turn latched onto the pre-existing hooks on the kayak. The carabineers can stay attached to the hooks at all times, and the straps can be stored away under the feet of the kayaker. They can be easily removed.

With the slide attached and in place, the individual can pull his body up the slide using the pull strap.

The system is shown completely assembled in Figure 15.12. The current method of the paddle with its attached paddle float is used to stabilize the kayak. The paddle is strapped to the boat using the cargo bungee netting on the boat.

After the user has pulled his or her body most of the way up the ramp, he or she can hold onto the other side of the kayak to pull the rest of the way up. The user should now be lying with his or her upper torso resting on top of the kayak. By pushing on the kayak with his or her hands, the user can roll his or her body over on his or her hips. This will result in the individual’s rear end falling into the seat of the kayak. Then, the user can lift his or her legs into the boat using his or her arms. The slide and the paddle float can be easily stored under the cargo bungee netting and the individual can return to the fun activity of kayaking.
INTRODUCTION
Much like training wheels on a child’s bike, conventional walking crutches prevent a user from developing his own sense of balance. Creating crutches for individuals with disabilities built with a certain degree of imbalance could promote practice and development of balance. Crutches have been designed to make the user test his or her balance without risk of falling. The design uses a spring that will be added tangent to the leg of the crutch. With an applied force to the spring, a deflection will alert the user to regain his or her balance and no longer rely on the crutch.

SUMMARY OF IMPACT
Balance-Inducing Forearm Crutches work by making the individual use some of his own balance in order to operate the crutches efficiently. These crutches are not meant to replace existing forearm crutches. They are meant to supplement traditional physical therapy techniques and after some practice, be used by clients on a regular basis who are working toward eliminating crutches. The stride someone uses while walking, referred to as gait, can differ depending on the type of injury a person has. The Balance-Inducing Forearm Crutches are meant to be used by a person who can comfortably walk using the two or four-point gait.

The user is most reliable on the crutches while he or she is moving their feet. It is at this point where the right or left crutch will deflect slightly, depending on what side they apply more weight to. The support that the individual is accustomed to would be limited, forcing the user to stop shifting their center of balance while walking.

TECHNICAL DESCRIPTION
The function of the spring in the Balance-Inducing Crutches is to allow controlled deflection. A spring does this by storing energy when stressed and returning it when relaxed. There are two different types of springs that would serve this design, an extension spring or a torsion spring.

The crutches used for the proof of concept are also the type of crutches that would be used to mass produce this product. They are ‘off the shelf’ items. Epoxy-coated adult forearm crutches were cut in two. Stainless steel torsion springs are attached between the two halves of the crutches. Each spring is designed to deflect no more than four inches if an 180 pound person puts half his weight on it. Beyond the four inch deflection the spring will act as a rigid body, supporting the person’s mass like an ordinary crutch to ensure safety.

Figure 15.15 shows the proof of concept in detail. Similar to a normal forearm crutch, the Balance-Inducing Crutch has standard features: forearm support, hand grip, base and foot of the crutch.
Figure 15.15 also gives a close look at the torsion spring used to promote imbalance in the system. Because of fatigue issues, a torsion spring would not be the best choice for this product. The spring functions well conceptually as a proof of concept, but in everyday use it simply would fail too quickly. An extension spring is the better choice.

Figure 15.14. Two, three and four-point Gaits.

Figure 15.15. The Balance-inducing Crutch.
FREESTANDING BILLIARDS BRIDGE

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INTRODUCTION
The game of pool is one that requires the use of two hands; one hand is required to power the cue stick, the other is needed to guide it. A bridge can alternatively be used to guide the cue, but it also requires the use of a secondary hand. The goal of this project was to create a freestanding device with the same capabilities as a regular bridge. Important design issues were therefore stability, adjustability, compactness, and appearance.

SUMMARY OF IMPACT
The only existing hands free cue-guiding devices attach to the cue stick and move with the stick via rollers. However, these devices make it difficult to maintain the cue stick at a desired angle during a shot and can only be used when there are no other balls behind the cue ball. The hands-free bridge is far more versatile, and allows individuals with the use of only one hand to be competitive in any situation. This device can also be used in place of a normal bridge.

TECHNICAL DESCRIPTION
The corresponding design is shown. The functions of the bases are stability and adjustability, so that the bridge can be reliably used in a variety of situations. The function of the top is to guide the cue stick, which is accomplished by resting the cue in the semi-circular notch during a shot. Protrusions on the top of the base insert into cavities on the underside of the top unit to keep the pieces locked together during a shot. The handles protruding from the base (shaped like T’s) are used to tie a piece of rope to the bridge. Once a shot is made, the user can pull up on the rope with the cue and remove the bridge from the table. Adjustability is realized by having one top that can mate to four different base units with heights of 2.5 centimeters, six centimeters, nine centimeters, and 12 centimeters. The 2.5 centimeter assembly would be used for the majority of shots because it is about the same height as a regular bridge. The other bases would be used...
when interference from other balls will not allow the bridge to be placed directly behind the cue ball. The bridge could then be placed behind the interfering balls; the increased height would allow the cue stick an unobstructed path to the cue ball.

The bases are made of brass, because of its high density, low cost, and appearance. A high-density material is imperative because the stability of the bridge is proportional to its weight. A high-density material results in a high weight while allowing the base width to be as small as possible. The 2.5 centimeter base weighs 1.6 pounds, while the 12 centimeter base weighs 3.2 pounds. (Both will have a base width of 3.2 centimeters). Cold closed die forging is selected as the corresponding manufacturing process from CES software. Selection criteria include economic batch size, tolerances, surface roughness, part size, part shape, part material, and cost.

The top unit is made of PTFE, commonly known as Teflon. Since the base unit is responsible for stability, the only function of the top is to guide the cue with minimal friction. PTFE is selected because of its extremely low coefficient of friction with wood and its good wear properties. With a top of PTFE and bases of brass, it is estimated that the bridge can remain stable under the friction generated from the cue putting a 20 pound downward force on the bridge. Using the same selection criteria as the base, CES yielded compression molding as the best manufacturing process.

A cost analysis showed that the entire set could be manufactured for $25, with only $9 due to material and tooling costs.

Figure 15.18. Prototype in Use
SIT-ON-TOP KAYAK SUPPORT SYSTEM

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INTRODUCTION

A supportive seating system was developed to assist individuals with lower extremity disabilities in maintaining stability and control of an ocean kayak. The design integrates an off-the-shelf life vest with reinforcing ribs and additional seating support. This allows a kayaker to paddle steadily the watercraft without the use of any additional accessories. With the use of the Cambridge Engineering Selector software, the process and material best suited for the ribs was found to be an injection molded polypropylene.

SUMMARY OF IMPACT

Currently, it is not possible for individuals with a lower limb disability to efficiently paddle an ocean kayak. Because they lack sufficient strength in their legs to maintain balance, they cannot paddle the watercraft without tipping over or falling into the water. Due to the lack of strength, it becomes unsafe for the individuals to operate the vessel. The goal of this project was to design a seating support system, independent of the kayak, which would safely keep a kayaker stable enough to remain rigidly seated while paddling.

TECHNICAL DESCRIPTION

The primary objective of the support vest was functionality. The vest was to remain rigid and supportive while allowing the user the free range of motion required to paddle the kayak. It was also important not to add too much to the already cumbersome array of equipment needed in this sport. With this in mind, the most critical component of the design was the reinforcing plastic backing of the life vest, which provided the majority of the support. Also, to prevent sinking, this rigid backing could not make the life vest much heavier than it was already.

The reinforcing polypropylene backing was made of rigid supporting members shown in Figure 15.19, which were sewn in vertical pockets located in the vest material. These vertical members, or ribs, traveled up the posterior torso from the tailbone to the underarm and mid-shoulder (Figure 15.20). These ribs provided the majority of the needed support as previously mentioned.

The vest also incorporated a seating area that was made of the same material as the life vest, with padding inserted to cushion and add comfort. This served two purposes: to allow comfort and flexibility, and to allow for more support by limiting the forward motion of the upper body. The underside of the seating area was covered with sharkskin, a rubberized neoprene material, used to maximize the friction between the seating system and the kayak material; thus limiting slipping and
adding control for the user. Finally, Velcro straps located at the end of the seating area were used to attach the lower portion of the Sit-on-Top Kayak System to the user. These materials are to be purchased and customized depending on the physical make-up of the user.

The Sit-on-Top Kayak Support Vest is worn similarly to that of an existing life vest. The system is entirely self-contained and is independent of the kayak. By combining an existing life vest with the other supporting features, the design offered the kayaker the desired support for efficient control of the kayak. The figure shows the prototype of the kayak support vest being demonstrated. The support vest fulfilled the ergonomic and support requirement.

It can be produced for $66.93.
MECHATRONIC LONG CANE

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INTRODUCTION
The design includes implementation of electronic sensors embedded into a long cane to aid individuals with visual impairments in avoiding low-hung objects. The goal of this project was to design and create a cane able to house and protect the electronic components while at the same time offering the same “look and feel” as a traditional long cane used currently.

Using Cambridge Engineering Selector software, design matrices were created to identify both a process and a material suitable for the cane design. The material selected by the software was fiberglass, to be processed by injection molding.

SUMMARY OF IMPACT
The long cane is the device employed by most individuals who are blind to aid in their navigation of the surroundings. These canes are inexpensive, lightweight, easy to carry, and effective in identifying low-lying obstructions to the user. The long cane’s drawback is that it is unable to alert the user to low hung objects along the user’s path. Attempts have been to develop an electronic travel aid in the form of a long cane that employs ultrasonic sensors to “feel” for objects that would not be in direct contact with the traditional long cane, but yet would still be an obstacle for the user.

TECHNICAL DESCRIPTION
The main design objectives for the product were to effectively house and protect the electronic components from the environment and creating the same look and feel of the traditional long cane. To quantify the “look and feel” objective, various data were collected using a traditional cane, and the prototype was then designed to closely match these measurements. Target criteria were stiffness and weight. Dimensions were essentially free variables, although the inner diameter of the portion of the cane housing the electronic components was fixed at 0.75 inches by the client. This dimension represented the minimum width of the circuit boards which process the signals sent and received by the ultrasonic sensors embedded in the cane.

Using the Cambridge Engineering Selector, a process and material (in that order) were chosen. Choosing the process required limiting materials based on shape factor, economic batch size, and the tolerances of the design. The material was then chosen based on the selected process combines with corrosion resistance, stiffness to mass ratio, and fracture toughness. The resulting selections from the software were injection molding (thermoplastics) for the process, and epoxy/glass reinforced polycarbonate (fiberglass) for the material.

The cane itself consisted of four main pieces: an upper handle, a middle section consisting of a top and bottom piece, and a lower section. The upper handle was designed to contain the two 3V batteries that powered the sensors and circuitry of the cane. Placing the significant mass of the batteries in the handle close to the point of cantilever allowed for a better imitation of the “look and feel” criterion. The middle section was split transversely to allow placement of electronic components during assembly. The two halves were held together with bolts. The bosses surrounding the through bolts also served to support the two circuit boards in the device. Lastly, the lower section served only to create the length of the cane required by the user. This end piece was non-structural in that it did not support any internal components; however, it still
had to meet stiffness requirements because this piece will receive all loading from the user tapping the device along the ground.

The total unit cost of the housing (without electronic components) is $10.50.
SNO-STOLE WHEELCHAIR WINTERIZATION KIT

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INTRODUCTION
The Sno-Stole is a winterization kit for a wheelchair. It is a means of providing increased stability and control for a wheelchair in snow and sleet conditions. An analysis of problems encountered with wheelchairs in winter conditions indicated that the principal difficulties were with the caster wheels rotating and digging into the snow. To solve these problems, skis were added. A forked-bar, which actuates the ski, also locks the caster wheels to prevent rotation. The forked-bar, cold closed die forged magnesium, follows a path on a modified die-cast aluminum C bracket. The skis and handles are injection molded from a High Density Polyethylene.

SUMMARY OF IMPACT
There are many individuals who use wheelchairs. Of this demographic, there are a sizable number of people who reside in the northern United States and Canada, as well as the northern European nations; all of which experience considerable snowfall in any given winter season. The Sno-Stole system would provide for improved traction and maneuverability during these inclement winter conditions. The Sno-Stole could provide these potential customers with an affordable and effective method of outfitting their wheelchairs for winter conditions.

TECHNICAL DESCRIPTION
The design of the Sno-Stole system focuses around two critical functions. First, it locks the caster wheels to prevent rotation. Second, it lowers a ski into position. The design of the Sno-Stole allows for both design parameters to be accomplished simultaneously.

The first component of the Sno-Stole is a bracket attached to the arms of the chair. The bracket has a C-shaped channel cut into both the front and back surfaces. A bar is fitted into this bracket, and secured with a handle which passes through the C-channel.
The bar contains a bend, to allow it to enter the caster fork. The bend also prevents interference with the other fixtures in place, such as the brakes and footrests. At the end where the bar enters the caster fork, the bar itself is forked.

There is a ski attached to the caster fork. The back end of the ski is attached by two carriage bolts in such a way so it can rotate. Attached to the ski and the caster fork is a return spring which returns the ski to a horizontal position where it is no longer in contact with the ground. The system is assembled in such a way that when the bar is moved down, the handle guides it along the c-shaped path in the guide bracket. The fork on the end of the bar enters the caster fork. This will prevent the caster fork from rotating. When it lowers to near the bottom of the track, it contacts the ski, causing it to lower until it contacts the ground.

The Ski is to be injection molded out of high-density polyethylene. Maximizing stiffness and minimizing weight and cost are main concerns for material selection of the ski. Other points of concern are for the ski to be resistant to corrosion and have the ability to deflect. The handle is to be manufactured from injection molded polypropylene due to a high shear modulus. The C Bracket is a Die cast aluminum part. Buckling and corrosion are the main concerns. The forked bar is a cold closed die forged magnesium component.

The estimated production cost is $30.
WHEELCHAIR TIRE CLEANER

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INTRODUCTION
Operating a wheelchair during inclement weather, results in the collection of various types of unwanted debris on the tires. This poses a problem as the wheelchair is rolled from outdoors to indoors. If this debris is not removed from the tires, damage can occur to such items as tile or wood floors and rugs. A wheelchair tire cleaner is a simple necessity that is generally unavailable.

SUMMARY OF IMPACT
Current designs of wheelchair tire cleaners are awkward, impractical, and unattractive. These designs also have limitations on placement, wheelchair compatibility, portability, and ease of use. The universal wheelchair tire cleaner is a simple device that can be mounted and used on any manual wheelchair. Comprised mainly of aluminum and polypropylene, the tire cleaner is suitable for all types of weather conditions. As a permanent attachment to the wheelchair, the Tire Cleaner is a simple and attractive device.

TECHNICAL DESCRIPTION
The overall Tire Cleaner design is shown in Figure 15.30. The device mounts on the wheelchair axle between the wheel and the chair. A cable attached to the connecting pin allows the brush head to be pulled into the tire via the actuator. When the actuator is released, a spring is used to disengage the brush head from the tire.

The main goal of this design is to create a simple and inexpensive universal device that did not sacrifice aesthetics. This goal is accomplished with three critical design characteristics - the shaft, the mounting bracket, and the cable actuator.

To allow use on all current manual wheelchairs, the device has an adjustable arm with a free cable actuator. The adjustable arm is comprised of one small shaft that slides within another larger shaft. The two shafts are locked in place with the use of a
The design of the cable actuator allows for mounting anywhere on the wheelchair frame within the range of the given cable. Mounted between the axle and the inside of the wheel, the tire cleaner blends into the design of any manually operated wheelchair. This is an important characteristic because users often do not want to attract additional attention to their wheelchairs.

The Pro-E image in Figure 15.33 shows the tire cleaner mounted on the wheelchair. Another important aspect of the design is the brush head. The connecting pin and the brush are both threaded allowing a simple and rigid connectivity to the actuation cable. Having the brush head threaded also allows for easy brush removal for replacements due to wear or exchanges for different special purpose brush heads.

Analyzing the overall design shows that operational forces are minimal. Therefore, the materials are chosen to sustain an accidental impact loading. Using a maximum allowable deflection of 50 pounds per inch, aluminum is found to be the optimum material for the two shafts. Since the shafts need to attach to the mounting brackets and the pin/spring housing, it has been decided that the brackets and the housing also be made of aluminum. This allows the pieces to be securely welded together. Following the same material analysis for the brush head yielded polypropylene as the optimum material.

Most of the components in the design are commercially available. Parts including the shaft, cable wire, actuator and spring are simple parts that are readily available from a number of commercial vendors. The only part that is not commercially available is the brush. This part will be out-sourced to a professional brush manufacturer.

A prototype of the design was constructed. All components used the specified materials with the exception of the brush head, the connecting pin, and the pin/spring housing.

Material and processing costs are approximately $14 per pair.
INTRODUCTION
The client for this project is an individual who uses a wheelchair. Even though his wheelchair allows a certain degree of mobility, the use of a car is necessary to cover longer distances. Because the client is not able to get out of his wheelchair and into the backseat of a car on his own, he needs assistance. Considerable strength is needed to move him safely in and out of the car. The low position of the seats of many sedans and the relatively poor accessibility caused by the shape of normal car doors proves difficult to transfer the client for the person providing assistance.

The purpose of this design project was to create a device that allows the client to use the strength of his upper body to aid in the transfer between the car and the wheelchair. The device should make the transfer between the car and the wheelchair much easier and safer for the client and his caretakers, reducing the risk of back problems.

The central elements of this design are two horizontal handrails that the client can grip and move along. These handrails have to be stiff and strong enough to support weight safely. They should allow an ergonomic hand position and they may not hinder the attending person. The wheelchair may not tip or even to fall over as this might lead to serious injuries. A lightweight and compact design to ease transportation of the device was a priority.

SUMMARY OF IMPACT
Currently, there is no commercial product available that completely fulfills the demand for a light, compact and easy to use device that eases transfer between a wheelchair and a car. There are several devices that make it possible to lift a person directly from a car seat into a wheelchair, however these devices are big, expensive, complicated to use and cannot be easily transported. The main objective for this project was to design a product that is not only
stiff, light and easy to use but also compact, robust and detachable. The final design fulfills all of these criteria and can be manufactured at an affordable price. Many common designs for wheelchairs use two vertical tubes to support the armrests on either side. As a result of a simple and universal design, the wheelchair handrails can be adjusted to nearly all wheelchairs after a few minor modifications.

**TECHNICAL DESCRIPTION**

Two guides on each side of the wheelchair connect the handrails to the vertical tubes that support the armrests. At the same time they prevent the handrails from pivoting around the wheelchair. These guides clamp to the vertical tubes with a small plate and two screws. They are the only parts that stay on the wheelchair permanently. A simple lock consisting of a pin with two different diameters fixates the handrails in the rear guides so they cannot rotate or slip out of the guide.

The front end of the handrail is supported by a leg to prevent the wheelchair from tipping over. The legs consist of two telescoping tubes. Both tubes are connected by a simple pin connection to allow a height adjustment for different wheelchairs or different handrail heights. A simple joint with two pins connects the leg and the handrail. The upper pin of the joint defines the axis of rotation, whereas the second, removable pin locks the leg in one of two possible positions. During use, the leg is locked in a vertical position and for easier transportation the leg can be fixed in a position parallel to the handrail. The wheelchair can be placed closer to the car if one handrail is shorter than the other. To allow the use on both sides of the car, the handrails can be easily exchanged.

A systematic material selection process for this design has been conducted with the Cambridge CES Selector 3.1 software. As a result of this selection, wrought aluminum alloy 2024-T4 was found as the ideal material for this task.

The same software has been used to estimate the cost per unit of $63 for a mass production of 100,000 units.
THE WHEELCHAIR BRAKING SYSTEM

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INTRODUCTION
Currently, wheelchairs are not designed with a braking device to slow or stop the wheelchair while in motion. The wheelchair braking system creates a convenient method for user and caretaker to control the speed of the wheelchair.

SUMMARY OF IMPACT
The wheelchair braking system has braking actuators for the user and the caretaker; this way either the user or a caretaker can control the speed of the wheelchair. This system eliminates stopping the wheelchair with the user’s hands. In current wheelchair designs, the user’s hands are the braking tools used to stop the forward motion, which is very inconvenient to the user and can cause injury. The wheelchair braking system has been designed so that it can be installed onto any wheelchair with mag-type wheels.

TECHNICAL DESCRIPTION
The design consists of three major subsystems that can be installed onto the wheelchair: 1) user’s braking actuator, 2) caretaker’s braking actuator, and 3) braking assembly.

The user’s braking actuator is universal and can be placed on either side of the wheelchair per the user’s preference. It is comprised of three major components: lever arm, lever box, and lever box support. This system is engaged by the user applying a force to the lever arms to control the speed of the wheelchair as needed. The lever arm is constructed from wrought aluminum alloy by cold closed die forging. A cable is attached to the lever arm to transmit the force applied by the arm to actuate the braking assembly.

The lever arm is located within the lever box. The lever box is a stock part that can be purchased off-the-shelf. The lever box is located on top of the lever box support. The lever box support is constructed from wrought aluminum alloy by stamping. The lever box support bears both the weight of the lever box and the weight of the user’s arm.

The caretaker’s actuator is a bicycle brake lever, which is placed on each of the caretaker’s handles. It is also attached to the braking assembly by means of a cable to transmit the braking force. The caretaker’s actuator is bought off-the-shelf.

The braking assembly is situated within the wheelchair’s wheel and substructure. The assembly consists of the rotor, caliper mounting post, and caliper. The rotor is constructed from wrought aluminum alloy by closed cold die forging; it is attached to the spokes of the mag wheel.

The caliper is placed upon the caliper mounting post, which is attached to the existing wheelchair tubing. The caliper will be bought off-the-shelf. The cables from both actuators are connected to the caliper, which the caliper is used to stop the rotor in order to control the wheelchair speed. The caliper mounting post is designed to withstand the resultant force that the rotor exerts on the caliper during braking. The cost of the wheelchair braking system per unit is $127.
Figure 15.41. Subassemblies of Wheelchair Braking System.

Figure 15.42. Braking Assembly, Consisting of Rotor, Caliper Mounting Post, and Caliper.
INTRODUCTION
An assistive aid was designed to help a person raise herself to a standing position. The handle design was retrofitted to a specific type of walker so that proper stability could be maintained while in use. The design allowed the user to grasp the properly positioned and oriented handles, assisting a person in standing up from a seated position.

A strength driven material design process was employed for the handle using the Cambridge Engineering Selector software. The optimal material for the handle base was found to be low alloy steel while the handle was best made of wrought aluminum. The process best suited for the design of the base was found to be cold closed die forging. The retrofitted walker standing aid satisfied all necessary design parameters.

SUMMARY OF IMPACT
Market research indicates that there are currently no similar products available. The ergonomic handle design decreases the amount of force that the client’s legs must exert by about half. This allows the user more comfort in the knees while maintaining a safe standing procedure.

TECHNICAL DESCRIPTION
Based on the need of the assistive walker handles to support the user, a design was created to accomplish this. Because this design concept had to incorporate support at the hands, adjustability and sizing issues had to be addressed.

The design of the handle assembly required that it support one-fourth of the total weight of the user. The final design can be seen in Figure 15.43. This figure shows the Pro-E solid model of the component and all of its sub-assemblies.

Figure 15.43. Final Design Prototype.

Figure 15.44. Walker with Leg Angle of 72 degrees.

The first thing analyzed was the stability of such a handle being used on the walker. The design required the handle to be attached to the walker’s rear legs, flipping down to horizontal. Normally,
walkers have straight legs, or a very small angle to the legs. This handle design, however, required the legs to be at a more dramatic angle. Care was taken in the selection of such a walker, as the angle of the rear legs is the main factor in the stability of the design. The walker selected has a leg angle of 72 degrees.

At this angle, and with the handles horizontal on the legs, the walker did not flip. The analysis showed that stability was better as the height of the handles on the legs increased. For the client, the handles were suited at about two feet from the ground, allowing easy access and proper orientation.

By analyzing the design to find the most critical loading scenarios that were likely to be encountered, the modes of failure for the different components were found. From this information, material and shape requirements were derived and CES plots were made to aid in the selection of the optimal material for the major components. From the original design parameters, each part was to be both lightweight and failure resistant. After these requirements were met, the specific material was chosen. Functionality and durability were of utmost importance so that a safe and useful product could be made.

With this material choice, failure modes were tested to ensure that the design and the material specified could withstand the loads encountered during typical use. The two main parts that needed to be tested for failure were the pin and the handle.

The pin, which connected the rotating handle to the base, would most likely fail due to shearing loads. A shearing analysis was done on a pin of one-inch diameter. It was found that this pin could withstand the force applied during use and therefore was chosen.

The handle was the next thing to be designed. The handle would most likely fail by bending. The handle was loaded in the assembly as a cantilever beam, in the worst case scenario that all of the force would be at the end of the beam. It was desired, for this worst case, that the handle not deflect more than 0.01 inch. The handle was analyzed as a tube, with a force of 31.25 pounds at its end. The handle deflected very little, making it a valid and safe design.

It was decided, for cost reasons and strength, the base be made of low alloy steel. The CES Selector software confirmed this material choice. The weight of the base was found to be less than one pound and its area was kept low. Once sized, the part was checked for other modes of failure to insure that the original assumptions were correct.

The final design was calculated to cost just under fifteen dollars to build and weight less than one pound. The maximum force that could be applied to the end of each handle was limited to about 50 pounds to resist the walker’s tendency to flip. The materials chosen could not only support the weight required, but could also withstand all of the typical environmental factors. This design addressed all of the major stability and safety concerns while remaining cost effective and low weight.

The device can be manufactured for under $15.
THE OUTREACH REACHING AID

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INTRODUCTION

Individuals who have restricted mobility may not have the ability to reach items that may be easily accessible to others. Some individuals often use assistive technology products that improve their range. These aids usually have a trigger grip similar to a garden hose sprayer nozzle. When the trigger is squeezed, two fingerlike parts at the end of an arm close together in a scissor-like manner, grabbing an object between them. The Outreach is an improvement on current reachers on the market today. This reaching aid is developed to be more versatile and stronger than current reachers by giving the user the strength and functionality of a fixed length reacher combined with the portability of a folding reacher. This reaching aid allows the user full control of its length from a 12 inch to 30 inch range, while still being affordable at a suggested retail price of $45.

Using Cambridge Engineering Selector (CES) software, the optimal materials and manufacturing processes have been chosen for this design. Careful force analysis allows for selection of materials that would result in a lightweight product strong enough for this application. The CES software has been used to determine that wrought aluminum would be used in the trigger housing, telescoping arms, and gripping fingers. Further study shows that ABS plastic would be used for the trigger.

SUMMARY OF IMPACT

Most reachers on the market today are very similar. They are fixed lengths, usually between 22 and 36 inches. The more expensive products are foldable, making them more portable, but they do not adjust to more than one length. Many people in the target market own multiple reachers for different circumstances. Smaller reaching aids are useful in confined areas, and a longer product is needed for objects that are not nearby. The design of the Outreach combines aspects of versatility and portability into a single design. The telescoping

TECHNICAL DESCRIPTION

Based on the need for variable length and increased strength the Outreach was created. Because this design concept had to incorporate the varying length arms, the entire reacher assembly had to be redesigned. In particular, the modified trigger mechanism became much more advanced in order to relieve slack in the cable used to close the fingers.

Unlike its predecessors, the new design had to incorporate the ability to retract and expand in addition to being able to lock once the correct length has been set. A coil-spring reel and brake mechanism was developed for the finger cable. This
assembly allowed for the arms to be extended and retracted while eliminating slack in the cable.

By analyzing the design for the most critical loading scenario that would be encountered under normal operating conditions, the most likely mode of failure was discovered for each component. With this data, material and shape requirements were derived and CES plots were generated to guide the selection of the optimal material for each component. From the original design specifications, stiffness was to be maximized while mass was kept to a minimum. Only after these two criteria were met was cost considered.

Using results from the stress and failure analysis conducted on the Outreach, the wrought aluminum alloy was chosen for the fingers, connectors, tubular arm sections and handle shell. Aluminum provided strength while keeping the overall weight low. Due to its availability, standard aluminum tubing could be purchased for the construction of the arm sections to save money on construction costs. The ideal material for the trigger was found to be abs plastic due to the ease of manufacture along with the durability and low cost associated with the material.

The final design was capable of holding up to 51 pounds at its max extension (30 inches). The Outreach is stronger, more versatile, and competitively priced.

To show that the intended design will function properly, a proof of concept was constructed, and can be seen in Figure 15.49. This prototype stressed the functionality of the telescoping arms and the cable tensioning system required for easy operation. The Outreach concept is shown in operation in Figure 15.50.

The final design was calculated to cost only $25 when built in a batch size of 100,000 units.
SAFETY GATE FOR AUTISTIC CHILDREN

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INTRODUCTION
Parents of an autistic child identified a need for a gate that could enable them to keep their child upstairs to prevent the child from roaming the home and engaging in destructive activities. An aluminum gate was designed that is placed at the top of the stairs. It collapses into three sections and is hidden from view when not in use.

SUMMARY OF IMPACT
Currently, the only types of gates that have been used by the clients to keep their child upstairs are baby gates. Baby gates are ineffective because the child can easily climb them. Another gate had been custom made to fit the size of the stair entrance. It swings out, with the risk of causing the user to fall down the stairs. Hence, the clients desired a gate that is collapsible, yet tall enough that the child cannot climb it.

TECHNICAL DESCRIPTION
The objective of this project is to design a gate that was collapsible and provided ventilation to the upstairs. To address the need for a collapsible gate, three sections are designed to make up a full sized gate. The first figure displays the final design for the gate. Each section is 7’ 8” inches tall and 1’ 4” wide and it attaches to another section by interlocking L-shaped pieces that prevent the gate from moving when in the open position. Figure 15.52 depicts the interlocking mechanism.

Each section is attached to the ceiling via a tracking system that allows the gate to slide open and closed. Every section has two wheels attached to the top crossbar allow it to slide on the track. There are three track pieces of varying lengths, one for each gate section.

To keep the gate closed a draw latch lock will be attached to the bottom crossbar on the stair side. This will keep the lock out of reach and of view from the child. The nature of this type of lock creates a paradox in unlocking it because one has to pull up on the lock, although it looks as though one must push down.

The gate is to be made of wrought aluminum tubing. This was determined using the selection criteria of strength, density and shape. Cambridge Engineering Selector (CES) software was employed to see what materials would meet the selection criteria. Using CES analysis for material and process selection yielded a choice of two materials and six processes. Wrought aluminum alloy and cast aluminum alloy were the two choices for a material, but cast
aluminum was eliminated since hollow tubes cannot be produced. The selection criteria for a process required that it be a joining process. Out of the six processes only fusion welding was applicable to aluminum.

Since each gate is custom made for the user’s home the cost to produce the gate is much higher than if it were to be mass produced. The figures below show a scaled-down model of the safety gate proof-of-concept.

Many items are purchased off the shelf. The final cost is $968 per unit.

Figure 15.53. Proof-Of-Concept Model of Safety Gate in Closed Position.

Figure 15.54. Proof-Of-Concept Model of Safety Gate in Open Position.
FOUR-WHEEL REVERSE BRAKING SYSTEM FOR A ROLLER

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INTRODUCTION
The purpose of this project was to design a four-wheel reverse braking system for a client’s roller, a walking assistive device that includes a carrying basket and seat. The system required easy and comfortable use while maintaining effectiveness. The ergonomic design was implemented in a universal fashion so that users with similar disabilities could use the braking system effectively. Using the Cambridge Engineering Selector software, a material and manufacturing process analysis was executed for each primary part of the system. The results yielded the primary material as low alloy steel AISI 9255 for the majority of parts, with a range of manufacturing processes for each part.

SUMMARY OF IMPACT
Currently rollers that include a braking system only provide braking of the rear wheels. Application of the brakes can also be very difficult in certain cases where the user may not have full control of one hand. A braking system was designed to provide braking of all four wheels, which could be disengaged with the use of one or two hands. The reverse braking action would provide the user with a stable and reliable support when standing still is required.

TECHNICAL DESCRIPTION
The objective of the design was to minimize the movement of the roller under braking. The application of efficient braking to all four wheels would accomplish this. The reverse braking was achieved with the use of compression springs at the rear wheels and torsion springs at the front wheels. One problem addressed during the design process was to design a universal brake lever strong enough to withstand the forces required to disengage the brakes through displacement of all four springs. Using the Cambridge Engineering Selector the optimal material was found taking into account...
consideration its stiffness and cost. The final design of the brake lever was a universal cross bar made from Low Alloy Steel AISI 9255, which the user can pull towards them from any point along the front of the roller to disengage the brake. With the production of 100,000 units, the optimal manufacturing process was found to be cold closed die forging.

To distribute the cable force implemented by the user to all four wheels rather than two, a converter was used shown in Figure 15.56. Having design conditions of lightness and stiffness, with a corrosive resistance to outdoor environments a Wrought Aluminum Alloy was found as the material of choice.

The final primary part of the braking system was the brake pad. Two brake pad designs were implemented depending on the spring used for the particular wheel. The figure shows the manner in which the tension cables would be used to disengage the brake from the wheel. Both designs were found to have similar specifications and stresses. The result found from the material and process selection, was to make each brake pad from a cast aluminum alloy through die-casting.

In summary, each material and process was found from considering things such as force analysis, strength, shape, cost, and batch size. Each secondary component such as the springs and cables would be purchase standard. The attachment of the four wheel reverse braking system can be seen in Figure 15.58.

Cost would be approximately $41.40 to produce the reverse braking system.
ONE-HANDED PISTOL LOADER

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INTRODUCTION
A one-handed pistol loader was designed for one-handed target shooters who require a safe and easy way to load their pistols. A client requested that the design team develop an easier way for him to work the action of his pistol with only one hand. After considering strength and hardness requirements/limitations, as well as other design criteria, CES software was used to determine the best material and manufacturing process for the device (assuming 100,000 units are to be made). The Pistol Loader will be made out of injection molded HDPE (High Density Polyethylene).

SUMMARY OF IMPACT
There are many different kinds of pistols which require different methods of loading, otherwise known as “action”. In order to load a bullet into the chamber, the user must first insert the clip. He or she then manually slides the top portion of the pistol back toward him/herself approximately 1.25 inches against the force of a coil spring that supplies between 10-15 pounds. It is very difficult and dangerous for one-handed users to accomplish this task. To load the pistol the client holds it between his knees and uses his one free hand to slide the action back. There are currently no products on the market to assist people with one hand in loading pistols. The Pistol Loader eliminates one of many limitations faced by people with the use of only one arm.

TECHNICAL DESCRIPTION
The device attaches to the user’s thigh by a secure and adjustable strapping system. It is sized in order to accommodate a wide variety of same-style pistols. When the user wishes to retract the action of the pistol he or she places the muzzle into the device and pushes down on the grip. The retracting portion of the pistol will remain stationary, as the device constricts it. The base of the pistol slides downward along with the barrel of the pistol, which protrudes through the hallowed bottom of the
loader. In other words, instead of the top part of the pistol retracting toward the user, the base portion of the pistol protrudes downward.

Cost analysis revealed that the product would cost $4.25 per unit.
INTRODUCTION
The objective of this design project was to produce an assistive device to help individuals with certain physical limitations pull up their pants. Such a device allows users to lead a more independent lifestyle, relying less on others for assistance. This device must be able to lift the user’s pants, along with any objects that might be in the pockets. This device must accomplish this while being as unobtrusive as possible.

Using a new approach, the design team was able to overcome several limitations of previous designs, such as the Prototype I Pants Puller-Upper (Figure 15.63). Previous designs failed because the user lacks the strength and mobility to control movement.

After consulting the client, the design team created the Pant-Matic, a new standard in assistive pant-raising technologies. The Pant-Matic allows users to conveniently raise or lower their pants with the push of a button.

The Pant-Matic uses dual electric DC gear motors with a rechargeable battery pack, mounted to a comfortable adjustable hip belt. Suspender-like clips securely grip user’s pants. This system is designed to stay on the user for several hours, perhaps under a large shirt, ready to assist at any moment.

SUMMARY OF IMPACT
Many individuals have muscular degenerative diseases. For these individuals, simple everyday tasks such as brushing teeth or getting dressed become very challenging without assistance. Assistive technologies that allow them to achieve these tasks without assistance are very important.

Using the Pant-Matic, individuals will be able to use the restroom without assistance. The Pant-Matic allows its users to regain their dignity, through self-reliance and independence.
two pieces will be the only components produced in-house.

The motor and clutched gear head will be outsourced, and are sized based on a specific output shaft torque and speed. The torque is calculated assuming the unit needs to lift twelve pounds. The speed is calculated assuming the Pant-Matic needs to lift the pants thirty inches in less than five seconds. The limited-slip clutch allows the user to set the slipping torque, preventing any injuries.

The control box, consisting of two buttons (raise/lower) will be outsourced as well, along with the rechargeable battery pack, suspender clips, and heavy-duty bands. This outsourcing of components will significantly reduce capital costs.

The Pant-Matic concept has been tested using a prototype. Testing of the prototype has confirmed that this design would be successful.
MONOSKI OUTRIGGER

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INTRODUCTION
A monoski outrigger was developed incorporating shock absorption in an effort to reduce injuries to the shoulders and upper arms of adaptive skiers. Adaptive ski programs have become increasingly popular in recent years. There have been major advancements in the design of the sit-ski, but little has been done to provide shock absorption in the outriggers. The redesigned outrigger incorporates a spring based damping device mounted in a scissor configuration. The Cambridge Engineer Selector software was used to select the best materials for the design. It was determined that all tubular shafts would be manufactured using carbon fiber, and all other hardware would be made of wrought Aluminum Alloy. In the highly competitive world of monoski racing athletes will be willing to pay extra for this new technology.

SUMMARY OF IMPACT
The need for new technology in the sport of adaptive skiing is abundant. Monoskiers can reach speeds of up to 60 mph while racing down the slopes. When using the outrigger for turning and breaking, tremendous forces are transmitted to the arms and shoulders of the athlete. Without any means of shock absorption in current outrigger designs, injuries are a common occurrence for adaptive skiers. The goal of the redesigned outrigger will be to provide a level of shock absorption that will prevent injury.

TECHNICAL DESCRIPTION
The design specifications of the monoski outrigger are that it must be strong, light weight, aerodynamic, and able to withstand exposure to snow and ice while in use on the mountain. Material selection based on these design criteria was preformed using Cambridge Engineering Selector software. Figure 15.66 shows a solid model of the proposed outrigger design. The design consists of scissor arm configuration with a mountain bike shock absorber mounted in the middle by means of two pin joints. This shock absorber scissor configuration has been designed after consulting mountain bike and ski experts. This scissor configuration ensures that all forces are transmitted through the shock absorber maximizing its effectiveness. It has been determined that injection molding of thermosets is the most economical manufacturing process for producing the carbon fiber scissor arms. Automated standard machining has been chosen as the process to manufacture the wrought aluminum components; Pin Pivot Connectors, Shock Support Brackets, and the elbow joint connector. Figure 15.68 shows the outrigger prototype as it would be used in stopping or turning the monoski.

Through cost analyses it was determined that the redesigned outriggers will cost $460.00 per set.
Figure 15.67. Outrigger Prototype.

Figure 15.68. Prototype Used In Braking.
INTRODUCTION
The Adaptive Head Pointer has been created in order to assist a college student who has a debilitating muscular disease. Currently, to type, write, or manipulate objects, the client uses a custom-made head pointer. However, when the client needs to switch between pointer implements (eraser, pen, pencil, etc.), he must call on a friend or aid for assistance. The new independent design allows the client to change implements as he desires through the use of an attachment, which mounts to the end of his headpiece. The design, modeled after a mechanical pencil, combines parts made of die cast aluminum and injection molded polypropylene.

SUMMARY OF IMPACT
Although there are alternative headpointer designs currently on the market, the scope and variety of usage are very limited. Focusing on the client, but keeping in mind there is a larger market available, the adaptive headpointer will vastly increase the personal independence, daily effectiveness, and efficiency of users.

TECHNICAL DESCRIPTION
The Adaptive Head Pointer's main design criteria were to create a light, durable, and cost effective way for the client to independently change his various head pointer implements. Due to design performance requirements, individual parts are given different material parameters. Utilizing the Cambridge Engineering Selector (CES) Software to obtain the optimal material's exhibiting these properties, Aluminum and Polypropylene were selected. As can be seen in the expanded assembly, Figure 15.69, the Outer Sleeve, Spring Compressor, and Inner Sleeve are all to be injection molded out of polypropylene, while the Grabber Arms, and Implement Holder are die cast out of aluminum. The selection for polymers require filters for high strength to weight ratio, low cost, and high fracture toughness, while the metals are also selected for these attributes as well as ductility, and high elasticity for the grabber arms. The process selection was also performed using the CES software, and based upon a required production volume of 100,000 units.

As can be seen in Figure 15.70 and 15.71, the adapter is connected via the spring compressor to an aluminum rod, which is mounted on the client’s headpiece. In order to change implements, the client approaches the table/surface mounted Docking Station and pushes the inner sleeve’s outer radius against the face of the base. This motion causes the spring to compress, extending the grabber arms, and allowing the implement holder to fall free of the assembly due to gravitational forces. The client can pick up an alternate implement by positioning the grabber arms in front of the appropriate base slot, and pushing in a similar manner to the unloading phase. Because the implements sit on the bottom of the base, once the grabber arms slide over the implement holder’s protrusion, frictional forces allow the spring extension to pull the new implement and holder back into the assembly.

This head-pointer, including accessories, will cost approximately $150 to manufacture, well under the $300-1600 range found on the market today.
Figure 15.70. Docking Station and Adaptive Head Mounted Pointer Side View.

Figure 15.71. Docking Station and Adaptive Head Mounted Pointer Overhead Angled View.
A BETTER CRUTCH

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INTRODUCTION
The goal of this project was to increase the comfort and functionality of the standard crutch. Proper crutch technique with standard crutches focus the body weight on the wrists, providing an uncomfortable experience for even the most physically capable user. Although our design will assist all crutch users, it focuses on individuals who are prone to further injury through crutch use. For example, postmenopausal women are susceptible to osteoporosis therefore leaving them vulnerable to bone injuries where they must use crutches. Because osteoporosis depletes bone density, not only will the bones take longer to heal, but also the extended crutch use could possibly cause wrist or shoulder damage. The Better Crutch prototype was designed to distribute the user’s weight between the wrists and the underarm. The approach included structured design methods such as the 6-3-5 method, the analogy method, Pugh method, and the TRIZ method.

SUMMARY OF IMPACT
The Better Crutch design successfully allows users to place weight on the underarms of the crutch without fear of damage to the radial and auxiliary nerves, which is not possible with standard crutches. Better Crutch users will experience enhanced mobility and increased comfort. Because of limited budget and availability of parts, the prototype is only a representation of the design.

TECHNICAL DESCRIPTION
The design includes a shock absorbing tip, increased tip-ground contact, an ergonomic grip, and an innovative “rocking” underarm support. The shock absorption is accomplished using a simple pin in slot design. The system is similar to a shock found on a pogo-stick. The springs are easily changeable with other springs of various spring constants so that the user can adjust the amount of stiffness in the shock absorber to personal preference. In order to provide greater foot contact, an “ankle” on the foot of the crutch is designed. The “Tornado Tip,”TM created by Walk Easy Inc., accomplishes the ankle function and increases tip-ground contact. The pistol grip is an ergonomic grip that is designed to be shaped to the hand and promote proper wrist position. Unlike the current handgrip design, the pistol grip will not rotate, which helps prevent unhealthy wrist position and increases the user’s control of the crutch.

The rocking underarm support is the most important part of the design. The material selected is wood, because it is lightweight, strong, and easy to shape. Instead of the straight bar shape of the standard crutch underarm support, the rocking underarm support is a U shape. The U shape cradles the underarm and keeps the crutch from slipping out from under the arm while in stride. The rocking function of the support acts much like a seesaw, attached to the crutch using a bracket. Attached to each of the brackets is a torsion spring to support the underarm brace while allowing the rocking function. The bracket is attached to the crutch with a metal sleeve, to decrease friction and increase durability. The rocking function keeps the support level to the ground throughout the stride, allowing the user to place weight on the crutch. The springs help move the crutch through the stride, providing easier and energy efficient walking.

The total cost to build the prototype is approximately $60. This excludes the Tornado Tips™, which cost an additional $30 (including shipping).
Figure 15.72. Better Crutch.
INTRODUCTION
A one-handed jar opener was designed for individuals with diminished muscle strength in the hands, wrists and forearms. The goal of the design was to reduce or eliminate the gripping force, twisting motion, and squeezing action necessary to open a jar. The criteria were adaptability, compactness and cost effectiveness. While there are products on the market that provide assistance in opening jars, the aid they provide is limited.

The design is based on the function and appearance of an oil filter remover, which provides the same function necessary to remove a jar lid.

SUMMARY OF IMPACT
The jar opener has met the clients’ needs and requirements. Requiring little force, the client is able to open the jar lid within seconds. The range of lids it is able to open is 85 to 90% of jars on the market. It is produced with a compact base that can easily fit inside a kitchen drawer with a handle that can be stored with other kitchen utensils. It is affordable for the average consumer.

Individuals with physical conditions affecting their ability to perform the routine tasks of everyday life often use assistive devices. The jar opener is more efficient compared to the jar openers on the market today.

TECHNICAL DESCRIPTION
The material used had to be capable of withstanding repeated applications of force. The base had to be space efficient and easily stored. In addition, the two clamps had to be able to withstand pressure when tightened around the jar and lid. It was also important that the clamps effectively grasped and opened the lid without slipping.

The jar opener has three main components: the handle, the base and the clamping system. The handle is made up primarily of a 6.25 inch long circular shaft with a 0.438 inch diameter that is easily cut. This is welded to a one-inch diameter and 0.5 inch thick circular disk. Welded to the disk is a 0.375 inch tube with a ball and spring in the side to lock the handle into the clamp. Rubber padding is also bonded to the circular base to increase friction between the jar lid and the disk.

The base is designed and built to accommodate the requirement of compactness of the customers. It is important to the customer that the device does not take up much space in the kitchen. It can be easily stored and bolted into any kitchen drawer. The base is an aluminum disk with a six-inch diameter and is 1.25 inch thick with a 0.375 inch steel cube welded to the center where the clamp is attached.

The two clamps in this design are based on the function and appearance of an oil filter remover. There are three arms on the clamp, each with rubber padding to increase friction between the jar and the arms.

When the free handle is placed over the lid and the jar is on the base, turning the handle causes the arms to contract toward the center, grip the lid and jar and open the lid.

The cost of the parts is $40.
Figure 15.73. Jar Opener.
ONE-HANDED JAR OPENER

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INTRODUCTION

Many elderly people experience severe arthritis and carpal tunnel syndrome as a result of consistent use of their hands and fingers throughout their lives. With weakened limbs, it makes gripping lids of jars securely difficult, and may be difficult to create the torque needed to turn the lid and release the vacuum seal.

This product is a jar opener that only requires the use of one hand (Figure 15.74). It will appeal not only to people with weakened limbs but also to individuals who may only have one arm or one hand.

SUMMARY OF IMPACT

This product will allow individuals to open jars with only one hand. They will not have to worry about holding the jar securely and then using their other hand to grab the lid and twist it open. As most people get older, they become physically weaker and creating the torque needed to open jars can be difficult. This product provides anyone who can hold a jar with the ability to open it with one hand by pushing it into the device. The ability to mount this product under a cabinet out of the way allows the consumer to have easy access to it when needed without being burdened with another countertop appliance.

TECHNICAL DESCRIPTION

The final product encompasses a “push method” of opening the jar. As shown in Figure 15.75, the v-shaped lid grip is mounted to a four-inch wide steel gear which rides along a steel track and rotates about its center which is suspended from a pair of rails using a circular shaft. As the gear is translated towards the rear of the rails, the v-grip rotates along with the gear and rotates the lid of the jar in a counterclockwise direction.

This design satisfies the four sub functions that needed to be addressed by having the individual hold onto the jar, which is much easier than trying to grip a narrow lid, and making the unit mountable so any height jar would work. By combining the gripping and rotation of the lid together in the same task, efficiency was maximized. Overall, it produces a very simple, but effective way of removing the lid of a jar while requiring nominal effort from the operator.

Overall dimensions of the unit show it hanging four inches vertically from its mounting location and measuring six inches across (Figure 15.75). The jar opener will measure nine inches in depth when mounted under a cabinet. This jar opener will accommodate jar lids ranging from ½ inch up to 3.5 inches.

Total cost to build this prototype was $50, which includes all parts and hardware.

Figure 15.74. One-Handed Jar Opener.
Figure 15.75. Jar Opener.
ATTACHMENTS TO STANDARD UNDERARM CRUTCHES FOR USE ON STAIRS

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INTRODUCTION
A pair of attachments was designed for standard underarm crutches. Through surveys and questionnaires it was determined that, when using standard crutches, it is difficult to repeatedly ascend or descend a staircase without fear of falling and causing further injury. It has been determined that adding a second leg to each crutch will not only diminish the risk of falling, but also reduce this fear. The attachments are designed to fasten to the majority of crutches and adjust for a wide range of heights.

SUMMARY OF IMPACT
Individuals either temporarily or permanently inhibited by leg injuries often use underarm crutches to aid in mobility. Although crutches are effective on level surfaces, they become cumbersome when used for ascending and descending stairs. The pair of assemblies, when attached to standard crutches, will enhance balance for the user and increase mobility, as well as collapse quickly and easily when not in use.

TECHNICAL DESCRIPTION
The structural tubes used are manufactured from the same material as used in standard aluminum crutches. Aluminum is used throughout the design in order to be lightweight while still remaining cost effective. The assemblies had to be able to withstand a variety of user weights as well as adjust for different user heights. In addition, the assemblies also had to be able to collapse quickly using a single hand.

Each assembly has three main components: the enclosed shock, the adjustment system, and the main clamp. The shock enables the user to lean forward when ascending stairs, and backwards when descending stairs, to prevent loss of balance. Furthermore it is useful on a variety of stair heights and can be adjusted for different user weights. The adjustment system consists of the standard button snap seen on standard aluminum crutches and allows the user to adjust the crutch and assembly lengths for his or her specific height. The main clamp employs a quick-release bicycle seat clamp and attaches the top tube of the assembly to the main structural tube of the crutch. The clamp allows quick, one-handed extension and collapse of the assembly. The total collapsed volume of the assembly is 25 cubic inches and the weight of each assembly is 24 ounces.

The cost of parts for the pair of assemblies totaled $21.
Figure 15.76. Standard Crutch with Attached Assembly.
INTRODUCTION

The one-handed corkscrew was developed to address the need of individuals with disabilities that limit the use of one hand. This design was intended for complete operation with only one hand, while most bottle openers require two hands.

The objectives of the creation of this product were to develop a method of opening a bottle that was: 1) one-handed, 2) physically easy to use, 3) effective in operation, 4) portable, and 5) aesthetically pleasing.

The one-handed corkscrew was developed through a rigorous design process that began with the identification of a problem and culminated in the development of a prototype. During the process, multiple methods of concept evaluation techniques were utilized.

Present bottle openers consist of portable cork removers and wall-mounted openers. All portable cork removers seen on the market require two hands for use. Only the immobile openers can be used with a single hand.

SUMMARY OF IMPACT

Arthritis, tendonitis, muscular weakness, and amputation limit the abilities of persons to operate many common devices. The corkscrew is among the more challenging devices to operate with a single hand.

Users of the one-handed corkscrew are required only to hold the device upright and push the trigger to operate the electric corkscrew. The design is easy to operate and produces no net moment on the bottle, thus requiring no stabilization.

TECHNICAL DESCRIPTION

The one-handed corkscrew consists of two counter-rotating corkscrews attached to a battery driven electric motor. The corkscrews are helical steel of gage diameter 3/32 inch and a screw diameter of 5/16 inch. The total length of the screws is 3.5 inches and the pitch is 15 degrees. The screws are made of high carbon heat-treated steel.

The screws are geared to counter-rotate. One of the screws is attached directly to the motor driveshaft. The motor driveshaft is directed through a four stage planetary gearing system. The motor used is a small DC motor run by four AA batteries.

The entire system is encased in an ABS plastic housing. The housing stabilizes all internal components of the corkscrew. The housing is attached to a movable guide that is used to direct the screws into the cork. The guide also functions as a stop against the bottle lip.

The one-handed corkscrew operates in three steps. First, the user places the device on the bottle top and starts the motor operating. The twin screws begin to drive into the cork. At a depth of one inch, the stop hits the bottle lip and the screws continue to turn, pulling the cork from the bottle. When the cork is removed from the bottle, the user then reverses the motor and the screws rotate in the opposite direction, removing the cork from the screws.
The cost of the parts for the corkscrew was approximately $63. The cost included a modified electric corkscrew.

Figure 15.78. One-Handed Cork Screw Assembly in Exploded View.
INTRODUCTION

Designs for jar opening devises were created using such methods as the 6-3-5 and were assessed using a house of quality, and the Pugh method. Every option was carefully considered, and pros and cons taken into account, recorded quantitatively, and the knowledge gained was implemented in future designs. The result was the OPEN-ALL®. Along with functionality, the OPEN-ALL® was designed with ease of assembly in mind.

The device quickly and efficiently assists in opening jars. In only moments, it can be adjusted to fit any size jar, and only requires the use of a single hand to operate. Other features of the OPEN-ALL® include a compact and easy to store design, as well as the versatility to open almost anything with a cap or lid such as jars, pill bottles, peanut butter, and juice bottles.

Current designs for jar opening assistants are often bulky, expensive and require the use of two hands to operate. Although the device overcomes all of those shortcomings, there is room for improvement in the current design. The arm of the upper gripping devise needs to be lengthened in order to better provide more centric pressure on the jar. Also, outlines could be drawn on the rubber grippers in order to ease the alignment of the jar. Ultimately, a simple self-aligning gadget could be implemented.

SUMMARY OF IMPACT

This project allows anyone to open any size jar regardless of how tight the lid is with a single hand. The design is useful especially for individuals with disabilities who may only have the use of one hand.

TECHNICAL DESCRIPTION

The base is two and a half inches high, eight inches deep and four and a half inches wide. Its maximum height is 20 inches, which is due to the length of the vice clamp. The large vice clamp essentially allows the client to use any seized jar on the market. It weighs only seven pounds, and about 45 percent of the weight is a result of using the industrial strength vice clamp ASD had chosen.

The vice clamps can provide more than sufficient amounts of pressure onto the ends of the jar, with a few squeezes of the trigger. The trigger also allows discrete height adjustments, allowing any sized jar within its range to fit in the device.

Figure 15.79. The lever arm is pushed counterclockwise to open a jar.
CHAPTER 16
UNIVERSITY OF MASSACHUSETTS AT LOWELL

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INTRODUCTION
The education of moderate to severe special needs students typically requires specialized equipment. This equipment ranges from simple activities or toys to room-sized sensory-integrated Snoezelen room environments. Both have specific advantages and disadvantages that must be weighed considering the benefits of the child; however, both share a common fault: lack of flexibility.

SUMMARY OF IMPACT
Unlike dedicated activities, the Activity Cube is a flexible and customizable learning tool, which can be adapted for many specific learning goals and styles. This allows teachers and other educational facilitators to effectively target the educational needs of a student, as might be outlined in an IEP for example. As the child learns and grows, the interchangeable sides can then be switched out for more challenging exercises.

TECHNICAL DESCRIPTION
Based around a cubic structure, there are four available sides. Each side is constructed in such a way to be interchangeable, having similar power supply and mounting requirements (Figure 16.1). Each side contains one activity of varying difficulty and purpose to engage and teach students. For an initial construct, the project contains a voice recording circuit, numeric counter circuit, a sensory circuit, and a timed light circuit.

The timed light circuit consists of two 555 timers controlling a series of various size LEDs. One 555 is designed to turn on for a short period of time, approximately seven seconds, which powers the second 555. The second 555 timer is set up as a stable oscillator at a frequency of about 19Hz. This second 555 timer drives a series of LEDs. This simple one-step activity provides an immediate response when a student presses a large button.

For a more advanced student, a numeric counter is constructed using logic components. Using Karnaugh maps and next state diagrams, a sequential counter is constructed using D flip-flops coupled with a BCD decoder. Buffered through an inverter, LEDs are wired for each decoder decimal output, representing each decimal digit.

The voice recording circuit is a side that allows a caregiver to record a personalized message, which is played back by the student pressing a button. Up to four different messages, each recorded on its own IC, is stored in non-volatile memory (Figure 16.2). When a student presses one of four switches, the IC is edge-triggered which allows playback through an audio amplifier and speaker. Of all activities currently on the cube, this is the most adaptable for a multitude of student needs. This side could be used for games, educational purposes, or fun.
The sensory circuit is designed to encourage fine motor skills by rewarding students with one of three sensations. The side consists of three small doors, behind which are individual rewards for the action of opening the door. The largest door has a series of lights that glow. The second door has a fan, which provides a tactile feedback. The third door has a small chime.
INTRODUCTION
The hands-free television remote was designed to provide a means to control a television using speech recognition. This project uses custom software, existing software, custom hardware, and a speech recognition program to achieve the desired goal of a hands-free television. Part of the existing software uses X10 technology to communicate from a computer to an X10 module that controls the universal television remote.

SUMMARY OF IMPACT
The Hands-Free Television Remote may improve the enjoyment of watching television by removing the frustration those individuals with disabilities experience when having trouble pressing one of the buttons on the remote.

TECHNICAL DESCRIPTION
Pico Electronics created the X10 communication protocol in 1970. This communications protocol uses existing 110 volt house wiring to communicate between modules. Other forms of networking, e.g. Ethernet, would require additional wires to be installed in a house.

The following are the key components to the system:

- Dragon Naturally Speaking 5,
- 16 Batch files,
- Cma17a X10 communication software,
- Assorted logic gates,
- X10 modules, (Relay board, TW523 interface module) and,
- A universal television remote.

Dragon Naturally Speaking listens for a command from a client. Depending upon the command issued from the client Dragon Naturally Speaking will activate one of the sixteen batch files. The batch file will call the program Cma17a and pass two parameters to the program. The two parameters are a house code and a unit code. The Cma17a program will take the two parameters and open the COM port of the computer and send an X10 package containing the house code and unit number to a 110-volt wall outlet from the computer. The X10 signal will then be broadcasted throughout the house to the waiting TW523 module that has the appropriate house code. Once the command reaches the TW523 the command will be interpreted and the appropriate relay will be turned on for one second. During this time the batch file will call the Cma17a program for a second time and pass it two new parameters, the first parameter will be the same house code as before but the second parameter will be a different unit number. The Cma17a will reopen the COM port of the computer and send this second package out to the 110-volt wall outlet. This second X10 signal will travel through the house wiring to the waiting TW523, which will turn on a second relay.

To integrate a remote control to the relay board, a universal remote was disassembled and wired into a logic circuit. When the relay board receives the appropriate house code and channel number it will turn on a relay for one second. When the logic circuit sees one of the relays turn on it will latch the input and wait for a second relay to turn on before a button on the remote can be “pressed”.

Using a four by four relay board from RCS Electronics the remote control will have the following functions available power on or off, increasing or decreasing the volume, changing the channels up or down, or pressing one of the 10 numerical buttons. If another relay board with more relays is selected then more functionality can be added to the hands free television remote to include VCR’s, DVD Players or other devices that can be controlled by a Universal Remote. Figure 16.4 is a flow diagram for the above process.
Figure 16.4. Flow Diagram.
THE LIGHT SENSOR ROBOTIC VEHICLE (LSRV)

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INTRODUCTION
The Light Sensor Robotic Vehicle (LSRV) was designed to provide children the opportunity to improve motor skills by moving a light, to promote creative thinking, and to enhance cognitive development.

SUMMARY OF IMPACT
The LSRV provides a child with special needs a toy that is controlled by a light. It is stimulating for the child and enables children to have control over a flashlight.

TECHNICAL DESCRIPTION
The main components are a light sensor, hardware that controls the toy, and the toy itself. For the hardware Handy Cricket, designed at MIT, is used. The Handy Cricket is programmed in a language called “Cricket Logo,” which is a simplified version of the powerful yet easy-to-learn Logo language.

Users can type in expressions and have them compiled on and run immediately, rather than waiting for lengthy compile and download cycles.

The toy component was designed by Radio Shack (Figure. 16.5). The power supply circuit provides isolation between the logic and motor circuits and the Cricket to operate better with noisy motors. The main power source are four AA cells (1.5V x 4 = 6V). The motor circuit can carry .5 amps of current. The LSRV has two switches, one power switch and a start/stop switch. The power switch simply turns the vehicle on. The start/stop switch is intended for the LSTV to use.

The cost of parts and materials was $130.
Figure 16.5. Toy Vehicle.

Figure 16.6. Handy Cricket.
ENVIRONMENTAL CONTROL SYSTEM

Designers: Stephen F. Hynes
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INTRODUCTION
The environmental control system was designed for an individual with no use of her hands or arms to control of the surroundings by using her voice. This system was comprised of x-10 hardware with a software interface called Active Home and Dragon software. Adjustments were made so that the user could change the TV channel and volume along with the appliances and lights in her room.

SUMMARY OF IMPACT
The design of this system was a great benefit to the hospital nurses along with the recipient. Without this system, any time the patient wished to change the television station a nurse would need to be called. This system allowed for not only control of the devices with the use of voice but use of the mouse or pushbutton on the remote.

TECHNICAL DESCRIPTION
The flow in which the user controls the system is illustrated below in Figure 16.7.

The user attaches a wireless microphone to the body and issues commands to the computer. Dragon Natural Speaking software then takes the sounds and converts them into text. If the text is a recognized command, the software will perform that command. The other piece of software for this system is a program that is available from X-10 it is called Active Home. This software pictured in Figure 16.8.

This can be run while minimized and when the user says a recognized command it will pull up the program and execute the proper function. There needed to be some slight modifications to some of the modules so they would function the way the system was designed. This was done by taking apart the X-10 modules and changing a capacitor. There were additional alterations that were necessary for the universal remote control to be controlled from the computer. By the use a standard modular telephone jack to connect the X-10 modules to the remote allowed the user to change the configuration of the room and change length or remote to X-10 modules without needing to be concerned about constraints of the wiring on the module to the remote.

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**Figure 16.7. Block Diagram of System.**
Figure 16.8. Active Home Interface to X-10 Modules.
SPEECH RECOGNITION FOR A VOICE-ACTIVATED ENVIRONMENTAL CONTROL USING HIDDEN MARKOV MODELS

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INTRODUCTION
Speech recognition capability was developed for a voice-activated environmental control system using digital signal processing (DSP) technology. The ultimate goal of this system, which was designed specifically for individuals with disabilities, was to facilitate the independent operation of various home appliances via voice activation. These appliances included lights, TV, VCR, radio, telephone, etc. The typical client would be a person who has a physical disability, has poor vision, or lacks fine motor skills. It promotes self-sufficiency and autonomy.

The Analog Devices ADSP-21065L EZ-Kit Lite was utilized to realize this functionality, thus taking advantage of the cost-efficiency and reliability of DSP technology. The implementation of hidden Markov models (HMMs), through their statistical modeling of speech generation, was used to achieve its recognition abilities.

The system, which is speaker dependent, was designed to recognize isolated words from a limited size vocabulary. The C programming language was used for implementation.

SUMMARY OF IMPACT
A block diagram of the speech recognition system’s operation is shown in Figure 16.9. The two different paths represent the two phases of operation of the speech recognition engine. During the first phase of operation, the training phase, an HMM has been created and modified for each word to be recognized in the limited size vocabulary of the system. Each of the words has three copies (different utterances of the same word) for training purposes in order to provide sufficient data to make reliable estimates of all model parameters. During the recognition phase, the likelihood probabilities of each of the constructed HMMs producing the encountered observation sequence (spectral information) from the test word have been calculated. The highest likelihood probability distinguishes which word is recognized.

TECHNICAL DESCRIPTION
The implementation of speech recognition realized on the Analog Devices ADSP-21065L EZ-Kit Lite board successfully recognizes four words with very high efficiency. The relatively conservative vocabulary size is due to the limited amount of program and data memory available on this particular DSP model, in conjunction with the way speech recognition using HMMs works. Due to the limited amount of training data available in this project, and to keep efficiency high, a modest vocabulary size of four has been decided upon. An addition of data memory directly onto the DSP can increase its capacity and efficiency dramatically.
Figure 16.9. Block Diagram of System’s Operation.
DOORBELL FOR INDIVIDUALS WHO ARE DEAF

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INTRODUCTION
The doorbell was designed to help individuals who are deaf or hard of hearing to know when someone is at the door. This device originally is a simple closet lamp, which is modified to use a strobe light to increase the brightness of the lamp and cause it to flash. The device includes the lamp and the doorbell push button, and uses 110 volts ac to operate. Whenever the bell is pushed, this activates the Xenon light and a high intensity flash that attracts attention even when an individual is looking in another direction. The flashing lasts 30 seconds before it stops automatically.

SUMMARY OF IMPACT
Individuals who are deaf rely on a variety of technology for better communication and awareness of their surroundings. The doorbell for individuals who are deaf was designed to be one of these items. It uses flashing light to alert instead of sound.

TECHNICAL DESCRIPTION
The 555 Timer One Shot Circuit: The first part of the circuit incorporates the 555 timer to supply 9VDC for the strobe light circuit for a predetermined amount of time by pressing a momentary N/O push button.
The Strobe Light Circuit: There are three parts to the circuit: 1) Oscillator centered around T1 transformer, 2) RC Network R8, R9, R10, and C6 which controls the flash rate, and 3) the Flash circuit. The RC Network: Capacitor C6 is charged at a rate determined by resistors R8, R9, & R10. This charging rate determines the flash rate. Flash Circuit: the voltage across C6 charges through R9, when it reaches about 70v (the firing voltage of the neon) DS1 fires, a high voltage pulse from the trigger transformer appears on the surface of the flash tube, the electric field inside the tube initiates the break over and the tube flashes. The cycle then begins again. Flash Rate: This is determined by the RC network. The time constant of the RC network is given by the equation $\tau = R \times C$.

The cost of parts and material was approximately $20.

Figure 16.11. Schematic.
INTERACTIVE MIRROR

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INTRODUCTION

For students with disabilities, the interaction of different sensory stimuli is beneficial for growth and learning. By using their senses together, they can better learn how to interact with their world.

This project, the Interactive Mirror, combines both light and sound to entertain and stimulate students with disabilities. Using a CD player in tandem with fiberoptic cables powered by multicolor changing lights, the student can see the light response to the music in the CD player. The mirror serves as a backdrop to the project to help amplify the visual elements of the product. Mirrors alone often provide entertainment and interest for students with severe disabilities.

SUMMARY OF IMPACT

Commercial products designed for people with disabilities are very expensive due to the lack of suppliers and the small customer base. One of the biggest problems facing special needs educators is decreasing budgets for this often overlooked group of students. The Interactive Mirror helps to bring a useful tool to the educators at a cost of approximately $300 versus commercial products with less functionality costing $1200.

TECHNICAL DESCRIPTION

The Interactive Mirror combines visual and audio stimulation to aid students with disabilities in associating the two senses. The Interactive Mirror consists of a CD player and speakers to provide the audio element of the design. The audio output of the CD player is also coupled into an audio amplifier via an audio 1:1 transformer. The amplifier drives a light organ circuit, which detects when audio is present and triggers a 120V AC output according to the audio input. When an audio signal is powerful enough to trigger the light organ, the 120V AC output of the light organ is energized. The light organ circuit has a potentiometer to adjust its sensitivity to accommodate different applications. For this project the sensitivity is maximized in order to make the operation of the product as simple as possible. With this design, the user only needs to insert and play a CD and turn on the powered speakers; everything else is automated.

Three LED arrays are powered by the triggered 120V AC from the light organ. These LED arrays are enclosed in black plastic and have a circular constrictive receptacle that accepts a fiber optics cable. The three three-foot fiber optics cables are stripped to expose the stands of the cable. The exposed fiber strands are then scored with a razor to enhance the visual effect of the LED light traveling through the individual fibers by refracting the light many times through the strand before it reached the end of the fiber.

A basic block diagram of the Interactive Mirror is shown in Figure 16.12.
Figure 16.12. Block Diagram of the Interactive Mirror.
INTRODUCTION
A time controller was designed for a 72 year old adult who has limited use of his arms, hands, legs, and voice. This device can control up to 256 electronic devices at the same time by computer. The user can set up the time to turn on or off the particular device or devices at particular times, or all of the devices at same time.

The hardware and program were documented and designed so that if simple modifications are needed in the future, only Visual Basic code will have to be modified. The user does not need any technical background to use the time controller.

SUMMARY OF IMPACT
The client has paralysis leading to difficulties with walking and using his hands. His voice is very low and sometimes he has difficulty speaking. The client can use the time controller to control devices without assistance.

TECHNICAL DESCRIPTION
This product uses X10 technology. X10 is a communication language that allows compatible products to communicate with one another through the existing 110V electrical wiring found in most homes. This was X10 eliminates the need of expensive wiring. The following are the system components:

- 9-25 Pin Connecting Cable
- PSC05 Two-Way Powerline Interface
- LM465 Lamp Module
- AM466 Appliance Module
- Two-Way RS232 to X10 Interface
- Microsoft Visual Basic 6.0 Software

The total cost of parts and material was $170.
Figure 16.14. Time Controller User Interface.

Figure 16.15. Time Controller User Interface for House Code A.

Figure 16.16. Block Diagram of Time-Controller.
INTRODUCTION
The goal of this project was to create a tilt mirror operated via switches. The Tilt Mirror is a device that would help improve independence for students with disabilities in using a mirror. It entails the development of an electromechanical mirror system that will adjust the mirror positions with up and down directions.

SUMMARY OF IMPACT
This tilt mirror is a motorized mirror controlled by up and down switches. The user taps the up or down switch with minimal pressure, and the mirror tilts to that direction. When the switch is no longer pressed, the mirror stops tilting. However, the mirror only tilts about 45 degrees upward or downward, and once it reaches that point, it automatically stops, unless the other direction is selected. In addition, the mirror also has a lighted frame to assist students with visual impairments.

TECHNICAL DESCRIPTION
The adjustable tilt mirror is covered by a box made of wood. The mirror size is 24 by 16 inches. This project consists of four single pole double throw switches.
switches (SPDT), a 12V DC gear motor, two big tap-on switches, a 12V DC adapter, and 12 feet light kit. The slow speed of the motor has been chosen at six rpm to simplify the circuit and to minimize the cost as much as possible by avoiding the speed control.

The shaft of the motor is inserted at the middle of the metal bar and two ropes are attached to the back of the mirror to the metal bar. As the motor turns, it causes the metal bar to rotate and pulls the mirror backward. Two SPDT switches are placed about eight inches away from the metal bar, and as the motor turns, this metal bar keeps rotating until it reaches the switch. It cuts out the current which leads the motor to stop. These two switches are used to control the mirror to tilt at the certain angle, but even if the user tries to force the mirror to tilt far back, it will not work. In addition, each of the two other SPDT switches are inserted inside the tap-on switches as on/off switches This avoids burn out of the motor when the user accidentally presses both switches at once because the motor can only rotate one way at the time. Furthermore, the tap-on has the ability to operate the tilting directions of the mirror. If the upward switch is pressed ON, it causes the mirror to move upward. By releasing the switch, the system is turned OFF and the mirror stops. This is the same for the downward switch.

Total cost of the part is $135.
SOUND ACTIVATED BUBBLE LIGHT SYSTEM

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INTRODUCTION
This sound activated bubble light system is developed to help children with disabilities have fun and turn on the system without assistance. To operate the bubble light, the child makes sound near the microphone, which can be clapping or any sound input from the other devices. When the system is turned on, the colors will change to red yellow, green, and blue with air bubbles inside the tube. The system is safe to operate, and it allows children to play with more independence.

SUMMARY OF IMPACT
The device will be used by children with disabilities who have limited mobility, speaking ability, and difficulty operating toys with their hands. These children enjoy watching the colors and listening to sound. A similar commercial device costs about $800. While the current device can be made for less than quarter of that price, that lower cost may enable a larger number of customers to access to this type of device.

TECHNICAL DESCRIPTION
The systems have a sound sensitivity control and electret microphone. The sound activated switch is a combination of analog and digital circuits. The self-stabilized-biasing circuit is used to design the powerful FET amplifiers, which include a BC547 standard transistor. The digital circuit consisting of an IC714 is an inverting Schmidt Trigger IC, from National Semiconductor. The ideal of the analog circuit is to capture the input signal and module in this frequency domain. This signal is then converted to digital signal as stated HIGH or LOW by the use of the Inverting Schmidt Trigger. The switch is designed to turn off the system about 10 seconds after sound input.

Figure 16.20. General Block Diagram.
after the first sound is detected.

Figure 16.20 shows the general block diagram of the design project. Figure 16.21 is the complete designed project. The bubble light system consists of many parts. The bubble tube is made of clear plastic and a bottom seal supported by a base. The air bubbles are set from the bottom by the air pump that reflects the light beams in different angles. The light bulk is provided from the base, which sheds light to the bubble tube through the rotating colored glass. The synchronous motor is used to rotate the glass that will change colors when the switch is turned on. The system operates at low voltage using the 120/12VAC transformer. The sound switch operates at a six volt DC power supply.

The project operates in the following manner. First, the user adjusts the level of sound, which will turn on the kit. Secondly, he speaks or makes sound from other toys into the microphone. The sound signal is carrying frequency that is captured by microphone input to the first stage and second stage amplifier. A trimpot is connected between the two stages of amplifier to determine the sound level sensitivity. The first two stages of the amplifier have an overall gain of roughly one hundred, which is fixable for the analog signal to input to the Inverting Schmidt Trigger circuit. This analog signal is converted to a digital signal, causing the digital input to go high, thus turning on the output relay switch. The time delay circuit is a parallel combination of a capacitor and a resistor which connects between the digital circuit and power supply. When there is no sound input, the capacitor times out due to the power dissipated by the resistor. The values of resistor and capacitor use 1M Ohm and one micro Farad respectively. The time delay is determined by the time constant formula $R \times C$ which is equal to 10 seconds.
SINGLE SWITCH CHANNEL SELECTION REMOTE CONTROL

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INTRODUCTION
The single switch remote control (SSRC) has been designed to provide an individual with poor motor skills to cycle among four favorite channels on the television. A large single switch enables a programmable remote to change the channel to the next preprogrammed channel. Each time the switch is hit, the channel cycles through the four preset channels on the remote. When the last channel is reached, the next switch push resets the cycle to the first channel. The SSRC is completely wireless to enable mounting in front of the user (Figure 16.22).

SUMMARY OF IMPACT
The design application was predetermined by the ability of the client. The SSRC provided the client with the ability to change his own channels without assistance.

TECHNICAL DESCRIPTION
Since the device must trigger the four separate buttons of the programmable remote control, a circuit is constructed to trigger four different SIP relays (0305-M) at four different times. This is accomplished using only the first two bits of a four bit binary sequential counter (74163) that feeds into a logic circuit that triggers the separate relays. The logic circuit is composed of a quad two input AND chip (7408) and a quad hex inverter (7404). When the clock of the counter is triggered the two outputs receive a two bit binary code. The inverter and AND gates are designed to give a high signal to only one relay. This circuit then closes the relays independently. Next, a circuit to trigger the clock is needed. A monostable multivibrator (74121) is used to design a “one shot trigger.” After the installation of the “one shot”, the entire circuit functions properly to switch on the four relays in sequential order. A problem then arises with the relays always staying on. The circuit was keeping the relay triggered on until the next relay was triggered. This is not acceptable since the relay is to control a television remote button, which, when left pressed, would continue to change the channel until it is depressed. This problem is addressed by creating a circuit that will turn the last logic gate on for only a short period of time when the relay could be triggered. Another “one shot trigger” is constructed to trigger a relay that will allow the bias to the logic chip. This particular “one shot” is designed using a timer (555) so that the period of the pulse sent can be adjusted. To activate this “one shot” so that it will start the pulse when the relay is triggered, it has to be fed from the first one shot.

This created another problem, because the one shot was feeding the counter and the 555 timer it had lost the power to give the clock enough voltage. To remedy this, a separate one shot exactly the same as the first one is used in conjunction with an isolation circuit to keep the two one shots separate. The isolation circuit is designed to short a transistor (3904) when the base received a positive one shot. The transistor then shorts a path from ground to a SIP relay (8537) which sends a positive voltage pulse through it. This pulse then enters the trigger of the second one shot using the multivibrator. The output of that one shot triggers the timer one shot. After this is done, the circuit works flawlessly with an average momentary switch. When the circuit was tested using the large single switch, the one shot is pulsed two times for every one push of the switch. It had been determined that the switch cover is so heavy that it is bouncing after the button press. To cure this problem a debouncing circuit is installed in the direct line of the button. It is composed of an RC circuit to use the discharge time of the capacitor. When the button is depressed, the capacitor discharges until its path to ground is open.
Figure 16.22. The Single Switch Channel Selection Remote Control.
SWITCH ACTIVATED LIGHT DISPLAY

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Supervision Professor: Walter McGuire  
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INTRODUCTION

The Switch Activated Light Display will be an interactive learning tool that will be a component of the multisensory environment for a high school classroom. The environment is meant to be safe and non-threatening. The students with disabilities or other limiting conditions enjoy gentle stimulation of the primary senses.

The Switch Activated Light Display is seen in Figure 16.23. It is a table top device that one to four students will be able to benefit from at one time. Since there will be 16 different patterns that the lights will produce, depending on the switches that are pressed, this will give the students a sense of cause and effect, enabling a sense of control.

SUMMARY OF IMPACT

The Switch Activated Light Display is designed for the students to use independently. Once the light display is turned on, by a flip switch on the back of the device, it accepts any combination of inputs from the jelly bean switches and produces the desired output. Since the students have poor hand-eye coordination, large jelly bean switches are used to activate the light display. The patterns that the lights will produce simulate the students’ senses, and since four switches are necessary to display all the patterns, this will encourage them to work together. This device is portable, because the classroom that the students are in is subject to change. Therefore, the device is compact and lightweight.

Figure 16.23. Switch Activated Light Display.
TECHNICAL DESCRIPTION
The dimensions of the main display are: 8-inch width, 6.5-inch height, and 2.5-inch thickness. The input switches each have a 2.5 inch diameter. There is one power supply. The switches are connected by a wire storage container. The teacher can easily adjust the length of the wires.

The major components in the switch activated light display are the basic stamp microprocessor, AT25128 EEPROM and MAX7219 LED Display Driver. The inputs to this device are four jelly bean push-button switches and the output is the 64 LED display. A general block diagram of the device is shown in Figure 16.24. First the patterns were determined for the LED display. The microprocessor was used to program these patterns into the EEPROM. Then the microprocessor was programmed with the main program that runs the light display. This program is a loop that accepts the input from the four switches, determines which pattern will be produced and displays it. In this program, the microprocessor initializes the LED display driver, determines the memory location the data is located in the EEPROM and retrieves this data. This data is then sent to the LED display driver and controls the output display. After the output is displayed the program accepts the next input and repeats the process.

Since this project is intended to be used by the students in a multisensory environment, it has low voltage. All the components in this project can function using five volts or less. It operates with a power supply that is 7.5 volts .5 Amps.

Including all the components, this project cost approximately $380.

![Figure 16.24. General Block Diagram.](image-url)
INTRODUCTION
The giant X10 remote control is a remote control with buttons that are one-inch in diameter. It controls up to nine X10 devices. The problem with the current X10 remote controls is that the buttons are too small for some individuals with disabilities. In order for individuals with disabilities to have their own independent living situations they need a way to turn their appliances and lights on and off.

SUMMARY OF IMPACT
This remote is an improvement over the only available giant button remote on the market, which retails for $1,500. This is because it is made at a fraction of the cost. Once the remote was complete it was given to a client supervisor where he plans to build more remotes with more functions, for many of the residents to use. The remote is intended to give people with disabilities more independence. When the remote was given to the client coordinator he said that this remote would make many tasks easier for some of the residents to become more independent.

TECHNICAL DESCRIPTION
The giant X10 remote control makes use of a common market universal remote control. This allows the big button remote to be universal between devices. The market remote is opened and the rubber buttons that will serve as functions on the giant button remote are removed. Then the contacts are scraped clean. Easier wire attachment is achieved by using 30-gauge wire, a low watt-soldering gun, and silver-bearing high-tech solder.

This is because larger wires will require more solder, which will melt the remote, or the contacts may be pulled off. The wires are then attached to push button switches. The final schematic can be seen in Figure 16.25.

The switches are mounted to a piece of perf-board, which is placed on top of Styrofoam. The Styrofoam, which has been carved out except for the sidewalls, has holes slightly smaller than the switches where the switches fit into and lock Styrofoam and perf-board together. This piece fits on top of another piece of Styrofoam, which has a spot for the market remote to fit into. This is so the remote will not slide around, and will keep the wires from being detached if dropped or banged around in the case.

The case is a hard plastic parts box that is 9.45 x 6.30 x 3.54 inches. There are eleven holes that have been drilled with a wood bearing drill with a one-inch drill-bit. Caution must be used when drilling or the casing may crack. The giant buttons are made from spools of thread. Each spool is cut in half and filed down so that it is smooth. Circles are cut from index cards and placed on each end of the spool to make a solid surface. They are then placed into the holes in the cover of the parts box, with the large end on the inside, so that the buttons stay in place. The bottom of the spools rest on the pushbutton switches, which have enough force when pressed to push the spools back up.
This is the full design of the giant X10 remote control, but is not limited to just X10 devices. A giant button remote can be made with any standard remote that is on the market. Depending on how large the buttons need to be, and the size constraints on the parts box, many more functions or devices could be added to the remote. This project is adaptable for anyone who needs a remote with large buttons, and can be specific to each user’s needs. The cost of this project is about $95 per unit.

Figure 16.25. Final Schematic.
TIME DELAY TALKING SWITCH FOR A DOOR WITH AN ELECTRIC WARNING SIGNAL

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INTRODUCTION
The Time Delay Talking Switch is to be applied on a door warning signal (Figure 16.26). It was designed to aid people with disabilities by preventing accidents associated with doors opening in crowded public spaces. This device can hold about 10 seconds of speech and has the time delay to control the door opening.

SUMMARY OF IMPACT
The design may help prevent injuries when doors are opened within a limited public space.

TECHNICAL DESCRIPTION
The design has two control layers: the internal control layer and the public control layer. The internal control layer contains a power switch, a record button, a microphone and a variable resistor that can control the volume of the speech. The public control layer contains an active system button, an external output, a speaker and signal lights.

The design used the pushbutton switch as the active system button, and has an external input pot that can plug in all kinds of external pushbutton switches. It depends what kind of pot is connected. The heart of the design is the ISD1110 voice record and playback chip. This device can handle single message playback, record and storage operations. It is manufactured by Information Storage Devices, and retails for about $4.50. It can hold 10 seconds of recording time.

The second important device is the control switch, the BASIC Stamp 1 (BS1-IC). It is a microcontroller developed by Parallax, Inc., which is easily to program by using a form of the BASIC programming language by using BASIC Stamp 1 Carrier Board. It simply controls the one shot input and two outputs: one goes to the voice record and playback device ISD 1110 and the other has a 10-second delay (which can be changed in the program) and also holds ON in 10 seconds to keep the relay open. The user is prevented from activating the control button again during the action cycle.

The sound output on the ISD chip is quiet; the LM386 chip helps to power up the output (the design gain is 200) and has an internal adjustable volume to control the sound.

The total cost of the switch device is approximately $200.
Figure 16.26. Time Delay Talking Switch.
INTRODUCTION
The voice activated tape deck controller was designed to provide hands free operation of talking library tape decks, which are loaned out, along with books on tapes, through a mail order system to patrons who meet eligibility requirements. Patrons of the talking library consist primarily of individuals with visual and/or physical disabilities.

SUMMARY OF IMPACT
The talking library currently has some methods of assisting patrons with the operation of the tape deck, but they are limited. A remote control can be attached to the tape deck but its only function is to turn the power on or off. Thus the tape would already have to be in the play mode for it to start playing when the remote turns it on. The talking library has a mechanical adapter that makes use of levers of different lengths to ease in the operation of the tape deck. Both of these methods, although helpful for some of the patrons, do not adequately meet the needs of users who are visually impaired or patrons with limited skills, such as individuals with paraplegia or quadriplegia. A voice activated controller that could operate all of the functions of the tape deck would give the user complete control over the tape deck and would eliminate the need for outside assistance after the initial setup.

TECHNICAL DESCRIPTION
Figure 16.27 depicts the voice activated tape deck controller positioned to control the tape deck that is supplied by the talking library. The design criteria for the controller was driven by both the devices with which it would be interacting, and the individuals that would be operating it. Based on the criteria the controller required four major sections.

The first section consists of the Voice Direct 364, a commercially available voice recognition chip produced by Sensory Inc. The voice chip has the ability to store a limited number of voice commands into its memory. The voice chip creates templates by sampling audio sounds during its training mode. Once trained, the chip can then be set into the listening mode where it will sample sound from the environment and compare it to the stored templates. When a match is found, an eight-bit output, corresponding to the stored template, is transmitted out of the voice chip.

The second major section of the controller is the control circuitry. The voice recognition chip has an eight bit output (but only 16 distinct outputs) and the tape deck has five function keys, stop, rewind, play, fast forward, and eject. Thus, it is necessary to use digital logic circuitry to convert the chip's outputs to ones that can be used to control the five function keys. The digital logic is also necessary to overcome two unfavorable behaviors of the voice chip. During initial power up and any time the reset switch is activated, the voice chip will set all of its outputs high for one second. This would result in all function keys being activated at the same time, which could in turn damage the tape player. Figure 16.28 shown below depicts the logic circuitry that is used to drive the stop function of the tape player. This same design is used to control the other four functions with the only difference being the order of the inputs.
The output of each of the five sections of control circuitry is connected to a DC solid state relay which when biased by the control circuitry will switch power to the third major section of the controller, a bank of solenoids. Push type solenoids are positioned over the keys of the cassette player. When the solid state relay is biased 12 volts at eight amps are supplied to the solenoid, providing the 96 watts required to produce the force necessary to activate the key.

The final requirement is the power source, which consists of two components. The first component is a dual output switching power supply. The power supply has a five volts at 3.5 amp output, which powers the TTL logic and the voice chip. The second output is rated at 12 volts at 4 amps. Due to size and cost constraints it was not practical to purchase a power supply that could supply the entire 12 volts at 8 amps to the solenoids. To work around this problem, a combination of a reduced power supply, in parallel with an 8200 microfarad capacitor, is used. The capacitor is charged by the power supply and, when discharged, produces the required energy to drive the solenoid. Using this method the physical dimensions of the power supply were reduced from 10x7x3 inches to 5x3x1.5 inches. The power supply being the largest single component in the device drove the minimum size requirements of the entire unit, thus reducing the size of the power supply allowed to reduce the overall size of the controller. Using this method also resulted in a substantial cost reduction of $110 or approximately one-fourth of the total $410 required for all parts and materials.

Figure 16.28. Digital Control Circuitry for STOP Function.
STEP SENSING FEEDBACK DEVICE

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INTRODUCTION
The client for this project is a young child who walks on the balls of his feet, such that when he steps he does not land heel first. His physical therapist suggested a feedback device to help train the client. This device provides audible feedback as he walks. If his steps are correct, the device is silent. If the client reverts to his tiptoe walking, the device beeps to remind him to walk correctly.

SUMMARY OF IMPACT
The use of this device helps reinforce what the user is trained to do during physical therapy sessions. The intent is to provide consistent feedback on incorrect steps, outside of the physical therapist’s office, in order to modify the user’s walking habit.

TECHNICAL DESCRIPTION
Input to the device is provided by a pressure-sensitive resistive sensor placed under the ball of the user’s foot. When the user walks correctly, the signal from the sensor exhibits a single pressure peak. When the user walks tiptoed, the signal exhibits a double peak, which triggers feedback from the device.

The unit employs a simple state machine sequential circuit. The three states are as follows: 1) waiting for input, 2) input went high, wait for it to go low, and 3) input went low, wait for it to go high again. If the input follows this high-low-high sequence with the proper timing, an incorrect step pulse is generated. The pulse is used to generate a tone from a buzzer, and to increment a counter. The unit has a display for showing the total number of incorrect steps.

The total parts cost for this project was approximately $70.
Figure 16.29. Step Sensing Feedback Device.
INTRODUCTION
The purpose of this project is to teach students with mental and physical disabilities the relationship between cause and effect through stimulating their senses with lights and sounds. This project is a series of three half-inch thick plastic tiles that light up and emit a tone when stepped on or rolled over by a wheelchair. Three tiles form a simplistic three-key piano. The action of standing on the plastic causes a reaction (light and sound). Each tile has a different corresponding tone and its own color: blue, red, and green.

SUMMARY OF IMPACT
Since the tiles are wide and durable enough to handle a wheelchair rolling across them, this project can be used for a wider range of disabilities than a similar product on the market. The two main components in the project are the floor tile and a black box connected by four wires. Each tile contains a 10-inch neon light rope and two ribbon pressure switches from the Tapeswitch Corporation. The external box contains the tone generator circuit and the light power supply. The wires connecting the box are approximately three feet long in order to keep them far away or being mistakenly stepped on. Activating and using this project is simple.

TECHNICAL DESCRIPTION
There are three layers in each floor tile: translucent plastic on top, foam in the center and hardboard backing. The plastic sheets are made of polycarbonate plastic that is an strong, rigid and translucent. Quarter-inch-deep channels are milled into the bottom of the plastic forming this pattern around the perimeter of the plastic. The three layers are stacked with the foam mat in the center and held together by bolts. These three layers are strong enough to withstand a heavy wheelchair load without damage to internal circuitry. The sensors are normally open, pressure sensitive devices. The sensor is constructed with a top and bottom conductor separated by a small distance. A small wire runs through the center of the switches on one side of this particular model. When this wire is depressed 1/16 of an inch, the switch closes (zero resistance). When pressure is relieved, the switch opens back up (open circuit). Two switches are used for each floor tile: one toggles the neon light, the other turns on and off the tone generator. The tone generator circuit is modified from Professor Dirkman’s light modulated tone generator circuit. Rather than using light modulation, the photo-resistor is replaced with a 10k potentiometer. The circuit with the photo-resistor is shown below. This circuit uses the all-purpose 555 timer to generate sound. The variable resistor between pins seven and six controls the pitch of the tone generator. The output from pin three is then sent to the 8Ω speaker mounted on top of the box. A 9V/1.67A power supply is used to power the three floor tiles and tone generator.

The material cost of this project is approximately $500.
Figure 16.30. Pressure Sensitive Floor Tiles (1 Tile and Black Box).
TACTILE MUSIC AND SPEECH STATION FOR INDIVIDUALS WHO ARE DEAF

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INTRODUCTION
The Tactile Music and Speech Display (TMSD) is designed to deliver sound to individuals who are deaf via vibrations. The TMSD has two modes, speech and music. In speech mode, the built-in microphone is switched on and the user can feel speech with the frequency sensitive vibrators (Figure 16.31). There are high and low channels for the vibrators. The low channel transmits the mid and low range voice formants (vowels), while the high channel transmits the high frequency voice sounds (e.g. parts of a word that contain the letter ‘s’). In music mode the microphone is switched off, and both the vibrators and the bass speaker are switched on, transmitting the full bandwidth of music. A problem with sensing sound through vibration is that frequency recognition is nearly impossible. What can be felt is rhythm. For this reason the TMSD contains a DSP process that passes audio through only when rhythmic. When in music mode, the user can switch between processing and no processing depending upon the musical material.

SUMMARY OF IMPACT
In speech mode, users who are deaf have greatly enhanced lip-reading abilities and environmental awareness. The vibrators deliver a strong speech response, combined with the visual stimulation from watching the speaker’s lips, body language and sign language. In music mode, the 3.5 inch speaker accurately delivers bass frequencies while the vibrators provide the high and mid range signals. Clearly rhythmic, bass heavy, dance music is idea for tactile sensing. The TMSD serves both as a useful tool for tactile speech sensing research, and a way for people who are deaf to enjoy music.

TECHNICAL DESCRIPTION
As seen in the block diagram (Figure 16.32), the TMSD includes a microphone, RCA input, attenuator, speaker amplifier, DSP board, vibrator amplifier, and the vibrators. Not shown is a switch for the power source. The microphone pre-amplifier consists of gain stages with filtering to extract voice formants, and a noise filter implemented with compandor IC to eliminate background noise. The output of the pre-amplifier or the RCA audio input can be toggled to switch between speech or music mode. The output of that switch goes to the master attenuator (gain control), which is a potentiometer. The attenuated output goes directly to the speaker amplifier. When in speech mode, the speaker amplifier is switched off so as not to allow feedback. The attenuator output also goes to the ADSP2181 EZKIT and to the second switch. The rhythm sensing process runs in the ADSP2181. The switch toggles between processed and unprocessed mode. The output of this switch goes to the vibrator amplifier which drives the frequency sensitive vibrators.

The rhythm sensing algorithm is created to allow audio to pass through only when rhythmic. It basically cuts up the music to create silences between rhythmic events. This allows a user who is deaf to differentiate between events going on in the music. The rhythm is sensed by summing and averaging absolute valued inputs, and then comparing these averaged sums with a threshold. If the difference is large enough, rhythm is present, and the sound starts to pass through. The algorithm creates an envelope to smoothly pass the audio through without glitches. For varying musical types, and sound levels, the threshold changes as the music changes, similar to charging and discharging a capacitor. Therefore, no user control is needed for the signal processing.

The cost for parts and materials was about $150.
Chapter 16: University of Massachusetts at Lowell

Figure 16.31. Tactile Music and Speech Display.

Figure 16.32. TMSD Block Diagram.
THERAPEUTIC MOTION DEVICE FOR HANDS

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Supervising Professor: Jay Fu
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INTRODUCTION
The hand motion device was designed to help a person with the moving and flexing of the muscles of the fingers. The unit moves the fingers of the client’s hands in a similar motion to a hand moving from an open position to a closed fist position. The client requested the project as the client does not have any independent motion in the hands, but has full motion in both arms and wrists. Having the muscles of the hand and fingers flexed is therapeutic. This device will make it so a therapist need not be present to perform this task. Also of note is that no other manufacturer of such a device was able to be found by the client.

SUMMARY OF IMPACT
The design criteria for the hand motion device were defined by the client. The client wanted to have the ability to exercise the muscles in his fingers without the aid of a physical therapist. The physical therapist moves each finger one at a time and this takes up a significant amount of time for both the client and the therapist. The hand motion device was designed so that it would be placed on a table and the client, who has control of his arms, would place his hand on the unit and begin exercising the muscles in his hand.

TECHNICAL DESCRIPTION
The unit is made up of two distinct parts. One consists of a linear motion system, mainly a mechanical design, and the other is the electronics creating and controlling the motion of the hand. The linear motion system is mainly made of a linear slide and a ball screw assembly from Thomson Industries. It allows rotational motion, that of a motor, to be translated into linear motion. The slide attaches to a piece of plastic with a roller at the end that contacts the fingers of the client. To ensure the safety of the client, the unit does not fully retract the roller into the casing so as not to pinch the fingers should they get caught. Also the motor used and the gear ratios chosen also lend the system to stalling if something were to get jammed.

The electronics originally were to be powered by the battery on the client’s wheelchair, but after further thought by the client 120VAC stepped down to a nine VDC was chosen so that the unit can be left on a table for ease of access. The +9 VDC is used to power the motor and supply power to another regulator which steps it down to ~+5 VDC to be used by the Stamp microcontroller and the optical switches used to control travel distance. The sensors are used as a forward and backward motion limit and when they are blocked the Stamp microcontroller moves out a particular loop to change the direction of the motor. The motor is driven by a TC4424 chip; it is a 3 A dual high speed MOSFET driver chip. This chip has two inputs and two outputs. When a logic level difference is present at the two inputs the outputs are switched accordingly. If both inputs are low or both are high there is no output from the chip thus eliminating a short circuit across the motor. The chip that was chosen also offers optical protection for the logic level inputs from the high current/voltage output.

The linear slide assembly was donated to the project by Applied Industrial Technologies of Wilmington Massachusetts.

The cost of parts and material was about $300.
Figure 16.33. Top Left: Unit Retracted. Top Right: Hand Relaxed. Lower Left: Unit Expanded. Lower Right: Fingers Extended.
DIGITAL CAMERA FOR WHEELCHAIR USERS

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INTRODUCTION:
The digital camera for individuals who use a wheelchair was designed to provide a comfortable way to be able to take pictures with ease. This device mainly consists of a cable that is adjustable and can be set to a desired position. At one end of the cable is a clamp to connect the device to a wheelchair and at the other end of the cable is the mount for the camera that also holds the solenoids used to trigger the buttons on the surface of the camera. The power wires are run through the core of the cable to simplify the use of the device. Ultimately, this device will give the opportunity to take pictures with ease.

SUMMARY OF IMPACT
The design is intended for use by a person who uses a wheelchair, but it can also aid individuals with limited hand use. This device gives the client the ability to take pictures without assistance.

TECHNICAL DESCRIPTION
The components consist of two STA one inch by two inch Push type solenoids, eight AA Lithium Metal Hydride batteries, a mount for a Sony Digital Camera, and liquid tight cable. All components are mounted together, which will make taking it on and off the chair easy. In order to operate the solenoids, 40 Watts of force must be applied, so four AA batteries are used for each solenoid which potentially can put out 48 Watts of power. Each power source is connected to a switch, which the client can simply turn on to activate each function of the camera. All of the wiring of the project is set inside of the cable so that no tangling of the wires occurs.

The cost of parts and materials was $600.
INTRODUCTION
Braille is an essential communication tool for people with visual impairments (VI). However, learning Braille is challenging – especially for preschool and elementary school children. Talking Dots was developed for two kindergarten girls with severe VI. The objective of Talking Dots is to develop an electronic Braille training device that improves on existing models by 1) providing exciting audio feedback and 2) reducing the need for constant instructor supervision. Secondary objectives include attempting to strengthen the user’s isolated finger movements.

SUMMARY OF IMPACT
Talking Dots is not only an instructional tool for teachers, but also functions as an independent learning tool for children with VI. The audio feedback incorporates interesting animal sounds and captivating songs, which encourage the children and peak their interest. The clients’ orientation and mobility therapist remarks that “teaching Braille skills (reading and writing) to students requires boring, repetitive exercises in order to develop significant tactile sensitivity, spatial memory, isolated finger strength, and numerous other basic Braille skills. The Talking Dots Braille Trainer is the first exciting, motivating game that teaches VI students (and their families) the Braille alphabet.” One client’s mother expressed an interest in using Talking Dots to learn Braille for herself. Initial trials have demonstrated enthusiastic use by children and adults alike.

TECHNICAL DESCRIPTION
The six pushbuttons correspond to the six dots of a Braille cell (Figure 17.1). The pushbuttons begin in the reset state, where they are pressed down and flush with the surrounding surface. When the user presses and releases the pushbuttons, they pop up 1/8 inch so that they are raised like a Braille dot. To use the device, the student simultaneously presses a combination of the six buttons that corresponds to a
Braille character. The device determines the related letter and plays back the corresponding prerecorded message. For example, if the configuration for the letter C (dots one and four) is pressed, then the message says, “C, cat, <meow>.”

The custom circuit design (Figure 17.2) is powered by a 9V DC battery source. The circuit includes a PIC 16F877 microcontroller (Microchip, Chandler, Arizona) programmed in C-language, an ISD4004 voice recorder chip (Windbond, San Jose, California), and an LM386 audio amplifier. A toggle switch allows the user to control hearing the letter and associated sound combination or just the letter independently. The volume is controlled by a potentiometer with audio tape connected through an audio amplifier to a speaker. An easy or hard toggle switch determines the degree of difficulty of the game. In the easy mode, users must press and release the combination of pushbuttons within a 500ms period; the difficult mode requires the user to press and release the buttons within 200ms. If simultaneous pressing does not occur, a message is played either indicating an incorrect entry (i.e. “represents no Braille letter”) or a message for another letter that was not intended. The instructor can record new messages to change the sounds associated with each letter. A library of audio messages is provided on a CD and the teacher or parent can connect the PC speaker output directly to the device.

The six pushbuttons are mounted on two rectangular blocks that can rotate between two positions. In the vertical position, the 2 x 3 array of pushbuttons form the Braille cell. In the horizontal position, the row of six pushbuttons corresponds to the position of the keys on a typical commercial Braille keyboard. On the underside of the swing arms, the path for the wires is routed close to the pivot point of the swing arms and down through the base to the circuit box to enable the arms to swing out into the Braille writing position. This allows the arms to rotate with minimal tension on the wires.

A white laminate face is used to provide a smooth surface and easy recognition of pushbutton and switch positions for VI users. The speaker is front-mounted to give optimal sound. “Instructor only” controls are mounted on the back of the device; they include volume control, the easy or hard toggle switch, and the audio record switches. The power switch and the letter-only or letter-and-sound-combination switch are located on the side of the circuit box for easy accessibility.

The cost of this project is approximately $250.

Figure 17.2. Circuit Diagram.
INTRODUCTION
The sensory play gym is designed to accommodate an eight-year-old girl with cerebral palsy, hearing impairments, and severe visual impairments. She has limited movement control of her head, hands, and feet. Her favorite position is in a side-lyer. Proper sensory development relies heavily on a child’s potential to interact with various stimuli. However, it is difficult to set up switches and stimuli for the client while she is in her side-lyer. The device allows the therapist to position many sensory stimuli in locations easily accessible to the client. Once the inputs and outputs are in place, the sensory play gym allows the client to explore her environment independently while receiving vital sensory stimuli.

SUMMARY OF IMPACT
Prior to the design of the project, the client could not benefit from sensory stimuli without additional help. The play gym allows her to interact without the aid of others. Her physical therapist said, “The sensory play gym will open new doors for her. The sensory play gym will allow her to enjoy a variety of self-initiated sensory experiences that she could not be able to have otherwise. These experiences will help her to learn cause and effect, communication skills. Self-initiated movement will also facilitate improvements in active range of motion of her arms and legs. She really loves it!”

TECHNICAL DESCRIPTION
The base structure of the play gym fits around the client’s side-lyer (Figure 17.3). The three detachable arches that complete the frame can be connected in different places along the rectangular base to fit the needs of the client. The input switch plugs are located at the base of the each arch. Clamps can be used to position the switch within easy reach of the child’s head, hands, or feet. The output stimuli are connected to the top of each arch.

Each arch functions differently. One arch contains two input jacks directly wired to the two output plugs. Any commercial switch can plug into the input jacks and stimuli (tape player, fan, etc.) can plug into the output plugs. When the switch is pressed, it turns on the stimulus. When the user releases the switch, the stimulus turns off. A second arch contains the same direct circuitry; however, it also has a Velcro covered piece of plywood attached to the inside of the arch (Figure 17.4). The wall edge is covered with padding to prevent injury to the client. By attaching different switches, toys, and materials of various textures to the Velcro, the therapist can place stimuli at the client’s fingertips. The third arch contains one input jack connected to three different output plugs via an electronic toggle circuit. Activation of the switch connected to the circuit causes the first output to turn on for 10 seconds. The next activation of the input causes the second output to turn on for 10 seconds, and likewise with the third activation. On the fourth activation of the input switch, the circuit cycles back to the first input.
The sensory play gym is constructed out of one inch diameter PVC tubing, selected for its small size and rigidity. Angled “L”-shaped pieces are used to connect the corners of the rectangular base frame. The base frame contains four different regions, each containing five holes spaced one inch apart. This allows the arches to be moved as needed. The arches are locked into place using a “T”-shaped piece at the base of the arch and two plastic coated bolts.

To protect the client, the wiring of the play gym is contained within the PVC tubing of each arch. One-eighth-inch standard audio plugs and jacks are used, making the device compatible with existing switches and toys. The toggle circuit is inside a plastic enclosure, which is attached to the PVC tubing. The diagram for the toggle circuit is shown in Fig. 17.5. A PIC16F877 microcontroller (Microchip, Chandler, Arizona) controls the circuit; it sets one of the three output pins to 5V for 10 seconds whenever the client presses the input switch. The ULN2003AN drives a relay switch to turn on the appropriate stimulus. The approximate cost of the project is $200.

Figure 17.4. Arches.

Figure 17.5. Circuit Diagram.
INTRODUCTION
An orientation game was developed for a 16-month-old boy with a genetic eye disorder called Leber's Congenital Amaurosis, which results in severe visual impairment (VI). As with many children with VI, he learned to walk without first learning to crawl. However, crawling is vital to developing the upper body strength and coordination required to use a cane and read Braille. Our game consists of four music cubes placed in different areas of a room. When the user turns on the game, music starts playing from one of the cubes. When the toddler hits the switch on the cube, music begins to play from a different cube. The game gives VI toddlers an incentive to crawl and explore by playing music in different areas of a room.

SUMMARY OF IMPACT
The client’s teacher said that, “The orientation game is an innovative and creative way for a child who is visually impaired to develop auditory localization skills and to be motivated to move out into the environment to locate the sound. The toys are a wonderful reward for the grand effort involved in moving across space, and finding the toy that cannot be seen. This game can also easily be adapted to create more developmentally challenging activities for [the client] as he gets older.”

TECHNICAL DESCRIPTION
The device (Figure 17.6) consists of a control box and four “sound cubes”, which are commercial toys that were each adapted by adding a speaker and large red momentary switch. The therapist can place the sound cubes in different areas around a room. When the device is turned on, music plays from one of the sound cubes. This encourages the toddler to approach and explore the toy that is emitting the music. Once there, the toddler can hit a momentary switch button on the toy, which triggers a sound cube in another location to start playing music.

The device can operate in two modes: 1) ordered mode and 2) random mode. In the ordered mode, the child becomes familiar with the orientation of the room by hearing the sound cubes activate in a predetermined order. Once the child is familiar with the orientation of the room, the parent or therapist can switch the device to random mode so that the sound cubes activate in a random sequence. The unpredictability adds excitement to the game.

The device is powered by a 9V DC battery source. The control box includes the toggle “on or off” switch, four potentiometers with audio taper to control the volume for each sound box, a toggle “ordered or random mode” switch, and the main circuit (Figure 17.8) that determines which sound cube to activate. When the device is in ordered mode, each time the toddler hits a switch a counter in the main circuit advances one step and the sound...
box corresponding to that number is activated. When the device is in random mode the mod-4 counter counts continuously at 50 Hz. When the toddler hits a switch, D-flip flops latch the current count and the sound cube corresponding to that number is activated. After the D-flip flops latch the current count, 3V is sent to the corresponding M-66 melody generator chip. These melody generators have three leads: one lead is grounded, one lead receives 3V power, and the third outputs the melody. The parent or therapist can easily change the melody of each music box by switching in different M-66 chips.

Each sound cube contains a speaker and a momentary switch button.

The cost of this project is approximately $75.
CHAPTER 18
UNIVERSITY OF TOLEDO

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INTRODUCTION
The objective of this project was to design and construct a manual-racing wheelchair for a young woman, diagnosed with spina bifida, who is a member of a racing wheelchair team. The client underwent surgery two years prior and had since grown out of her old racing wheelchair. However, she has the desire to return to racing and to compete, and therefore, is in need of a larger wheelchair. Traditionally, racers use a V-Cage ride in the kneeling position. Although the client cannot kneel, she prefers this style of cage. Having little flexibility in her legs, she needed a safe, ergonomically custom tailored chair built with a low center of gravity, three-point ground contact and V-Cage style frame. Figure 18.1 shows the aluminum frame that was built along with the side safe guards. The client’s legs rest against the frame, and her feet are strapped to a footplate under the frame; this footrest provides additional comfort. Figure 18.2 shows the prototype Figure 18.3 shows the young female athlete using it, while surrounded by the team of students who built it.

SUMMARY OF IMPACT
Competing in athletic events is an important factor in the lives of many individuals. However, this is more difficult for individuals with disabilities. This client is a 17-year-old with paraplegia who is a former member of a racing wheelchair team and would like to begin racing again. She has outgrown her previous racing wheelchair. This new racing wheelchair will allow her to compete successfully in racing. It is ergonomically custom tailored to fit her needs. It meets the basic guidelines of three-point ground contact, low center of gravity and ease of accessibility.

TECHNICAL DESCRIPTION
Design considerations included constructing a unit that is lightweight, aerodynamic, stable, durable, comfortable, and ergonomically designed. It will enable easy transfers. Several factors influenced the selection of the various components of the wheelchair including the client’s comfort, preference, safety, lack of racing experience, and cost. An I-Cage frame, shown in Figure 18.4a, is...
better suited for a person with the client’s limitations. However, she is comfortable with the design of her previous racing wheelchair as she is accustomed to resting her knees on its V-Cage frame, and would like to continue to race in this position. Yet, a standard V-Cage frame as the one shown in Figure 18.4.b, does not support her legs because the front of the cage extends too far outward. A custom made V-Cage frame was thus designed to accommodate the client’s preferences where a footrest was added to it to support her feet. The frame was made of one-inch 6061 T-6 aluminum tubing, and is smaller in the front to allow the client’s legs to rest comfortably on the frame.

All racing wheelchairs are equipped with a steering compensator system. It consists of two sets of handlebars with the compensator serving as the connecting link. The closer set of handlebars, when tapped, turn and lock the wheel at a preset angle. This allows the racer to take the turns around the track and to continue pushing, instead of steering. Once the racer is on a straightaway, she simply hits that set of handlebars the other way and the wheel straightens out. The further set of handlebars is used for steering when needed.

Two different rear wheel sizes were considered for the chair, 26 inches and 700C (27.56 inches). A 28 spoke 26 inch wheel was chosen because it is inexpensive and easily replaceable. Hand rims are attached to the rear wheels and are used to propel the wheelchair along the track. Fourteen-inch tire coated hand rims were selected, which is the standard size for women. The rear wheels on a racing wheelchair are generally cambered at an angle ranging from zero degrees to 20 degrees with a minimum of 12 degrees recommended. The client chose 12 degrees based on her previous racing experience. An 18 inch spoke front wheel was chosen based on racing wheelchair standards. An aluminum front fork was used because of its lightweight, durability, accessibility and low cost.

The frame is equipped with a footrest due to the client’s physical limitations and it provides comfort as well. The seating is made of nylon since it is strong and will not irritate the client’s legs. The standard overall length of a woman’s racing wheelchair ranges from 56 inches to 64 inches, but it is not limited to these lengths. The size of the cage was determined by having it custom fit to the client.

This was determined as the client was seated in a wooden model of the chair as shown in Figure 18.5.

To successfully accomplish the project objectives, the calculations for the location of the center of gravity (c.g.), roll stability and stress analysis were completed. The center of gravity of each body segment was calculated in order to determine the entire body’s center of gravity. This was needed to compute the roll stability critical velocity, which determines the maximum speed a wheelchair can withstand before overturning. Since the client’s upper body position varies throughout each stroke, the equation used to calculate the c.g. was left in terms of the torso and arm angles, $\theta_T$ and $\theta_A$, respectively. These two angles are shown in Figure 18.6. Based on the client’s anthropometric data listed in Table 1, the horizontal location of the body’s entire center of gravity measured from the hip joint was expressed as follows:

$$X_{cg} = 1.1965 \cos(\theta_A) + 7.7095 \cos(\theta_T) + 3.3634 (1)$$

When in the racing position, the angle of the client’s torso varies by about 10 degrees. The torso starts out at 25 degrees and goes up to 35 degrees by the end of her stroke. It was found, using equation one, that the change in torso angle causes a slight change.
When designing a wheelchair one must take into consideration the maximum speed the wheelchair and racer can withstand before overturning, this is known as the roll stability critical velocity. Dynamic roll stability analysis is the standard procedure performed to produce that speed. The roll stability critical velocity can be defined as the velocity at the instant when the torque rotating the racing wheelchair and rider is equal to those forces holding it down. It was determined by equating the torques acting upon the center of gravity about a line connecting the outermost rear and front wheels of the racing wheelchair. The purpose of this analysis was to determine whether the new wheelchair design could withstand speeds up to 20 mph during track racing without flipping over. This speed is a maximum for world-class athletes and is well above the average speeds of a beginner racer. The roll stability critical velocity was calculated to be approximately 22 mph using the location of the body’s c.g. at mid-stroke.

Structural analysis was conducted using the I-DEAS Master Series™ Software (Integrated Design Engineering Analysis Software). Two loading conditions were simulated to represent a load of 120 pounds (weight of the person) applied on the fender, and on the front of the left side seat bar. The first loading condition simulated a situation where the rider is going in or coming out of the racing wheelchair. The second loading condition simulated the rider, centered on the very front of the seat, during a turn.

### Table 1: Client’s Anthropometric Data.

<table>
<thead>
<tr>
<th>Body Segment</th>
<th>Length (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torso Width</td>
<td>14.00</td>
</tr>
<tr>
<td>Hip to Top of Head</td>
<td>26.50</td>
</tr>
<tr>
<td>Hip to Hip</td>
<td>15.50</td>
</tr>
<tr>
<td>Armpit to Armpit</td>
<td>16.00</td>
</tr>
<tr>
<td>Armpit to Thumb</td>
<td>23.00</td>
</tr>
<tr>
<td>Upper Arm</td>
<td>13.00</td>
</tr>
<tr>
<td>Forearm</td>
<td>10.50</td>
</tr>
<tr>
<td>Wrist to tip of Middle Finger</td>
<td>7.25</td>
</tr>
<tr>
<td>Seat to Armpit</td>
<td>15.50</td>
</tr>
<tr>
<td>Back to Mid-knee</td>
<td>18.50</td>
</tr>
<tr>
<td>Mid-knee to Foot</td>
<td>16.00</td>
</tr>
<tr>
<td>Foot</td>
<td>8.50</td>
</tr>
<tr>
<td>Total Body Weight</td>
<td>115 lbs</td>
</tr>
</tbody>
</table>

in the horizontal location of the center of gravity with respect to the hip.

![Figure 18.4a. I-Cage: For Individuals with Limited Flexibility in Lower Extremities, Usually Needing a Footrest.](image1)

![Figure 18.4b. V-Cage: For Individuals with a Large Range of Motion, Usually Racing in the Kneeling Position.](image2)
Invacare Corporation and Invacare Top End donated several of the components encompassing the chair. Also, Sportaid provided a 20% discount on the two rear wheels. The total cost of all parts and material was $2,800.

Figure 18.5. Client Seated in a Wooden Model.

Figure 18.6. Stick Figure Diagram of the Racer Seated in the Racing Wheelchair with the Arms in the Extended Position.
MODIFICATION OF A MANUAL RACING WHEELCHAIR

Designers: Jeffrey Laird, Michael Esser, Wesley Saum, Russell Stucke, Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Rehabilitative Medicine, Metro Health Center, Case Western Reserve University School of Medicine
Supervising Professor: Dr. Mohamed Samir Hefzy
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INTRODUCTION
A young male who has been diagnosed with spina bifida has limited range of motion and reduced lower body control. A racing wheelchair was custom-made for him by a previous group of engineering students during a previous semester to provide him with the ability to power and steer it effectively, as well as to make it comfortable. Because of problems with steering and seating, the boy could not use the racing wheelchair. The purpose of this project is to modify the existing racing wheelchair so that the client can use it. As shown in Figure 18.7, the existing chair’s steering system was set at an angle close to horizontal, which made the wheelchair unstable and difficult to steer. The compensator that was used was attached to the fork in a manner that produced little or no resistance to rotation. Due to this ineffective steering mechanism it was impossible for him to propel the wheelchair, since one hand was required to steady the front wheel. The steering mechanism was modified as shown in Figure 18.8 by adding a Y-bar to the front fork, moving the compensator bar below the frame, cutting and re-welding the front of the frame to improve the caster angle, and removing the upper steering wheel. The existing seating used a lap belt for safety and a leg sling for restraining the client’s legs as shown in Figure 18.7. However, these were both uncomfortable for the client and could not hold him in the seat safely. Modifications to the restraint system were conducted by introducing an adjustable set of shoulder straps and a cloth platform on which legs could rest lightly as shown in Figure 18.8.

SUMMARY OF IMPACT
The steering mechanism was modified to eliminate the tendency to uncontrollably roll out of alignment.

TECHNICAL DESCRIPTION
A compensator is used for steering and it consists of a bar that is affixed to the main spine of the chair. This bar is then connected to a pair of handles affixed at an angle to the front fork; adjustable stops
on the compensator bar control the limits of motion.
The front fork is mounted at an angle, known as the caster angle, which provides stability and helps to keep the wheelchair from straying during a turn. Variations in the caster angle affect the balance between ease of turning and stability. In the original design, the caster angle was such that the rider’s weight produced a large moment about the steering axis, which tended to cause the front wheel to roll out of a straight path and into an extreme turn. In addition, the compensator was mounted from the compensator bar directly to the front fork. This produced no return force out of a turn, and no stability in straight racing, because the compensator was largely pulling along a line parallel to the front fork. During track racing the compensating mechanism’s main function is to provide the racer with an easy way to keep the front wheel of the racing wheelchair at the correct turning angle, so the racer can continue to propel the wheelchair during the turns of the track. When the bar is moved to the “turn” position, the compensator stretches, providing a return force used to align the front wheel when the turn is completed. This return force is more useful during street racing, when the steering is set to the straight-line position and turned against the force of the compensator, causing the front wheel to tend to swing back to the straight-line position.

The steering system was modified by adding a Y-bar to the front fork, replacing the old compensator with a stronger one, moving the compensator bar below the frame, cutting and re-welding the front of the frame to improve the caster angle, and removing the upper steering wheel. The dimensions of the frame were established based on the anthropometric measurements of the client. The new dimensions of the racing wheelchair were checked by calculating the critical roll velocity for a turn radius of 60 feet. This is the maximum speed at which the wheelchair can be safely moved through the turn without tipping on its side. The critical speed was calculated as 21.6 mph, which is much larger than the maximum expected speed of the client of 15 mph.

The seating in many racing wheelchairs places the rider in a tucked position. The legs are generally folded, and the rider sits or leans on them during the race. Some wheelchairs directly restrain the rider’s legs, while others allow the rider’s weight to prevent the legs from moving. Restraints for the upper body are typically used to prevent the rider from leaning too far backwards and tipping the chair. These back restraints also provide a brace, so that the rider’s driving force is not limited by his or her weight. This idea is similar to the lap belts used on weight-room machines so that forces can be exerted downwards greater than the lifter’s weight. The seating system of the original wheelchair, shown in Figure 18.7, featured a simple cloth seat snapped onto the frame, and a cloth strap to support the client’s legs. Unfortunately, the lap belt provided in the existing design was uncomfortable to the client, and the leg strap was ineffective at keeping his legs in a safe and comfortable position. The client had a tendency to slip forwards and out of his seat, which was an obviously dangerous state during a wheelchair race.

To improve the user’s upper-body restraints, adjustable padded shoulder straps were used allowing easier fitting and less restricted movement. To support the client’s legs, a cloth platform was added as a contoured leg platform to hold the user’s knees and feet in a loosely tucked position, while keeping his weight on his seat and shoulder straps as shown in Figure 18.9. This accommodated the user’s preference of not sitting on his legs, and would keep his balance forward and center of gravity low.

Total cost for all parts and material was approximately $260.00. Labor for constructing and painting the modified chair was donated.
RIDING LAWN MOWER ADAPTATION

Designers: James Calevro, Bryan McFaul, Frank Ramos, Stephen Sedlak,
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Client Coordinator: Dr. Gregory Nemunaitis
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Biomechanics and Assistive Technology Laboratory
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INTRODUCTION
The purpose of this project is to adapt a riding lawn mower with a safe and reliable hand operated breaking system to allow an individual with complete paralysis of the lower half of his body to operate it independently. Design requirements include allowing his parents to use the original breaking system as they continue to use the mower. Also no alterations were allowed to be made to the original outside body panels of the lawn mower, which limits any drilling to the frame of the mower. The adaptation includes installing a hand-controlled system that activates the brake. The system consists of a hand lever and a linkage mechanism. The hand lever, shown in Figure 18.10, is pinned to a small shaft that rotates on a bearing that is rigidly mounted on the frame of the mower. The linkage, shown in Figure 18.11, consists of three parts: an upper connecting plate, a connecting rod and a lower connecting plate. The upper connecting plate is welded to the small shaft that the hand lever is pinned to. The lower connecting plate is clamped to the foot pedal of the mower. The connecting rod joins the upper and lower connecting plates. As the rider pushes the hand lever, the small shaft rotates forcing the linkage mechanism to rotate, which in turn pushes the brake pedal down. The system is disengaged as the hand lever is allowed to return to its initial position.

SUMMARY OF IMPACT
A male high school student has L2 paraplegia. This individual has a complete paralysis of the lower half of his body including both legs, but excellent use of his arms and upper body. This person is very active and participates on the high school wrestling team. He has a desire to assist his family in mowing the lawn using their riding lawn mower. This was not possible, as the mower uses a braking system that is

activated by a foot brake. Adaptation of the lawn mower with a hand operated braking system allows this individual to operate it independently. This will permit him to enjoy completing family chores, and to possibly earn extra money mowing lawns for neighbors. This custom-made adaptation also allows the use of the original breaking system, which permits the rest of the client’s family to continue using the lawn mower.
TECHNICAL DESCRIPTION

Two approaches were considered for the project: develop an independent braking system, or adapt the original one. An independent system would have to take into account that the brake also acts as a clutch and would require the installation of a new clutch mechanism. This would be complicated and costly. Adaptation of the original braking system requires installing only a simple mechanism to activate it, which was the most simple and cost effective way to accomplish the project objectives. A gear train, a pulley system and a linkage system were considered to activate the braking system. Gears allow a reduction in force, are less complicated and do not require as much space as pulleys. Pulleys allow the reduction in force at the user’s end, but are complicated and require a lot of space. Linkages are the most direct and simple way to transfer force. A hand controlled system that includes a hand lever and a linkage mechanism was thus designed, constructed and installed on the lawn mower to activate the brakes.

The hand lever was pinned to a small shaft that rotates on a bearing that was rigidly mounted on the frame of the mower. The lever was placed on the left side of the tractor, because the brake pedal was already there. In addition, there were already two levers on the right side of the tractor: the speed and deck height adjustments. It would be impossible for the client to brake and change gears on the same side with one hand. The linkage consisted of three parts: an upper connecting plate, a connecting rod and a lower connecting plate. The upper connecting plate was welded to the small shaft that the hand lever is pinned to. The lower connecting plate was clamped to the foot pedal of the mower. The connecting rod joined the upper and lower connecting plates. As the rider pushed the hand lever, the small shaft rotated forcing the linkage mechanism to rotate, which in turn pushed the brake pedal down. The system was disengaged as the hand lever was allowed to return to its initial position. A four-bar linkage analysis was conducted to determine the critical angles and linkage lengths for proper assembly. Using the lengths determined from the analysis, a model was constructed using 10-ply poster board. The model helped to determine the placement of the four-bar linkage to avoid obstructions to its movement.

Figure 18.12 shows a CAD drawing of the final assembly of the linkage mechanism. A spring scale was used to determine the force required to move the brake pedal through its complete range of motion. This force was found to be 50 pounds. Stress analysis was conducted to determine the lowest factor of safety in the different components of the linkage, and was found to be 17. Once the prototype was assembled, it was mounted to the lawn mower. The original design required a shim to be placed under the mounted bearing to account for the brake pedal offset. The brake pedal had a 10-degree offset from the perpendicular of the mower frame causing the lower connecting plate not to be aligned with the upper connecting plate. However, it was decided that bending the connected rod would be more aesthetically pleasing and easier than using a shim. The connecting rod was thus bent into an “s” shape to account for the brake pedal offset. The brake was then tested while riding the mower and functioned properly. The linkage assembly was taken apart and painted with epoxy enamel for a durable finish. A handle grip was also installed at the end of the lever to provide safe gripping.

Concerning safety factors, a seatbelt was going to be installed. However, it negated the mower’s safety shut off mechanism in the seat. The seat, when compressed from the rider’s weight activated the safety switch of the mower allowing the mower to be started. When the rider gets off the seat, it releases the safety switch cutting off the electricity to the engine causing the mower to stop running. The client’s father expressed concern that if the mower overturned, the rider being belted to the seat would prevent the mower from shutting off as intended by the manufacturer. The client also indicated that he had previously used his grandfather’s mower without incident and feels comfortable with the current seat design that does not have a seatbelt.

The total cost of all parts was $180.
MOTORIZED FISHING ROD AND REEL

Designers: Douglas Mischley, Justin Armstrong, David Hite, David Bermudez, Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
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INTRODUCTION

The goal of this project was to automate a fishing rod and reel system to allow an individual with C5 tetraplegia with limited arm movement and strength to fish for a long time with relative ease and comfort. With a standard fishing rod and reel, one turns a hand crank to retrieve the line. However, the client’s hands get tire quickly from the repetitive rotational motion, and he does not have enough energy to reel the line in. The client desires a fishing rod and reel system that allows him to retrieve the line by just activating a switch that is comfortably mounted to the fishing rod. Adapting a system for casting is not necessary since the client will only be perch fishing off a boat in which the fishing line just needs to be dropped into the water. A DC motor controlled by a switch to bring the line in is used as the retrieval system. The motor is mounted to a steel plate that is mounted on to the reel as shown in Figure 18.13 (A). Two spur gears are used to transfer the required torque and speed to the shaft of the reel as shown in Figures 18.13(A) and 18.13 (B). A gearbox is installed to cover the moving gears to prevent client’s hands or clothes from injury or damage as shown in Figure 18.13 (C). In order to keep the reel stable while the client reels a fish, the unit is mounted to a fixture that is easily attached to the client’s wheelchair armrest as shown in Figures 18.14 (A) and 18.14 (B).

SUMMARY OF IMPACT

A discussion with the client’s physician concluded that he has a form of multiple sclerosis. He has minimal feeling in his legs, and has limited movement with his right arm and hand. He has slightly better strength and movement with his left arm and hand. This individual has been an avid fisherman, yet due to his conditions, he cannot fish for even a short amount of time on his own. The motorized rod and reel system that was developed will allow him to go perch fishing from a boat during the summer. The unit will allow him to
retrieve the fishing line with the reel without difficulties. Yet, he can still set the drag, play the fish, and experience the feel of the fight.

**TECHNICAL DESCRIPTION**

In order to motorize the fishing rod and reel unit used by the client, the following issues were considered: casting, reeling and mounting of the rod. No modifications to the rod and reel for casting purposes were required since the client wishes to fish from the edge of a boat by dropping the line directly into the water without having to cast. In order to retrieve the line, a motor was used. The adaptation involved using an aluminum plate to allow mounting of the fishing reel. An electric motor and a gear train used to power the reel were also mounted to the plate as shown in Figure 18.13.

Based on normal Lake Erie perch fishing conditions, an eight-pound test line was used on the fishing reel. A tension force higher than eight pounds would cause the fishing line to break. Analysis was thus performed to determine the required torque at the reel handle, “Thandle” in Figure 18.13, to overcome an eight-pound tension in the fishing line. This was calculated by multiplying the torque generated at the spool, “Tspool” in Figure 18.13, by the internal gearing ratio of the reel. Tspool was calculated by multiplying the tension force (8 pounds) by the distance from the center of the reel spool to the spool arm. The required motor torque was calculated as 201.52 pounds per inch by multiplying the reel handle torque by the gear train value where the gears mounted on the motor shaft and to the reel handle have 256 teeth and 85 teeth, respectively. Also, the motor speed should allow a handle reel speed of 60-90 rpm. Using the gear train value, the required motor speed was calculated as 20 to 30 rpm. A 12V DC Motor, model number PM8014-PS2190, was obtained from Electrical Systems Company, Inc. The motor produces 205.5 pounds per inch of torque, runs at 26 rpm. and weighs 10 pounds. A rocker switch purchased from Newark was sufficient to the client’s needs. The operating force of the switch was investigated to ensure that the client could use the device.

Concern of the client’s strength limitations required ensuring rod and reel stability while reeling in a fish. A strap across the client’s chest that would attach to the end of the fishing rod would keep the rod and reel setup from being pulled into the water upon catching a fish. However, this would limit the mobility and compromise the comfort of the client. Instead, a cantilever beam that could feasibly attach to the armrest of the client’s wheelchair and offer a sturdy mounting for the handle of the rod was used as shown in Figure 18.14 (A) to provide stability for the adapted rod and reel unit. An aluminum-mounting block that attached easily to the cantilever beam extending from the client’s wheelchair armrest was used to hold the electric motor as shown in Figure 18.14.

The entire rod and reel assembly was attached to the aluminum block, and was cantilevered in such a way so the rod and reel would hang in front of the client while he sits in his wheelchair. The length of the client’s arm was the deciding factor on where the unit was mounted on the wheelchair. The reel had to be close enough to the client, so he could reach and release the line when casting. Structural analysis has shown that the design was safe.

The total cost of all parts was $300.
BEACH WHEELCHAIR

Designers: Christopher Tallman, David Ryan, Abdul Al Hawal, Philip Escobedo
Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Department of Physical Medicine and Rehabilitation,
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Supervising Professor: Dr. Mohamed Samir Hefzy
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INTRODUCTION
An individual with Multiple Sclerosis (MS) cannot move his body from the neck down. He desires to enjoy the beach with his family while seated inside his wheelchair. Conventional wheelchairs have standard narrow wheels which sink in the sand easily. This does not allow him to access the water front preventing him from enjoying the beach. The purpose of this project was to design and fabricate a wheelchair that allows him to access the waterfront. The frame of the constructed unit is made out of furniture grade Polyvinyl Chloride (PVC) to resist corrosion. Wide wires are used to prevent sinking in the sand. The design differs from that of conventional chairs in that large wheels are in the front, which makes pushing the wheelchair in the sand easier. Large diameter set balloon tires are used in the front and smaller caster style swivel balloon tires are used in the rear. The structure of the chair includes three parts: a seating frame, a seating sub-frame and a back frame. A footrest, a pushing handle, two armrests and a reclining back seat are incorporated in the unit as shown in Fig. 18.15. Seat and chest restraints are also incorporated to ensure safety.

SUMMARY OF IMPACT
The client the wheelchair easy to use, and started using it on the beach, as depicted in Figure 18.16. This beach wheelchair will allow the client to spend time with his family enjoying the beach.

TECHNICAL DESCRIPTION
The design requirements included developing a beach wheelchair that does not have the limitations of conventional wheelchairs of digging into the sand. It was to resist heat and corrosion, be easily assembled and disassembled, be lightweight and durable, and be ergonomically designed for ease of operation. The frame of the wheelchair was made of furniture grade PVC pipe (two-inch diameter and quarter-inch thick) to prevent corrosion, and be lightweight and durable. Inflatable balloon tires were used because they are easy to move over sand. Large 12 inch diameter Roleez balloon tires were used in the front and seven-inch caster style swivel Roleez balloon tires were used in the rear to prevent the chair from digging into the sand. Despite the
floatability of the oversized tires, the wheelchair is not intended for use in the water. This is stated on a placard attached to the reverse side of the seat. Having the larger wheels in the front make it easier for a person to push the client over the sand. The caster wheels in the back allow easier maneuverability.

The structure of the chair includes three parts: a seating frame, a seating sub-frame and a back frame. The seating frame supports the load of the chair and the person. The seating sub frame transmits these loads to the front and axles. A 1.058 inch hollow shaft, 1/8 inch thick, made of galvanized steel is used for the front axle. The rear caster assembly is comprised of PVC. An aluminum hinging system is used to connect the seating frame and back frame allowing the back of the seat to recline from vertical to horizontal. The seating frame is cushioned on both the seat and back, and incorporated a headrest providing additional comfort. Seat and chest restraints are also incorporated to ensure safety. Footrest and armrests are also incorporated to the seating sub frame to provide extra comfort. The rear axle of the wheelchair is supported by two PVC pipes that are connected to the back frame, as shown in Figure 18.17, and acting as a bracing to keep the rear wheels at the proper elevation as the chair moves over uneven terrain. A rear axle connecting bar made of PVC piping is used to support the rear axle by connecting it to the seating sub frame as shown in Figure 18.17, which provides greater stability to the rear wheels. A pushing handle is attached to the back of the seat to allow the client to be pushed over the sand.

Structural analysis was conducted on the different components of the wheelchair using Mechanical Desktop, an AutoCAD design package. All parts were found to be safe with a minimum factor of safety of three for a total load of 300 pounds.

Total cost for all parts and material was approximately $415.00.
HOT AND COLD WATER DISPENSER

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INTRODUCTION
The purpose of this project is to enable an individual with C-5 tetraplegia to fill his cup with cold or hot water without the assistance of others. A hot/cold water dispenser is adapted electronically, using a programmable logic controller (PLC) that is controlled by a joystick. The PLC controls two stainless steel three-way solenoid valves that were used to replace the existing water taps. The joystick has four possible positions: hot eight ounces, hot four ounces, cold eight ounces, and cold four ounces. The PLC and its power supply are mounted on the side of the water dispenser unit as shown in Figure 18.18. The joystick is mounted on the frame of the water dispenser as shown in Figures 18.18 (A) and 18.18 (B). The tubes coming out of the three-way valves are combined using a Y-connector and end in a final 0.25 inch diameter PVC tube as shown in Figure 18.18 (A). The control valves and part of the tubes are covered with a stainless steel safe guard as shown in Figure 18.18 (B). In order to use the unit, the client drives up so that the left side of his wheelchair is adjacent to the front of the water dispenser. This allows him to reach the joystick. Before operating the joystick, he must insert the PVC tube coming out of the unit into his cup, which is placed in the cup holder of his wheelchair. He then uses the pressure from his palm to push or pull the joystick in one of the four possible positions to fill his cup.

SUMMARY OF IMPACT
The client is a 44-year-old male with no use of his legs and trunk. To ensure that the client consumes the proper amount of fluid each day (8 to 10, 16 oz. glasses), his wife or colleagues will fill a glass with

Figure 18.18. Adapted Hot and Cold Water Dispenser and Components. (A) shows the tubes coming out of the three-way valves and how they were combined using a Y-connector to end in a final 0.25" diameter PVC tube. (B) shows the unit with the stainless steel safe guard. (C) shows the PLC module and its power supply in their enclosure.
cold water or hot tea throughout the day. Using this cold and hot water dispenser, he is able to perform this task independently. The design allows him to pull his wheelchair up next to the dispenser and fill his own cup, needing only to guide a tube into it and select the type and amount of water he would like using the joystick.

**TECHNICAL DESCRIPTION**

A standard hot/cold office water cooler was adapted with a programmable logic controller (PLC). A joystick that was used to operate the water dispenser controlled the PLC. Two stainless steel three-way solenoid valves, with a maximum pressure rating of 25 psi, were used to replace the existing water taps. Timers that are internal to the PLC, which receives a command signal from a joystick, controlled these valves. The joystick had four possible positions: hot eight ounces, hot four ounces, cold eight ounces, and cold four ounces. The force required to operate the joystick was measured as approximately two pounds, which was within the client's capabilities. A power supply was used to convert the standard 120 volts AC wall socket into 24 volts DC required to operate the PLC. An enclosure (8"x10"x16") was used to mount the PLC and its power supply on the side of the water dispenser unit. The PLC is a 170 ADM 370 10 TSX Momentum Controller that controls up to 16 inputs, eight outputs and is rated at one Amp. at 24 VDC.

The joystick was mounted on the frame of the water dispenser at the same level of the joystick of the client's power wheelchair. To allow this, the unit was placed on a wooden stand to raise the dispenser up eight inches. The tubes coming out of the three-way valves were combined using a Y-connector and end in a final 0.25 inch PVC tube. A shroud was used to cover the valves and wiring, offering protection from accidental tampering. All of the electrical components were housed in enclosures that had a National Electrical Manufacturing Association (NEMA) rating of four, which means that they could be directly sprayed with water but not fully submerged.

To operate the dispenser the user moved the joystick in one of the four possible directions to select the amount and temperature of the water he desires. A signal was sent from the joystick to the PLC, which told one of the valves (either hot or cold) how long it should remain open. To determine the relationship between time and volume dispensed, the system was tested. It was found that 28.4 seconds and 13.9 seconds were required to dispense eight ounces and four ounces, respectively. After the requested amount of water has been dispensed, the PLC signals the valve to shut completing the task. If the user were to select the wrong option with the joystick he would be able to correct this by using a stop button that is included in the joystick enclosure. The stop button overrides every command sent to the PLC via the joystick. This feature was added to increase the safety of the design. Also since the client will not actually have to hold the tubing while his cup is filling, there is no danger of a finger burn as hot water passes through the tube.

The program that controls the fluid dispenser was created using Proworx NXT software. The system is initially turned on by the energizing of the normally open joystick, but is then kept on by an internal coil that is energized by a timer. This allows the client to let go of the joystick after he has initially activated it. The program consisted of six networks that controlled various commands by the client: networks one and two control the pouring of eight ounces of cold water and hot water, respectively; networks three and four control pouring four ounces of cold water and hot water, respectively; networks five and six control the cold water valve and the hot water valve, respectively.

Since the client likes to drink hot tea in the wintertime, it is recommended that the jug be partly filled with water and multiple tea bags added and mixed. This will alleviate the need of the client to unscrew the cap of the cup to put a tea bag in it. Using tea mixes or other mixes that contain sugars or other substances that could build up in the system over time is not recommended. Maintenance on the water dispenser is low. The tubing may need to be replaced once every few years and the control valves should be periodically flushed out.

The total cost of all parts was $1400.
SLEDGE HOCKEY SLED

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INTRODUCTION
A 16-year-old male with T3 paraplegia is an active wrestler in his high school and desires to play on a local sledge hockey team. The purpose of this project is to design and construct a sledge hockey sled to allow this individual to play sledge hockey. The sled was designed to satisfy all International Paralympics Committee sport rules which are the same as those of ice hockey except that players use a sled with two skate blades underneath the seat and one runner under the front. The players use two hockey sticks that are shortened and have picks on their butt ends. These picks allow players to propel themselves on ice which is done by digging the picks into the ice and pulling themselves forward. The other end of the stick is used to move the hockey puck. The sled was designed to be safe, lightweight, durable and maneuverable. This was accomplished by making a frame, with a shape of a U, out of powder coated steel tubing and the tuuks and frame mounts out of aluminum. The seat was custom made to fit the body of the client. Figure 18.19 shows the different components of the sled, and Figure 18.20 shows a picture of the final prototype.

SUMMARY OF IMPACT
The client has been contacted to play on a sled hockey team because his strong upper body will allow him to excel in the sport. However, this individual did not participate because he could not afford purchasing a sled. In addition, all available sleds are not ergonomically designed to accommodate his body. The sled that is designed and constructed will allow him to play on the team. and enjoy a new sport. In addition, this individual will have an opportunity to stay in top physical condition.
TECHNICAL DESCRIPTION

Many components of the sled were based on sleds already in use today since sled designs do not vary much, due to the rules set by the International Paralympics Committee’s (IPC). The focus was to improve the design for weight savings, construction, and adjustability. The total weight of the sled was a major concern. The sled had to be strong yet lightweight so that the player could glide easily across the ice. Three materials were considered for the sled’s frame: steel, titanium, and aluminum. Titanium was both strong and lightweight, but problems arose with welding and material cost was comparatively extremely high. Aluminum offered strength and weight reduction, but using it would require special equipment for welding. Hence, 16-gage lightweight steel tubing was used for the frame of the sled. The U-shaped frame has also been powder coated to protect from corrosion.

Pro/ENGINEER computer aided design software was used to produce the detailed drawings of the different components of the sled. The seat, made of sturdy foam, was custom fit to the client’s body and included safety straps to meet the IPC’s regulations. Blades from CCM® hockey skates were used as they provide durability and the ability to be sharpened. They were made of stainless steel to prevent oxidation. Tuuks and adjustment rails were made of aluminum. The ability to adjust skate stance and length of sled has also been incorporated into the design, which allowed the sled to fit the client better and improved the dynamics and maneuverability of the sled. The blades at the bottom of the sled can be adjusted outward while the client is learning the sport for increased stability. As he becomes more advanced in the sport, he can move the blades in to increase the maneuverability.

Tuuks were used to attach the skate blade to the base of the sled. One idea was to use the tuuks that are normally used on a pair of conventional hockey skates that are shown in Figure 18.21. This type of tuuk was light and strong but it was molded to fit the bottom of a foot. However this skate tuuk had some height concerns. In order to comply with IPC rules the bottom of the base of the sled had to be between 8.5 and 9.5 centimeters from the ice. Using this tuuk would require that another piece to be attached to it to achieve this height, which could affect safety. A tuuk made out of a block of aluminum with holes machined into it to reduce the weight was thus chosen as shown in Figure 18.22. This design was strong and compact and fit well under the sled. Also this style of tuuk would easily accommodate all IPC rules and give the sled a very professional look.

Three runners for the front of the sled were considered. The first was another blade that would just slide on the ice as seen in Figure 18.23 (A). It was found that it is illegal to have a blade in the front due to safety reasons, as it would make the sled hard to turn. The second was a hard nylon ball that would be held in place with three pins screwed into it and anchored to the sled, as shown in Figure 18.23 (B). This would make the sled glide easily over the ice; also this type of runner could be replaced quickly and easily with simple hand tools if it were to become damaged. However machining of this runner was involved, as it required setting the ball directly in the center of the sled and attaching it to the sled. The third was the method of choice and consisted of a U-shaped bent pipe welded to the frame. This runner was strong and lightweight and glided over the ice very well. This design was also easy to manufacture and is durable.

Structural analysis has shown that the design was safe. The total cost of all parts was $1000.
ADAPTATION OF A POWER WHEELCHAIR FOR CARDIOVASCULAR ENHANCEMENT

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INTRODUCTION
An active professional with C5 quadriplegia desires to adapt his old style power wheelchair to exercise his arms actively and his legs passively. The purpose of this project is to adapt his wheelchair with a cardiovascular enhancement system that will allow him to exercise his arms actively as the chair is moving. The wheelchair propels forward as the client pushes a joystick. In order to allow the client to propel the wheelchair as he exercises his arms actively, an integrated mechanical and electrical cardiovascular enhancement system is designed and constructed. This system is mounted onto the power wheelchair to generate the same propelling command signal, but by not using the joystick. This integrated system includes two hand cranks, two pulley systems and two motors. In order to exercise, the user rotates these two hand cranks using his arms causing the chair to move. Each hand crank, along with its pulley system and motor, are attached to one of the wheelchair sides using a removable stainless steel framework as shown in Figure 18.24. Tri-pin handles are attached to the cranks to provide adequate wrist support. A switch is incorporated into the system to allow the client to propel his wheelchair either using the existing joystick, or by exercising his arms and rotating the hand cranks. Figure 18.25 of the next project depicts the wheelchair after it is adapted with the cardiovascular enhancement unit (this project) and the motion generation system that allows passive exercise of the user’s leg (next project).

SUMMARY OF IMPACT
An active professional has limited use of biceps, trapezius and deltoid muscles, but cannot move his lower extremities. He owns an old style power wheelchair that he uses as a backup means for transportation. However, since he has become a wheelchair user, he does not exercise any part of his body. The energy requirements for using his power wheelchair are not adequate to stimulate a cardiovascular response. Over time insufficient exercise will lead to the increased risk of blood clots and decreased blood flow in the lower extremities. In order to reduce these risks, a system was developed and installed on his wheelchair to allow him to exercise his upper body actively and generate a cardiovascular response as he propels his wheelchair forward. Hand crank rotations will provide him a cardiovascular exercise that improves blood flow and increases heart rate.

TECHNICAL DESCRIPTION
The upper body exercising rotation of two tri-pin hand cranks powers the wheelchair causing it to propel forward in the same manner as if the user were maneuvering with the joystick. Two motors,
each connected by a pulley system to one of the hand cranks, are used to run in reverse to create a voltage output from the user’s mechanical input. The output voltage is then passed through an integrated circuit that converts it to a signal identical to that resulting from the joystick motion. This signal is sent to the wheelchair control system bypassing the signal from the joystick. A circuit box is used to house the Cardiovascular Enhancement Circuitry (CEC) along with an extension of all lines from the joystick. The CEC taps into the power and ground from the joystick lines. One input of voltage from each motor is also connected to the CEC via the circuit box. This voltage input is converted into a voltage that mimics the direction and speed voltage from the joystick. A switch is used to choose either the existing speed line and direction line from the joystick or the speed line and direction line from the cranking system. The remaining lines from the joystick only pass through the circuit box in route to the existing control system. The direction and speed lines are determined by the position of the switch and then are sent to the existing control system.

Each crank shaft, along with its pulley system and motor, are mounted on one of the two sides of the wheelchair using two stainless steel frames as shown in Figure 18.24. Each frame is attached by a pivot to the rear of the chair and held in place in the front by a pin. The rear pivots consists of two overlapping steel tubes, one rotating inside the other. The larger tube is welded directly to the chair while the smaller tube can be easily lifted and removed. Each crank is supported to its mounting frame using four-bolt flanged block bearings. The position of the hand cranks is determined based on the user’s shoulder height in a seated position, his comfortable arm reach, and his upper arms range of motion. To allow a comfortable operation, the radius of rotation of the tri-pin handle around its axis of rotation has been established as three inches such that during one revolution of the hand cranks, the distance from the tri-pins to the floor will rise and fall between a maximum of 34 inches and a minimum of 28 inches (average of 31 inches as shown in Figure 18.24); also, the distance from the handles to the back of the chair will change from a maximum of 17 inches to a minimum of 11 inches (average of 14 inches as shown in Figure 18.24). The wingspan of the wheelchair with the upper body exerciser unit mounted on it is 34 inches as shown in Figure 18.24. The arm frames swing open on the rear pivot providing easier entry and exit from the chair. The critical loading condition is simulated by applying a 100-pound load vertically to the arm frame when the frame is hinged open 90 degrees with respect to the chair as shown in Figure 18.25. Using a factor of safety of two, the size of the rear mounting bolts and the diameter and thickness of the pivot one-inch square tube were determined by assuming that they support this entire 100 pound load applied at 17.3125 inches from the rear pivot as shown in Figure 18.25. SAE grade eight low carbon steel bolts (Sy = 130ksi) with 0.375 inches in major diameter, and 304 stainless steel tubing material (Sy = 40ksi) 0.125 inch thick were used.

Two groups of students worked on this project during two different semesters; a system was developed by the first group, and then modified by the second group. The total cost of the different components of this cardiovascular enhancement system incurred by the two groups was $1400.
ADAPTATION OF A POWER WHEELCHAIR TO ENABLE LEG EXERCISE

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INTRODUCTION
An active professional with C5 quadriplegia desires to adapt his old style power wheelchair in order to be able to exercise his legs passively and his arms actively (see previous project) as the chair is moving. The purpose of this project is to design and construct a motion generation mechanism and attach it to the wheelchair to rotate this individual’s otherwise motionless legs. This mechanism includes two heel style foot pedals that are mounted to the wheelchair. These pedals rotate causing the rotation of the individual’s legs. The pedals are rigidly attached to a shaft that is driven through a pulley system which, in its turn, is driven by two pulley systems that are driven by the two drive shafts of the two motors powering the wheelchair. This mechanism is supported by an added fifth wheel and the frame of the wheelchair. Boot-type splints and ankle foot orthoses are used to provide ankle support. Figure 18.26 shows a detailed engineering drawing of the different components of this motion generation system that are added to the wheelchair. Figure 18.27 depicts the wheelchair after it was adapted with the motion generation system (this project) and the cardiovascular enhancement unit (previous project).

SUMMARY OF IMPACT
An individual with C5 quadriplegia has limited use of biceps, trapezius and deltoid muscles, but cannot move his lower extremities. He owns an old style power wheelchair that he uses as a backup means for transportation. However, since he has become a wheelchair user, he does not exercise any part of his body. This has a negative effect on the blood flow in his body, in particular within his lower body. The motion generation system that was developed and installed on the wheelchair will allow this individual to exercise his lower body passively by rotating his otherwise motionless legs as the chair is propelled forward. This provides pleasant passive leg motions, making thus exercising more interesting to this individual.

TECHNICAL DESCRIPTION
The exercise mechanism adapted to the power
wheelchair provides passive exercise of the user’s lower body by means of two foot pedals to which the user’s feet are strapped. These pedals rotate as the wheelchair is moving forward. As the user’s feet are strapped into the pedals the individual’s feet are also rotated inducing the passive exercise of his legs.

The power wheelchair adapted was an old style chair that uses two pulley systems, one on each side, to drive each of the two rear wheels. The pedals’ motion generation mechanism was developed making use of this feature by employing a system of belts and pulleys that would utilize the power generated by the wheelchair motors. The pedals were thus attached to a shaft that was driven through a pulley system located in the center of the wheelchair. This pulley system, and in its turn, was driven by two other pulley systems that were located on each side of the wheelchair and driven by the two drive shafts of the two motors powering the wheelchair. This system did not affect the stability of the chair. Also, the speed of the leg rotations was controlled by properly sizing the different pulleys.

The drive pulley consists of a 3.55 inch diameter steel pulley that was connected to the drive shaft on one of the wheelchair motors. Square tubing was bolted to the front of the wheelchair in order to provide a mounting surface for two bearing joints and a place to connect the pedal assembly to the wheelchair. A 3.95 inch diameter pulley and a two-inch diameter pulley were attached to one end and onto the center of an 18 inch aluminum shaft with an outside diameter of 0.75 inch, respectively. This shaft was then placed through the bearing joints, and a half-inch V-belt was used to connect the 3.95 inch pulley to the drive pulley. A connecting frame made of tubing was used to attach the pedal assembly to the square tubing bolted to the wheelchair. This frame was mounted on top of a free moving wheel.

The pedal assembly consisted of two pedals, each attached to a crank arm that was attached, and in its turn, to one end of an eight-inch long aluminum shaft. The pedal assembly was driven by a second pulley system which consisted of the two-inch pulley mounted on the 18” inch shaft and a 5.5 inch diameter pulley mounted at the middle of the eight-inch aluminum shaft connecting the two crank arms; a V-belt connected these two pulleys. The pedal assembly was attached to the connecting frame using also square tubing. Based on the anthropometric data of the client, pedal crank arms three inches in length were used in order to prevent his legs to be moved out of his maximum range of motion. The pedals that were used were heel style pedals with Velcro straps. Ankle support was provided by incorporating a boot-type splint; this splint ensures that there is no leg movement to the user’s left and right as his legs are being passively exercised. The splint was secured with Velcro straps to the client’s foot and mid-calf. Ankle foot orthoses were adapted to fit around the outside of the user’s shoes and were mounted to the pedals as shown in Figure 18.27

Two groups of students worked on this project during two different semesters; a unit was developed by the first group, and then modified by the second group. The total cost of the different components of this motion generation system incurred by the two groups was $700.
WHEELCHAIR LIFT FOR MOBILE HOME ACCESS

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INTRODUCTION
An individual using a wheelchair lives in a mobile home with an attached deck, ramp and steps. The steps are in the front of the deck while the ramp is on the side. She has a difficult time getting in and out of her trailer during the winter. When it snows, it is difficult for her to clean the ramp, and she must use the steps, which requires her to get out of her wheelchair and scroll down the steps on her buttocks. The purpose of this project is to design, construct and install a free standing lift that will allow this individual to remain in her wheelchair while transporting herself to and from the deck of her mobile home. The lift is powered by a 12 VDC marine battery allowing it to be used in case of power outage. It includes a platform that is raised and lowered using a linear actuator. The platform consists of a horizontal square frame covered with a quarter-inch thick steel plate as shown in Figure 18.28; the frame is made of three-inch steel square tubing, 3/16 inches thick. Wheels made of round nylon stock are attached to the platform to allow it to travel on two I-beams that are used as guide rails and are rigidly attached to the base of the lift. A storage rack is rigidly installed on the platform, as shown in Figure 18.29, to permit easy loading and unloading, and to allow the user hands to be free as she is using the lift. This provides safety and convenience. Also, a dead man switch is used to operate the lift which provides additional safety. Figure 18.29 shows the lift in an elevated position as it is being tested by its user.

SUMMARY OF IMPACT
Before the ramp was installed, the client had to climb out of her wheelchair, scroll down the steps on her buttocks to the ground, pull the wheelchair down off of the deck, and then climb back into the wheelchair. In order for her to go up to the deck, this procedure was reversed. The ramp provided her easier access to her home, but during the winter months it was increasingly difficult for her to use it due to snow and ice. Both processes were tiring, especially if she had to do it several times to retrieve groceries or anything else from her automobile. Also, when she scrolled up and down the stairs, she had to take an extra set of clothes with her when the weather was bad because she would get wet and dirty lowering herself down the stairs. The lift unit that was constructed and installed in her mobile home will allow her to transport herself from her automobile to her home in a safe and efficient manner. The client appears to be happy with the lift.

TECHNICAL DESCRIPTION
The purpose of this project was to design, construct and install a wheelchair lift to allow a wheelchair user easier access to the deck of her mobile home. The lift was designed to raise her 34 inches from ground level to the level of the deck that leads to her front door. The fixed base of the lift was free standing and included vertical guide rails to raise and lower a moving platform. The guide rails were two I-beams rigidly attached to the base of the lift. The platform consisted of a horizontal square frame made of three-inch steel square tubing, 3/16 inches thick. The frame was covered with a quarter-inch thick steel plate that was directly attached to the square tubing. Wheels made of round nylon stock were bolted to two U-channels that were welded to the moving frame as shown in Figure 18.28 and Figure 18.30, allowing it to travel on the guide rails. The wheels were made of round nylon stock to prevent a large amount of friction. These wheels, similar to the wheels on a forklift, supported the platform by counteracting the moment produced by the load.

A linear actuator mounted vertically and capable of lifting 1500 pounds was used to produce the motion. It consisted of a mechanical screw drive encased in a cylinder. A motor, mounted on top of the cylinder, drove the screw. The actuator was attached to the moving frame with a pin through its eye hole. It was mounted at the bottom of the fixed base using two cylinders welded together which created a pin around which the actuator could rotate. This design allowed the actuator to rotate if subjected to any torque, preventing thus the bending of the enclosing tube. If this tube were to bend at all, the screw drive inside the actuator would not be able to travel up and down, causing the lift not to function. A 12 Volt DC Marine battery along with an inline trickle charger was used as power supply, which required minimum wiring.

A storage rack was rigidly installed on the platform to permit easy loading and unloading, and to allow the user hands to be free as she is used the lift, which provided safety and convenience. Also, a dead man switch was used to operate the lift to provide additional safety. Structural analysis was conducted using the I-DEAS Master Series™ Software (Integrated Design Engineering Analysis Software). All parts were found to be safe with a minimum factor of safety of three. The unit was tested before installation as shown in Figure 18.29, and was found to be safe.

Total cost for all parts and material was approximately $1200.
ADAPTING A VAN DRIVER SEAT FOR AN UNEVEN SEATING CONDITION

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INTRODUCTION
A wheelchair user has a form of infantile arthritis with a limited range of motion and little muscular strength from the middle of her torso down. Also, because of her arthritic condition, motions at her left hip joint are drastically reduced since the joint is fused. This causes her to have uneven seating as she sits on any flat surface, and she cannot safely drive her van. As she drives her van, she uses her purse to elevate her left buttock as shown in Figure 18.31, which helps slightly improve her stability. Due to weak torso muscles, she becomes unstable as she makes turns: she falls left as she makes right turns and falls right as she makes left turns. The purpose of this project is to adapt a seat for her van to allow her to drive safely.

The existing van seat was replaced by another bucket style seat taken from a sports car. A removable Roho High Profile Quadtr® adjustable air filled cushion was used to elevate her left buttock. The cushion, shown in Figure 18.32, has four compartments that can be individually inflated at different specified pressures. To provide side-to-side support, a lateral restraining system was designed, constructed and attached to the frame of the seat. The cushion and the lateral support system are easily removable to allow other people to drive the vehicle.

SUMMARY OF IMPACT
This individual is active and has a demanding schedule that requires her to travel frequently. Because of lack of trunk muscles to provide proper lateral support, she became unstable as she made turns. While driving her vehicle, she would fall out of her seat when she made a sharp turn. She would fall over laterally into a position where she could not get herself upright without taking her hands off the wheel of the vehicle. Obviously this created a dangerous and unsafe situation, putting her and others at a high risk of a serious accident. The successful adaptation of a bucket style sports car seat that was permanently installed into her van allowed her to drive safely and comfortably. The removable air filled cushion elevated her left buttock, allowing her even seating. The removable
lateral restraining system prevented her from falling out or shifting in the seat.

**TECHNICAL DESCRIPTION**

The existing seating arrangement does not adequately ensure a comfortable and a safe ride to the user since constant readjustment to sit upright in the seat is needed. The existing seat was replaced with a bucket style sports car seat with vertically angled foam supports on its sides (both horizontal and vertical sections of the seat) as shown in Figure 18.33. The seat was taken from a Mitsubishi eclipse. It was chosen because it offered a wide seating base, and an adjustable back support positioning. This allowed the driver extra support when turning, to remain seated in an upright position. Using a sports car style seat with a removable cushion was preferred over using a permanent contoured seat since the user indicated that the van was to be driven by other members of her family. The client had acquired a body molded seat cushion that she placed on the seat of her wheelchair, allowing her even seating. While she was pleased with it, making a similar one for her van was not considered because of the high associated costs: the price of one unit is $1750. Instead, a commercially available “air filled” cushion was used, namely the Roho High Profile Quadro adjustable air filled cushion. This cushion had four separate compartments that could be individually inflated at different specified pressures allowing the support of the one side of the user that needed more support (due to the missing hip), while adequately positioning the user to be properly situated for driving. This was an effective solution since the total cost for the cushion, fabric covering, air pumps, and valve was approximately $380.

Lateral supports were needed to prevent this individual from tipping over laterally when making a sharp turn. Based on how the client gets in and out of her van, a fixed side support was developed. In order to get into the van, the client stands up out of her wheelchair, moves to the side and “falls” back into the driver’s seat which, mounted on a six-way movement mechanism, could move to the back of the mini-van and swivel parallel to the user’s wheelchair. The side support system consisted of two parts: fixed and removable, as shown in Figures 18.34 and 18.35. The fixed part included two one-inch square tubes, 1/8 inch thick that run parallel to each other and were welded directly to the frame of the seat. The removable part included a second set of three-quarter inch square solid tubes that slid into the fixed square tubes. Two square brackets, six inches by four inches, were bolted to the ends of the sliding tubes to provide an extended area of side support. Pins were used to properly position the sliding tubes inside the fixed tubes. All parts of the side support system were made of low carbon, hot rolled steel. Permanent foam padding was attached to the square brackets to properly hold the client in position.

Structural analysis was conducted to verify that the square brackets could sustain safely vertical and horizontal loads of 300 pounds using the I-DEAS Master Series™ Software (Integrated Design Engineering Analysis Software). The three-point harness that existed in the car was preferred over using a five-point harness as a seat belt. Due to her limited movement, the client would not be able to connect all of the straps needed for a five-point harness.

A large portion of the bottom of the adapted seat was cut off, and a flat pan was welded at its bottom which allowed bolting the seat to the mounting plate located in the van. To complete the installation of the adapted sports car style seat into the vehicle, the seat belt lock was attached onto the seat frame and the base of the seat frame was connected to the mechanism that moves the seat inside the van. The total cost of all parts and material was $750.00.
INTRODUCTION
The goal of this project is to determine the best way to fold a modified posture control walker for a child with limb deficiencies in both arms and legs. The child is an eight-year-old boy who is missing both arms from the elbows down and both legs from the knees down. He does not have properly developed hip sockets, so the femur is connected to the pelvis primarily by soft tissues. The child wears prosthetic legs, and needs additional support from a support belt held by adults when not using a walker. However, he needs adult supervision even when using a walker. His parents and teachers would like him to be able to ambulate independently and play with other children without the need for adult supervision. An outdoor ability of interest to him is to be able to play kick ball with his friends. To provide the independence for him, a reverse walker (KAYE Posture Control Walker Model W3BR5) is modified to be used, hand-free. A weight belt for him to wear to provide additional upper-body support is incorporated into the walker along with a back comfortable interface. The front opening of the walker is increased to provide more open area for leg movement when playing kickball and using a urinal. Ratchets are added to the rear wheels to keep the walker stationary and provide stable support when kicking a ball or doing other activities such as drinking water from a water fountain. The size of the rear wheels is increased to add stability on uneven surfaces such as grass. The modified walker meets all of the project requirements to provide greater independence for the child. However, in widening the front of the walker by five degrees on both sides, and permanently connecting the front and back support walker for rigidity, the walker is not able to fold.

SUMMARY OF IMPACT
The optimal folded dimensions for the walker were determined to be approximately 12.00 inches thick by 31.00 inches wide by 36.00 inches tall. With these dimensions, the folded walker easily fits into the trunk of most cars, making it easy to transport and compact to store. The walker design retains all the added support in the original modification, continuing to provide the greater independence requested by teachers and the parents.

TECHNICAL DESCRIPTION
The modified reverse walker was modeled in Pro-Engineer to determine the dimensions for developing a foldable version. The optimal folded dimensions for the walker were determined to be approximately 12.00 inches thick by 31.00 inches wide by 36.00 in. tall.

A finite element analysis was conducted to determine the points of stress in the current design, and the impact of eliminating some of the cross
members in order for the walker to fold. The finite element analysis results suggested that the modifications would not affect force transmission by moving the point of angle of bend towards the back to allow straight telescoping tube on the outside of both left and right supports as movable side brace and pivoting the side supports about the pivoting frames. Using one-piece back frame will transfer most of the force straight to the ground. The main structure will consist of a one-piece back frame with two looped tubes used to provide efficient load transfer to the back frame. The others include two side frames that pivot in brackets to a folded position. The existing wheel assemblies will be used and are attached to the structure using retractable buttons. Three additional improvements were added to the list of design parameters after the boy made his initial trial of the walker. These included a method in which the child can engage and disengage the ratchets on the back wheels himself, ideally from a control on the armrests. Adjustable arm rests/guides will be added to improve the control of the walker. With the belt as the sole means of guidance, the walker tended to "drift" especially on textured or uneven surfaces and it was difficult to "steer". A more robust belt closure was implemented to enable the boy to secure the belt tightly by himself.

Figure 19.2. Re-designed Weight Assist Walker.
ADAPTIVE TOY CAR

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INTRODUCTION
The aim of this project was to modify a Power Wheels Firerock™ Jeep® Wrangler by Fisher-Price to enable a child with upper and lower limb deficiencies to drive the electric toy car. The jeep operates from a single pedal using the retardation provided by its two electric motors to stop. The motors power the two rear wheels and a switch controls their direction. It has a maximum speed of 3.5mph, and is designed to carry one child up to 65 pounds, (29.5kg). The steering is controlled by manually turning a wheel attached to a bar connected to the front axle. The child is missing both arms from the elbows down and both legs from the knees down. His femur is connected to the pelvis primarily by soft tissues. The child has difficulty getting in and out of the Jeep, reaching and controlling the steering wheel when inside. The main aim of the project is to modify the steering control, accelerator and drive direction controls to enable him to control the vehicle.

SUMMARY OF IMPACT
Accomplishing the objectives while maintaining the integrity of the vehicle, and not disrupting the style or entertainment value of the vehicle, enabled the child to drive the electric car and interact with his friends.

TECHNICAL DESCRIPTION
A test-drive by the boy revealed that the steering control required power assistance and easier access to enable him to reach and use it comfortably. The direction control button needed to be automated as he kept forgetting to press it and hence the vehicle would travel in the opposite direction to which he was expecting. The accelerator, located on the inside floor of the vehicle was out of comfortable reach for him and since it was a simple on/off switch would jerk the child as it started. The identified problems were eliminated as illustrated in Fig. 19.3.

Steering: The locations and orientations of the wheels with their linkages were reversed with the left wheel on the right hand side and the right wheel on the left hand side. This resulted in the steering link being moved forwards providing the needed room to insert a servomotor. The Futaba S5302 servomotor used was rigidly mounted in this space beneath the battery and between the front wheels. Rubber grommets provided with the servomotor was used to reduce the shock of impact load as the servomotor turns. This was expected to reduce the

Figure 19.3. Technical Modifications.
loading stress on the servomotor, and hence enhance its lifetime. The largest of the supplied servo arm was used to provide a fixing point for the linkages to the steering link. These links consisted of ball joints at each end of a 4/40 inch thickness threaded rod. The rods were cut at 130 millimeter length and threaded into the ball joint assembly that was bolted onto the servo arm/steering link. The servomotor connected electronically into the controller. This was housed close to the servomotor due to the short length of connection cord. The servomotor control and the speed control stored in a small plastic box and the servomotor control were connected to the joystick with potentiometer via the control receiver.

Power Switch and Dashboard: The power switches for the control receiver and the speed control were connected to the main color-coded ON/OFF power switch on the dashboard. The dashboard was made from a piece of 18x5x1/4 inch plastic. On top of the dashboard mounts the power switch and joysticks flush with its surface. The dashboard was held in position with hinges when down and matching Velcro strips when lifted to the windshield as in Figure 19.4.

Speed Control and Control Receiver: A variable speed control was implemented by using a speed controller with reverse function. It was connected to a joystick with potentiometer through a control receiver. The speed of the drive motors would then vary with the amount the joystick is moved and their direction changes with the direction of the joystick. It is located with the servomotor controller due to the short length of connecting cord. The speed controller also connects to the drive motors and the main six volt battery. It has its own power switch which controls the power to the servomotor and drive motors. The control receiver was the connection between the servomotor control, speed control and the joysticks. It was a dual band R/C receiver, powered by eight AA batteries. It had a power switch and a low battery alarm, which sounded when the batteries were nearing depletion. Snap connectors were used to run wires to the joysticks, where they were soldered to the potentiometer.

The child’s ability to enter the vehicle independently needed improvements. A fold down control panel was added to the vehicle to allow the child to reach the controls without twisting and stretching his back. Finally, it was made easy for him to get in.

The total cost for the toy car and the parts for the project was $623.
STAR TRACER

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Supervising Professor: Steven F. Barrett
Client Coordinator: Kay Cowie, Special Education, College of Education
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INTRODUCTION
A mirror board was designed for enhancing hands-on learning about the nature of visual processing disorders experienced by individuals with dyslexia. A previous version of a mirror board was made out of a wood board base, a 12x12 inch square piece of mirror, Styrofoam, and two bent pieces of coat hangers. The device worked by placing the mirror in a notched out section of the wood board so that it would stand up with a slight tilt. Then the coat hanger pieces were bent and placed into two holes drilled into the base, and then the Styrofoam was rested on the hangers as a raised divider in the middle of the mirror. Finally, a piece of paper with the image of a star outlined by a bigger star was placed onto the wood board.

Once set up, students attempted to trace the two stars by looking into the mirror. Anyone who tries this finds out that it is difficult to complete the task. When attempting to trace the star, the mind is confused by looking into the mirror and cannot relay to the hands which direction to move the pencil in order to turn the edges of the star. Unfortunately, a client’s mirror boards were not made from durable material and the client was in need of new mirror boards.

SUMMARY OF IMPACT
The newly designed mirror boards are durable, lightweight, contained in one piece, and can be quickly and easily transported and assembled. Thirty new mirror boards were made. The new versions were renamed “Star Tracers.” Since receiving the new star tracers, the client has used them in elementary schools, and with church groups and civic groups. In addition, university classes have used the Star Tracers to educate future teachers.
Figure 20.1. Completed Star Tracer
TECHNICAL DESCRIPTION

Initial designing plans involved the goals of making the Mirror Boards lighter, safer, more durable, and easier to transport. Each Mirror Board was designed to incorporate its own carrying case. This was accomplished by making the base of the Mirror Board the actual case; the divider that would replace the piece of Styrofoam would be the lid to the case. Sides were added onto the base and then notched. A section was cut into these sides so that the divider could be slid into the grooves and therefore act as a lid to the casing.

Prices on available hinges were researched. If a hinge was to be used, the price to build the Mirror Boards was going to increase dramatically. Instead of using an expensive, fancier hinge it was decided that aluminum rods could be used instead. Four pieces of aluminum rod would be used and four holes would be drilled into the base in order to hold the pieces of aluminum. The aluminum rod would be bent at the top and Velcro would be wrapped around the top bent portion in order to hold the divider onto the aluminum rods. The other side of the Velcro would therefore be placed on the divider board. The divider board was to be durable yet lightweight and inexpensive. It was decided that particleboard be used as the divider and lid of the casing.

Finally, the mirror had to be chosen. The problems associated with the mirror were that the mirror was heavy, breakable, and contained sharp and jagged edges that could possibly cut someone. As an alternative, mirrored Plexiglas was used.

After all of the products were decided upon, and a prototype was built, the construction of 30 mirror boards began. After they were assembled, the wood was varnished and polished to seal the wood. It was decided that small luggage carts would be purchased from a local store to transport the Star Tracers. The pieces of each Star Tracer were placed into the base casing and the divider lids were slid into place. Ten of the Star Tracers were placed onto each cart and they were easily transported to the client.
Figure 20.2. Disassembled Compacted Star Tracer.
INTRODUCTION
The tricycle has been designed for a seven-year-old client who has been diagnosed with osteogenesis imperfecta (OI), a genetic disorder characterized by bones that are essentially too brittle. This condition leads to bone fractures occurring often with little or no apparent cause. The client has Type III OI and exhibits symptoms of a short stature (he is the size of a three-year-old), bones that fracture easily, loose joints, poor muscle development, and bone deformity. The client can sit in an upright position, but his legs must be supported underneath and positioned in front of him. The development of this tricycle for the client has been an engineering design challenge due to the customization for his small size, restricted range of motion, and physical limitations.

There are commercially available handicap tricycles on the market. However, they are mainly designed for people with simple balance problems to more involved cases of cerebral palsy, spina bifida, Downs syndrome, muscular dystrophy, and autism. There are no known commercially available customized tricycles available for persons with OI. Even if a commercial design were available, it is likely that it would be too large for the client and not provide adequate support.

SUMMARY OF IMPACT
The opportunity to overcome physical limitations provides an increased sense of confidence in the client’s abilities. The developmental therapists that work with the client anticipate that use of the tricycle will promote his bone growth, muscle mass, strength, coordination, and range of motion. It is hoped that the opportunity for continual physical growth through use of the tricycle will ultimately result in the necessary strength development that will allow him to stand upright and perhaps take his first steps.
crank arm is seven inches. A small shock absorber is mounted to one of the crank arms to add resistance to the pedal stroke. The shock absorber mounting is adjustable along the crank arm to allow for increasing resistance as needed. The pedaling system has variable stroke that is independent of the pedaling speed and will never force the client’s legs. Foot restraints are positioned on the pedals to prevent the client from rotating his legs laterally during load cycles.

The pedal stroke has been coupled to a linear velocity transducer (LVT). When the client pedals the tricycle, the LVT triggers the power supply to the motor. The signal from the LVT requires conditioning before entering the microprocessor. This is accomplished through a precision full-wave rectifier with gain. Then the signal is sent through a low-pass filter, which will provide the microprocessor with a smooth signal ranging between 0 and 5 volts. This signal transmits the rate at which the client is pedaling to the HC12 microprocessor.

The output of the microprocessor is sent through additional signal conditioning. An H-Bridge circuit controls the current necessary to drive the motor. In the past, senior design groups have spent the whole semester working on an H-bridge and rarely getting it to work. Due to the complexity of the design an H-Bridge rated at 12 volts, and 35 continuous Amps was purchased.

Electrical feedback of the tricycle speed ensures that the motor is running at a speed proportional to the work being done by the client. A Hall Effect sensor located on the fork of the tricycle provides this feedback. Hall Effect sensors vary in their ratings as well as the type of feedback signal they produce. A Hall Effect sensor that is capable of producing a signal directly to the microprocessor with no conditioning is being used.

The drive train component took a very long time to design and evaluate. The main system of the drive train rests on the differential in the rear axle. Since the tricycle is rear-driven, the differential allows for rotation of the rear tires at different angular velocities when cornering. The differential is driven by a 152 in-lb, 0.25 horsepower gear motor through a 1.13:1 ratio chain drive. The motor is powered by a 12 VDC lead acid battery. A standard wall outlet battery charger is also incorporated into the electrical design.

To translate the angular velocity of the axle to the wheels, friction slip clutches were employed. Friction washers were placed on either side of the hub, along with a spring washer and 2 notched washers to make the wheel rotate when the axle rotates. Since the diameter of the axle is 1”, the wheel hubs had to be modified. An Acetal sleeve bearing was incorporated so that the wheels could spin freely on the axle when the friction drive was not engaged. To engage the friction drive a quick-release cam nut, similar to that on a standard bicycle tire, was used. Disengaging the wheels was important so that the tricycle could be moved when not in use.

When the client discontinues his effort to pedal the tricycle, the motor ramps down for a smooth stop. From the stop position, the tricycle can be put into reverse gear. In the unlikely event that the motor should suddenly stop during operation, the slip clutch on each rear axle will prevent rear wheel lockup.
INTRODUCTION
The non-invasive infant respiration and temperature monitor detects the respiration rate and temperature of a sleeping infant and outputs the respiration rate, temperature and an alarm for lack of respiration or high temperature. This monitor reduces the risk of crib death, or Sudden Infant Death Syndrome (SIDS) caused by a cessation of breathing known as apnea.

The non-invasive infant respiration and temperature monitor uses a pressure pad placed along side the infant’s rib cage to detect pressure changes caused by respiratory movement. It also includes a temperature sensor placed beneath the infant in order to detect fever. An infant positioning pad is used to prevent the infant from moving away from the pressure pad or off of the temperature sensor. A liquid crystal display (LCD) outputs the respiration rate and temperature. A warning message is displayed on the LCD for a 10-second pause in breathing or temperatures over 99° Fahrenheit. A

Figure 20.4. Infant Respiration and Temperature Monitor.
SUMMARY OF IMPACT
The non-invasive infant respiration and temperature monitor reduces the risk of crib death for all infants including those at risk for SIDS. Risk factors include infants born to mothers who smoked during pregnancy, infants born to teenage mothers and infants with siblings lost to SIDS. By continually monitoring the breathing rate of these infants, the likelihood of crib death occurring diminishes greatly. The monitors currently available for infants at risk for SIDS are available by prescription and involve wires attached to the infant. These include the transthoracic electrical impedance monitor, which uses electrodes attached to the infant’s chest, and the pulse-oximetry monitor attached to an extremity such as the foot or finger of the infant.

TECHNICAL DESCRIPTION
The non-invasive infant respiration and temperature monitor consists of hardware and software as well as non-electrical physical components. The hardware consists of sensors, circuitry and a microprocessor. Programming was done on a Motorola HC11 microprocessor using the C Language. Other components include an air-filled pouch used to detect respiration and an infant positioning pad that ensures proper contact between the monitor and the infant.

In order to detect the respiration rate, a highly sensitive pressure sensor is attached to the air-filled pouch. The output from the pressure sensor is amplified and filtered for high-frequency noise before being input to the A/D Converter of the microprocessor.

A solid-state temperature sensor is embedded in the infant-positioning pad beneath the infant in order to sense the infant’s body temperature. The output from the temperature sensor is amplified and biased before being input to the A/D Converter of the microprocessor.

An LCD is connected to the microprocessor and displays respiration and temperature information as well as alarm messages. A piezo-electric buzzer is also attached to the microprocessor and sounds for lack of respiration lasting 10 seconds or longer as well as fever.

The microprocessor is programmed to analyze the pressure signal and calculate the respiration rate. The respiration rate in breaths-per-minute is output to the LCD. If no respiration is detected for 10 seconds, a buzzer sounds and a warning message is displayed on the LCD. The microprocessor has also been programmed to calculate the temperature and display it in degrees Fahrenheit on the LCD. A buzzer sounds for temperatures above 99°F.

The monitor continues to monitor respiration and temperature when an alarm sounds. If the alarming condition returns to an acceptable range, the monitor resumes normal operation. Otherwise, the alarm must be acknowledged by cycling microprocessor power.

The total cost for the project was approximately $80.

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Figure 20.5. Block diagram of the system.
PERSONAL COMMUNICATION DEVICE

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Client Coordinator: Wyoming New Options in Technology (WYNOT)
Supervising Professor: Dr. Jerry Cupal
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INTRODUCTION
The Personal Communications Device for Individuals with Speech Impairments (PCDISI) was designed to aid a person in communicating with another individual. The device is designed based on a current production model of the LightWRITER™ (LW) manufactured by Toby Churchill Ltd. A LW is a device that allows a user to type sentences or phrases via an attached keyboard. The sentences or phrases are displayed on a pair of LCD screens. One screen faces the user and the other faces the person the user is “talking” to. In addition to the display our design includes a speech output that speaks what the user types.

SUMMARY OF IMPACT
Currently, the clients have one LW and were interested in purchasing more; however additional LWs are beyond their budget. Furthermore, they were seeking a device with similar functionality that could be built and tailored to the specific needs of a given individual.

TECHNICAL DESCRIPTION
The personal communications device consists of a standard PS/2 keyboard, a Motorola HC11E9 microprocessor, twin four line by 40 character LCD displays, and a RC Systems text-to-speech (TTS) processor. The design utilizes off-the-shelf components in an effort to reduce component cost and to simplify the design. An HC11E9 running in single chip mode controlled the keyboard, LCD screens, and the TTS processor. The various devices use TTL compatible voltage levels, therefore enabling a direct interface to the HC11, simplifying the design.

Several different ports are being used on the HC11 to control the various components. The text-to-speech processor uses the serial communication interface port. The LCD screens and the keyboard use generic input/output (I/O) ports. The design utilizes most of the available I/O resources of the HC11. The rationale for this was to maximize resource efficiency and to minimize programming, packaging, and power consumption.

The HC11 receives input from the keyboard, converts it into an ASCII value, and outputs that ASCII value to the LCD displays and the TTS processor. The HC11 is just under the white plastic connector in Figure 20.7. The board on the left in Figure 20.7 is the TTS. Also shown is the speaker for the TTS, the internal battery pack, and the volume control.

The keyboard outputs characters by means of a scan code; different from the standard ASCII character set. The LCD screens and the text-to-speech processor take only ASCII input. This presents a problem, as somehow the keyboard input must be converted to ASCII so that it can output to the LCD screens and the text-to-speech processor. The keyboard’s PS/2 interface contains two wires of interest, the data and clock lines. Both lines are connected to generic I/O pins of the HC11. The clock line is monitored for a transition from the idle state (high) to the start state (low). Transition data is
“read” by the HC11. Data is shifted one bit at a time into an internal register as it is received by the I/O port. This must be done for the data is sent serially by the keyboard as the character’s scan code. The HC11 checks this scan code against known values. When it finds a match, it outputs the associated ASCII value to the LCD displays and the TTS processor. The program includes checks for CAPS LOCK key, Shift key, etc.

The LCD displays and the TTS processor receive the ASCII value separately. The LCD displays require parallel data. The TTS could operate with parallel data, however, due to the limited number of I/O pins on the HC11 and to maintain upgrade capability of the TTS, the data is sent serially through the SCI port of the HC11. Configuration of those ports on the HC11 was matched to the needs of the device. Default configurations were used on the LCD displays and the TTS.

An infinite loop dominates the programming. The keyboard input is read, displayed on the LCDs and “spoke” by the TTS. Those three steps are then repeated. The unit does contain a battery voltage level indicator. The battery voltage is checked while waiting for input from the keyboard. When the battery voltage drops below approximately eight volts, the LED color will turn from green to red, alerting the user that the battery needs to be charged via an external connector visible in the upper right of Figure 20.7.

The cost of parts/material was about $400.
AUTOMATIC CASTING DEVICE FOR FISHING

Student Designers: Brian Granger and Kyle Norris
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Client Coordinator: Kathy Laurin, Wyoming New Options in Technology (WYNOT)

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INTRODUCTION

There is a demand for specialized sporting equipment to meet the needs of individuals with disabilities. The problem faced is to develop a partially automated casting device suitable for use by an individual with a disability. The casting device with the associated motorized reel will be the first step in enabling a wide range of people with disabilities to fish. This device may then be used in conjunction with various control systems to meet the needs of a specific individual, for example, sip and puff, head switch, or joystick control. The project focused on the design and construction of the casting device.

SUMMARY OF IMPACT

The intention of the project was to design a casting and retrieval system that can be used by an...
individual with limited manual dexterity. It is important to note that a hands free casting system is not being proposed. The casting as well as the retrieval will require push-button inputs. The individual is able to press buttons, but does not have enough coordination/strength to cast without assistance.

**TECHNICAL DESCRIPTION**

With the intent of enabling an individual with a handicap to fish independently, the design executes the following sequence of operations. First, the user turns on the device and adjusts the desired cast distance using two pushbutton inputs. From this point, the cock input is selected to ready the casting arm for the cast. Next, the individual presses the cast pushbutton to wind the torsion spring, activates the line release solenoid, activates the trigger solenoid, and then de-activates all components at the appropriate time during the cast. The final step in the operation is to depress the retrieval push button to latch the reel and set the system for fishing. Once a fish is hooked the retrieval button can be used to bring the line in close enough for another cast.

Some of the details of the mechanical portion of the design include a sorbothane bumper and steel main shaft. The main plate, reel holder, bearing blocks and trigger mechanism are 6061-T6 aluminum. The stepper motor is mounted below the main plate, with the drive belt coming through the bottom of the plate. The line release solenoid is mounted on one side of the reel holder with the John’s Reel on the other side. A cable connects the two over the top of the reel holder pulley. The trigger mechanism is operated by a solenoid mounted underneath the main plate. The fishing pole holder is mounted on bearings. It is made of aluminum and is allowed to rotate between the bumper and the self-locking trigger mechanism.

The control system will use four user inputs, one limit switch input, and will control four pieces of hardware: stepper motor, push type solenoid, pull type solenoid, and a double digit seven-segment display. The functional block diagram is provided below.

The control system consists of the MC68HC912B32 evaluation board (EVB). The controller accepts five inputs, performs calculations, and then controls the hardware accordingly.

![Casting Device Component Diagram](image-url)
INTRODUCTION
By simply using different types of switches, the lives of children with disabilities can be changed. For example, activating a battery-operated toy with an assistive switch allows even children with severe disabilities the opportunity to control external events. This control over external events helps a child to understand cause and effect, predictability, and normality. When a child with developmental disabilities understands the connection between the activation of a switch and the resulting action it triggers, the knowledge of cause and effect is gained. Therefore, the basis for future learning is established.

SUMMARY OF IMPACT
One of the current problems facing assistive technology users, including switch users, is the cost of the available items. One way to provide more affordable solutions is to educate and teach the families of switch users how to make their own switches and adaptors. For example, some assistive technology vendors sell large button switches from $25.00 to $45.00, tread switches for $40.00, and pillow switches for $35.00. Amazingly, all of the parts used to make these assistive switches can be bought and custom made into assistive devices for an average cost of around $10.00. The “Life’s a Switch” manual details for readers of any background how to adapt and make switches to create their own assistive switches.

TECHNICAL DESCRIPTION
In order to accomplish these objectives and successfully create more cost effective and reliable devices, the “Life’s a Switch” manual covers the following topics: safety, basic circuits, equipment operation, switch technology, switch adaptation, switch design and implementation, and troubleshooting. The manual is written for a generally non-technical audience with the purpose of enabling readers with the knowledge to construct their own assistive switches.

The safety section of the manual assumes that the reader has limited knowledge of electrical safety and battery care. The purpose of this section is to teach the basics of electrical safety and battery care so the reader is safe and comfortable when working with either power supply.

The basic circuits section provides an overview of voltage, current and resistance, Ohm’s law, the basic elements in a circuit, the role of switches, and the difference between parallel and series circuits. The understanding of these subjects is necessary for one to successfully construct an assistive switch.

The tools needed for constructing assistive switches include a multimeter, soldering iron and wire stripper. The equipment operation guide instructs the reader in the use and basic safety of these tools.

The switch technology section introduces the reader to the specific terminology used with switches. With this information, the section also helps the reader choose what type of switch is best suited for a required application and an overview of commercially available switches.

Adapting normal switches to make assistive switches requires the construction of battery
interrupters, extension cords, and jacks and plugs. The switch adaptation section includes instructions for these needs and an overview of how all the components fit together with the switch and a device connected to the switch, such as a toy.

The final switch design and implementation section compiles the knowledge from all previous sections as instructions detailing different applications of assistive switches. This section allows for the most creativity of the reader. A troubleshooting guide following this section helps the reader correct likely mistakes made during the construction of assistive switches.

An accompanying workshop to this manual provides hands-on experience for the public in making assistive switches. The workshop focuses on teaching the basic switch construction skills and the specific application of assistive switches to adapting toys for the use of children with disabilities.
INTRODUCTION
The audio messaging system was designed to assist people who cannot talk. This device is a handheld box that plays prerecorded messages. These messages can be stored on the device at a time. Any message can be played by pressing the button corresponding to the prerecorded message. This device aids persons who are in situations where other communication options are not available. This device differs from the products currently available in the number of messages available in a portable unit. This project was designed using a commercially available voice chip controlled by a Complex Programmable Logic Device (CPLD).

SUMMARY OF IMPACT
This device was designed to be lightweight enough for a small child to operate and easily carry. It also needed to be inconspicuous and easy to operate. This allows the person using the device to have it with them. This device is designed to help the user communicate easier and more efficiently. This allows increased self-sufficiency.

TECHNICAL DESCRIPTION
This design was implemented using an ISD 2560 voice chip. This voice chip was chosen because it had a storage capacity of 120 seconds, and it was designed specifically to record and play voice messages. This chip had a sample rate of 4.0 kHz and a filter pass band of 1.7 kHz. It had the potential for high quality voice playback. The ISD 2560 was also fully addressable and can be controllable by a CPLD.

The 120-second message storage capacity was divided up into sixteen segments. Each message on the chip corresponded to a button on the external casing of the design. The duration of each message was approximately 7.5 seconds. A membrane keypad was selected because of its lightweight and low profile.

The membrane keypad used in the design also had a removable legend. The legend beneath the keypad can be changed to reflect changes in the contents of the messages. The microphone used in the design was the WM-62PC electret microphone manufactured by Panasonic. This microphone was omni-directional and had a passband that extended from 20-16,000Hz.

The amplifier used in this design was the LM 386-N. This amplifier can be used at various voltage levels including 5VDC. This voltage requirement allowed it to be connected to the same voltage source as the voice chip and the XILINX chip. The amplifier was connected differentially to help reduce popping when the messages start and stop. The amplifier was connected to the volume control for the system. A 100k\(\Omega\) logarithmic-taper stereo volume controlled the playback volume. The circuit diagram for the design is shown in figure two.

The cost of parts was approximately $80.00
Figure 20.13. Circuit Diagram.
ADAPTIVE HEARING ASSISTIVE DEVICE

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INTRODUCTION

The problem addressed by this project is that hearing aids can be expensive and many people with hearing disabilities cannot afford them. The main reason for these high costs is that each individual’s hearing problems are unique and hearing aids have to be custom made to address a particular hearing problem.

There are four main hearing problems that are addressed by this design. First, there is difficulty hearing at certain frequencies. In this case, a hearing aid that amplifies everything may do more harm than good. Second, many people have problems hearing in noisy environments because of the background noise. Third, hearing loss in only one ear is common. Fourth, there are the cases of severe hearing loss that can dramatically hinder a person’s ability to perform daily activities.

This design’s solution to these four problems is to use analog electronics in a network of filters that can adjust the gain for a wide range of different frequencies. An additional feature will be the ability to adjust the amount of gain in each ear that the user hears. The goals of this project are to make the design flexible enough to help a majority of the people with hearing loss, make the design inexpensive, and make the design small enough so as not to interfere with every day life.

The first requirement of this design is that it must be able to handle the entire frequency range of sound. The second requirement of this design deals with the gains for each of the signals. The volume of the output signal falls into two categories: the volume of each frequency band, and the volume to each ear. This design requires that the minimum gain for this device be low enough so that hearing is not damaged any further and also that the maximum gain is loud enough to help extreme cases of hearing loss.

According to the Occupational Safety and Health Administration, any noise louder than 85 decibels (dB) can cause hearing loss over an extended period of time.

SUMMARY OF IMPACT

The system of filters allows the user to amplify only the frequencies that they need, while the directional microphone that is used removes a majority of the background noise present in a noisy environment taking care of the second type of hearing loss mentioned.

One application for this device would be to have individuals who would like a hearing aid take a hearing test. Then based on the results of that test, the designer could set the value of the gain for each frequency stage as well as the gain to each ear, and provide the user with a product where he or she only needs only to control the master volume of the device.

TECHNICAL DESCRIPTION

The design uses a system of five analog filters: one low-pass, three band-pass, and one high-pass filter. Each filter covers a different range of frequencies and the gain for that filter can be adjusted by the user. The design also includes a circuit to adjust the volume from one ear to the other if the user has hearing loss in only one ear. The result is a system much like a graphic equalizer, allowing the user to adjust the hearing aid to best fit his or her personal hearing problems. Finally, a circuit is added that allows the user to also send the signal to either the left or right ear, or send an equal signal to both ears.

Currently the device does a number of things well. First, all five frequency ranges can be easily adjusted and there is a noticeable difference in the signal coming in when they are. During testing, adjustments allow for the subject wearing it to tune into the television or to a certain style of music. When adjusted properly, it also reduces a large
amount of background noise and allows the user to hear the person in the foreground more clearly. Volume to the left and right ear are easily adjusted.

However, there are some drawbacks that occurred during testing. The high-pass filter was designed differently than the other four filter stages. This resulted in much lower input impedance than the other four filters. The low input impedance of the high-pass filter meant that it drew more current than the other filters, which produced a soft high-pitch tone no matter how the filters were adjusted. At times the tone became very loud if the gain on the high pass filter was turned all the way up because then it drew almost all of the current and none of the signal went to the other filters. To solve this problem, a wide band pass filter should be used instead of the high-pass filter. This would provide similar input impedance to the rest of the filters, and would hopefully remove this design flaw.

The packaging for this design is also a cause for concern. The prototype clips onto a belt and headphones are plugged into a stereo jack. This seems bulky, but if it went into production, then the size could be reduced by half, if not more.

The power consumption of this device is equal to about 4.1 W, which is slightly higher than hoped for when doing the original design. This implies that the device would need to be powered by a rechargeable battery in order to be practical. The design works for about 10 hours before the signal begins to get clipped, at which point the device becomes useless.

The overall cost of this project was approximately $30.
CHAPTER 21
WAYNE STATE UNIVERSITY

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INTRODUCTION
The ETL Clock Reminder is designed for elderly individuals who are starting to experience memory loss due to dementia, early stages of Alzheimer’s disease, or other age related conditions. The device serves as a talking clock, with a large time display and a reminder system that provides verbal as well as visual alarms and prompting. A family caregiver or staff attendant sets the time alarms, reminder configurations, and prompting messages.

A substantial number of the residents in an assistive care facility, while living independently in their own apartments, need to be reminded about meal times, daily events, and taking medications. The residents do not like to be a “bother” and generally seek technology and strategies to remain as independent as possible. The facility has tried a variety of talking clocks and reminder systems, but all have limitations.

The Clock Reminder is designed for high reliability. While it may have been possible to write a custom application to run on commercially available Pocket PCs or PDAs these devices are neither reliable nor consistent enough to be used for this application and they often cannot produce audio messages with sufficient volume. The ETL Clock Reminder overcomes these limitations by utilizing dedicated electronics designed specifically to meet project requirements.

The ETL Clock Reminder is designed based on staff and resident input. It is a relatively sophisticated device and is scheduled as a two-semester project. Due to a number of technical reasons, the project has not been completed within the two-semester period. This paper describes work to date.

SUMMARY OF IMPACT
When it is necessary to change the configuration or alarm settings, a pinhole switch on the back of the unit activates the program mode. This is done to prevent inadvertent setup changes and to keep the display free from complex menus. The ETL Clock Reminder is designed to be easy to setup and use. A graphic LCD display quickly conveys all necessary information to the user via text and icons. To set the alarm times and messages a simple menu structure is designed to walk the user through entering alarm events, times and the associated voice recording. Alarm acknowledgement is accomplished with the press of a single button that illuminates when the alarm is activated.

The ETL Clock Reminder consists of several key components (Figure 21.1). The Clock reminder utilizes a 128 by 64 pixel display with a viewing area of 66.8mm(W) by 35.5mm(H). The display is a
transmissive type with a yellow-green backlight. An ambient light sensor is utilized to automatically adjust the display brightness to make it easy to read in any lighting condition. The display communicates to the host processor via a dedicated eight-bit parallel bus.

The graphics display is much more versatile than character-only displays as custom icons and large digits can be displayed. A scaled sample image of a typical display can be seen in Figure 21.2. The Character fonts and Icons are stored in an external 64K serial EEPROM.

In addition to a visual indication of time and alarm events, the ETL Clock reminder can announce the time or alarms using a recorded voice message. The unit can record up to 120 seconds of audio utilizing an ISD4200 Series Chipcorder® from Winbond. This audio reproduction method is preferable since the recorded audio can be in any language and can be from a recognized source – for example that of a teacher or family member. The system has an internal speaker and amplifier.

The actual time and alarms are stored on a battery backed real time clock (RTC) IC that has a built-in calendar. The component used is a Dallas Semiconductor DS1305 IC.

Power for the device comes from an external wall cube type adapter or from internal Ni-MH batteries. To safely charge the batteries a charge controller IC, (bq2002C) from Texas Instruments is utilized. Over current and over temperature conditions are monitored and corrected. Regulated power for the clock is via a high-efficiency switching regulator.

The Microcontroller utilized for the project is a Microchip PIC16F877. The Clock code is programmed using the C language for maximum flexibility. The PIC 16F877 is chosen for its flash programming capabilities, presence of required peripherals, and availability. Peripherals used include the SPI port for communicating with the clock, voice, and memory ICs. The PICs internal analog-to-digital converter inputs are used to monitor the light level and battery voltage while the parallel port interfaces to the display.

The entire clock circuit fits on a two-sided printed circuit board (PCB) measuring 50 millimeters× 92 millimeters. Most of the components on the PCB are surface mount types to keep the size of clock to a minimum.

TECHNICAL DESCRIPTION
The remaining tasks include debugging the oscillator circuit used in the RTC circuit to correct an instability issue, finishing the clock software, and fabricating the enclosure. The oscillator instability issue may involve a PCB layout change. The software items to be resolved include finishing the display driver code as well as finishing the code to display large characters on the display. The general clock reminder and recording software also needs to be written and debugged. The mechanical fabrication of the enclosure needs to be done for the final packaging to be complete.
MOBILE ROBOT PROJECT

Designers: Jinhong Kim, Yanling Wang, Cheng Wang, Ouyang Xingwu, Ahmad Nasser, Guopeng Hu, Jian Li, Caiqin Bai, Asad Abu Failat
Client Coordinator: Patricia Nizio, Detroit Institute for Children
Supervisors: Dr. Robert Erlandson, Mr. David Sant
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INTRODUCTION
Preschool children with disabilities who require a powered wheelchair as they mature must learn the cause-effect relationships between a joy-stick, or other controller, and wheelchair movements. Many of these children must also be evaluated for switch placement on their wheelchairs because they have consistent volitional movement from limited regions of their body. The Mobile Robot is a therapeutic robot designed to facilitate preschoolers in acquiring cause-effect, pre-wheelchair mobility skills while supporting therapists in the switch assessment process.

SUMMARY OF IMPACT
Past experience with a variety of small mobile robots at a client agency has demonstrated the effectiveness of these devices to engage children and thereby facilitate learning cause-effect relationships and...
rules-of-the-road”. Furthermore, the children are so thoroughly engaged that therapists can conduct switch placements and evaluations with compliant and task focused children.

The previously used robots were donated mobile robots that were retrofitted with remote radio frequency controllers. The mobile robots worked well for awhile and then broke down. Since they were donated, no readily available replacement parts existed and over time the units were retired. Current radio controlled toy cars and trucks are designed to move either too fast or too slowly. They tend to be small and not easily controlled by the target population of children with disabilities. Hence, there was a need to build the Mobile Robot.

TECHNICAL DESCRIPTION

The first step was to design and build the mobile robot chasse. The chasse is aluminum and the unit uses two drive wheels, with two additional wheels for stabilization. The drive wheels are powered by permanent magnet DC gear motors with a 150:1 gear ratio motors. See Figure 21.3.

If both drive motors run at equal speeds, the robot moves straight ahead. The robot turns by driving the wheels at different rates. If the drive motors are concurrently run in opposite directions, the robot stands in one place and turns. Each drive wheel has a custom designed and built encoder. Figure 21.4 shows a functional block diagram of the mobile robot’s main systems. The RF Joy-Stick Controller is a separate unit. Its functional diagram is shown in Figure 21.5.

Onboard the mobile robot, all the subsystems communicate over the controller area network (CAN) bus. This network topology is chosen primarily for its ease of use and modularity.

Additional devices can be added to the bus with minimal software changes.

The RF joy-stick controller uses a joy-stick commonly used in powered wheel chairs. See Figure 21.6. The joystick is connected to a PIC microcontroller and an RF transceiver to make it completely wireless. The microcontroller reads in the analog data from the joystick using its built-in analog-to-digital converters and packetizes the data in digital form for use by the RF transceiver. The RF transceiver has built-in error correction algorithms to ensure that the data arrives intact to the robot.

At the base unit the RF transceiver decodes the packetized data and places the data on the CAN bus. These CAN messages are read by all of the modules on the bus and are used as inputs to the Navigational Sensor System (NSS) and motor controller.

The NSS is designed so that as a child controls the robot’s movement, it will not run into walls, another person, furniture, or objects. If there is no place to go, the robot stops. Using information from two front and one rear ultrasonic sensors, the NSS calculates the distance to the nearest object and places the appropriate navigation messages on the CAN bus for use by the motor controller. The NSS performs collision avoidance by diverting the robot’s motion away from detected objects or obstacles. A speaker is used to produce a tone whenever the robot has detected an object in its way.
HEAVY DUTY PAPER SHREDDER

Designers: John Blackburn, Terry Jadan, Jim Kokoszka, Kamnoosh Mafie, Andrea Maynard, Jennifer Peters
Client Coordinator: Lynne Haggman, Western Wayne Skills Center, Livonia, Michigan
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INTRODUCTION

Many vocational special education programs utilize paper shredding operations as part of their training programs. The job tasks are not complicated and can be performed by students with cognitive and/or physical disabilities. Paper shredding is also attractive because it can lead to commercial contracts with local area businesses for waste removal, reduction, and recycling. In some cases, schools have established a composting operation using the shredded paper.

Inexpensive commercially available shredders are difficult to feed and are prone to jamming and other malfunctions. Heavy-duty industrial shredders are relatively expensive and again prove difficult for many students to operate. The client school wanted an in-between shredder, one that could handle moderate loads, be easy to feed and operate, be safe, easy to empty, and one that could handle multiple sheets of paper, with an occasional staple. This project provided such a device.

SUMMARY OF IMPACT

The device is shown in Figure 21.7. Field testing demonstrated that the system was safe, easy to use, not jammed by staples, and performed well for the required volume and rate of paper feeding to the device. The device is larger than originally anticipated and could not be placed into the room currently used for paper shredding. Another room is currently being prepared for the device and the paper shredding operation. Representatives from several schools have seen the device and have expressed a desire to purchase one.

TECHNICAL DESCRIPTION

The device utilizes two parallel shafts rotating in opposite directions. Each shaft has fifteen 7 ¼” inch diameter, 24 tooth carbide tipped circular saw blades, separated by metal spacers. A ½ horse power, 1725 rpm, continuous duty electric motor drives the two shafts. The motor has an automatic thermal overload. The shredding assembly requires a noise-damping chamber to reduce the operational noise level.

The feed chute has a curved face plate, adjustable height feed slot (to accommodate wheelchair users as well as users who want to stand), and a detachable shelf for students who need paper stock readily available. The paper feed accepts a stack of paper up to an inch thick, although the physical capabilities of the student users will limit actual paper input to no more than about 10 sheets of paper.

As the paper is fed into the shredder, it encounters the dual rows of shredding blades and is shredded. A low-pressure pneumatic conveying system moves the paper from below the cutting mechanism to a point above the output storage bin. A rotary blower provides airflow of 500 cubic feet per minute. The blower is attached to the conveyor pipe before paper is introduced.
The conveying pipe is composed of six-inch diameter PVC pipe. The horizontal conveying pipe, with its upper half removed for a length of 13 inches, is located below the cutting mechanism in a flanged trough constructed of melamine board for its low friction properties. The flange is secured to the aluminum base plate providing a smooth transition from the cutting mechanism and the conveying pipe. The transition volume also contains front and rear steel diverter plates to ensure a smooth flow from the cutting blades into the conveying pipe and then onto the storage bin.

The vertical conveying pipe carries the cut paper approximately four feet to an opening into the storage bin and then down into the bin. A combination of gravity and airflow direct the material into the bin. A mesh fabric guide keeps the paper in the bin and allows the air to be exhausted from the system.

The assembly is mounted on a mobile cart constructed from Creform products. Creform is a pipe and joint technology with over 400 compatible parts that is used extensively throughout the automotive industry for material handling, and equipment and part positioning.

Safety was a paramount design consideration. A steel case encloses the rotating steel cutting blades. The case thickness ensures that a broken blade will not penetrate the case and injure someone. The shaft was designed to minimize shaft bowing and deflections. The electric motors have an automatic thermal cut-off in case of jamming.
INFRA-RED SENSING SYSTEM FOR INVENTORY AND PROCESS CONTROL

Designer: Guiping Liu
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INTRODUCTION
Individuals with cognitive disabilities are precluded from a variety of sorting and packaging jobs because they are not able to remain focused on the task, make frequent errors, and require prompting from a job coach or co-worker to stay focused or correct an error. The Infra-Red Sensing System for Inventory and Process Control system is a system to help address the vocational needs of individuals with disabilities.

SUMMARY OF IMPACT
Time has permitted only a pilot test of the Infra-Red Sensing System for Inventory and Process Control. The preliminary testing shows that the system performs according to specifications. The system provides error-proofing capabilities in that it can identify if the worker reaches into the wrong bin and provide an auditory warning to the worker that he or she is making an error. The system prompts the worker to stay focused if the sensing system does not sense the worker reaching into a bin within a specified period of time.

TECHNICAL DESCRIPTION
The ValuScan system is shown in Figure 21.10. The sensing elements consist of two long narrow units, one contains the emitters and one contains the detectors. The scanning protocol used by the sensing elements allows detection of not only a break of the infra-red light beam between emitters and detectors, but also data as to where along the length of the sensing element the break occurs. The sensing elements connect to the ValuScan controller unit, which in turn connects to a Windows based PC via an RS 232 serial interface.

The sensing elements are mounted on a Creform® frame. Creform® is a pipe and joint technology with over 400 interconnecting parts. Creform® is widely used in a variety of industries for material handling and positioning systems. The frame is designed to hold one to four plastic bins at an ergonomically appropriate angle for a worker.

Visual Basic was used to create a user interface program. This program allows a supervisor to set up the job specifications, the number of bins, the number of parts per bin, sequence critical, and a prompt time. If no sensor occurs during the specified “prompt time”, the system assumes that the worker’s attention has wandered, and a voice prompt reminds the worker to focus and continue the task. The supervisor can record the prompting message.

When the task starts, the PC monitor shows the number of bins and indicates, by changing color, when the worker reaches into a bin. The system also decrements the part count in the selected bin. If the task is sequence dependent, i.e., packaging or assembly that must be done in the specific left-to-right order, the system prompts the worker with an error message if he/she enters a bin out of sequence.

When the worker has selected an item from each of the bins present, another prompt indicates that one packing cycle is complete.

The system also records the starting time of the job, the times associated with each bin entry, and the job end time. This allows a detailed task/worker analysis.
Figure 21.10. ValuScan Sensing Elements.
WEB BASED TRANSPORTATION RESOURCE GUIDE FOR INDIVIDUALS WITH DISABILITIES

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Client Coordinator: Lore Watt Corradino, Analyst, Southeast Michigan Council of Governments (SEMCOG)
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INTRODUCTION
Perhaps the largest obstacle to sustained employment for individuals with disabilities is finding transportation to and from work. Federal law mandates that public transportation systems provide service to individuals with disabilities. If transportation demands of people with disabilities increase and local, regional and state allocations to public transportation decrease - regular service is cut to meet the mandated requirements. The proposed web based resource guide will enable a government agency and a public transportation company to aid individuals with disabilities in finding viable transportation from a variety of sources and thereby help reduce the load on the public carrier.

SUMMARY OF IMPACT
The prototype system only covers portions of one county. As such it was not meant to replace the current phone-in system, but rather provide enough evidence so that transportation company staff could provide feedback.

TECHNICAL DESCRIPTION
The project started with exploration of a Geographic Information System (GIS) and integrated transportation and resource database as the main government agency and a public transportation company resource system. The GIS portion used ESRI’s Arcview® and ArcIMS® systems. A state department of transportation and a public transportation company provided GIS data regarding the cities and counties in the specified region, as well as bus routes. Both these agencies provided engineering and technical support for installation of their data onto the system.

The first GIS effort involved securing, installing, and rendering operational the software. This first phase also involved securing community resource data, and limited bus route data. The first objective was to create a demonstration GIS system for presentation to the clients. The demonstration system was crude and designed to illustrate only the essential features of a GIS resource system to individuals who were not familiar with the technology and the potential benefits to their operations. This objective was met, and the clients agreed to provide additional support (staff time, data sets, information, expertise) for development of a larger scale prototype system.

The clients wanted the larger scale prototype system design and development to follow two parallel paths; 1) a GIS version, and 2) a web based non-GIS implementation.

The second GIS prototype system incorporated all the available bus route data available for the target region. Data on private transportation suppliers were obtained. These data had to be incorporated into a GIS suitable database for inclusion with the bus route information. Further, the design students...
worked with other professionals to obtain data on community resources available for individuals with disabilities to help them obtain and secure employment. These resources included community economic development organizations, churches, vocational job placement agencies, and child day-care providers.

Figure 21.11 shows a screen image of the target region with preliminary data. Shown are major bus routes, the home location of selected clients and a key as to their employment status (employed, part-time, seeking, and unemployed), area businesses and a key as to their employment plans (seeking fulltime-hiring, seeking part time hiring, not hiring).

The third related project is the non-GIS Web Based Transportation Resources Guide for Individuals with Disabilities. This project utilized an Access database. A prototype web based information management and reservation system was designed and implemented in cooperation with the clients. Figure 21.12 shows a sample screen from that system.
INTRODUCTION

Teachers and therapists often use a matching correspondence approach to counting for students with cognitive disabilities. For example, if 10 items are to be counted for packaging, the job coach would lay a piece of cardboard on the worktable containing a 2x5 grid of squares. The student would then be instructed to place one item in each square until all the squares were filled. When the student has filled all the squares the job coach would remove the items for packaging.

The Matching Correspondence Counter (MCC) is designed to support students with counting and packaging tasks. The grid varies depending on the job and the ability of the student. The grid can vary from 1x2 up to 5x5. However, as the number of cells in the counting grid increases the matching correspondence counting task gets more difficult for the cognitively disabled students. The students tend to place objects on the counting grid randomly. As the number of grids increases the students slow down. They seem to have difficulty figuring out which grid cell to use for placement.

A teacher or job coach configures the task requirements: number of items to be counted, prompt times, and prompting messages.

Students are prompted by the coordinator to place an item into a cell where the indicator lamp is turned on. When an object is placed into the cell, the indicator lamp is turned off and the student prompted to continue fill cells whose indicator lamps are lit. When the required count is reached,
the coordinator informs the student to stop and package the counted items. If the required count is more than 10, the number of cells in the MCC, the coordinator keeps track of the total count and informs the student to empty the cells into the packaging container. As the MCC cells are emptied, the coordinator turns the indicator lamp back on. When the specified count has been reached the student receives the job done prompt to empty the cells into the packaging container.

**SUMMARY OF IMPACT**

A prototype matching correspondence counting device has been designed and assembled. Figure 21.13 shows the completed device. There are 10 instrumented counting cells. The device has not yet been field-tested.

**TECHNICAL DESCRIPTION**

Figure 21.14 shows the instrumented counting cell. Each cell has a small indicator lamp. There is a row of infra-red emitters and detectors at the bottom of the cell which detect the presence of an object in the cell. The inclined plane is made of anti-static plastic.

Students drop an object into the cell. The anti-static inclined plane guides the object to the bottom of the cell where it will break the IR beam between at least one emitter - detector pair. The emitters and detectors are connected via an “OR” logic so that any break will trigger the presence of an object.

The MCC utilizes a Microchip PIC16F876 flash microcontroller to monitor each cell and control the illumination of the LED prompting indicator. The PIC16F876 microcontroller also handles communication between the sensor bins and the ETL Coordinator System. A block diagram of the MCC is shown in Figure 21.15.

The MCC’s microcontroller periodically scans the bins and filters out any electrical noise that may be introduced in to the system. The results of the scan are stored in the controller and are accessed over an RS-232 serial link by the coordinator. The coordinator system has complete control over the MCC and using simple ASCII based commands can perform the following functions:

1) Get the MCC’s Firmware Version (Useful for attached device identification)

2) Turn On the MCC’s LED emitter power supply

3) Turn Off the MCC’s LED emitter power supply

4) Set the prompting Indicator LED

5) Get the bin occupancy status

6) Get the number of connected bins (Useful for diagnostic purposes and configuration)

A typical communication flow begins with the coordinator inquiring about the attached devices firmware. From this information it knows that it is connected to a MCC unit. From there the coordinator issues a command to turn on the LED emitters. After a brief stabilization period the coordinator performs a self test of the prompting LEDs to verify that they are working. The coordinator then determines how many bins are connected to the system. Once this information is retrieved the coordinator system is ready to be used.

During use the coordinator periodically queries the MCC for bin status, issues user voice prompts, and turns on visual indicators based on the input received.
CHAPTER 22
WRIGHT STATE UNIVERSITY

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INTRODUCTION
The design is a device for children with a wide variety of disabilities that aids in the process of standing. The children’s ages range from six to 10, and the design accommodates a classroom of approximately eight to 10 students. Nearly all of the children use a wheelchair but still have minimal motor function in the lower portion of their bodies. The apparatus constructed provides necessary supports to the knee joint, hip joint, and ankle. All three supports are adjustable in order to accommodate the dimensions of each individual child. The supports are designed according to the type of body joint and are constructed out of safe, durable, and low maintenance material. The table attached to the apparatus allows the child to participate in regular classroom activity. It is also adjustable for the child’s individual height. In addition, the apparatus contains a foot platform that restricts the movement of the feet and provides a comfortable standing position. Since multiple students use the apparatus, it was designed to be lightweight allowing for easy transportation between classrooms. By creating a height adjustable table, the device helps prevent muscle atrophy, increases muscle stability and provides a stable classroom environment.

SUMMARY OF IMPACT
All the required design specifications were satisfied. The client was satisfied with the results.

TECHNICAL DESCRIPTION
The project consists of five parts. The first part is the base structure of the apparatus. It is comprised completely out of 70/75 extruded aluminum and sheet aluminum. The two by two extruded aluminum with 1/8 inch walls is structured in a 30 by 48 inch \( \square \)-frame containing two more cross bars with a length of 26 inches each. Off the front brace bar of the \( \square \)-frame another two by two aluminum tube 30 inches long is extended upward. A second piece of 70/75 extruded aluminum but with dimensions of 1 ¾ by 1 ¾ inches with a 1/8 inch wall and 20 inches long is telescoped into the 30 inch long extended piece. After shaving 1/32 inch off the sides of the 20 inch telescoping portion, it slides with ease and little play similar to a telescope. Nine corresponding 17/32 inch holes are drilled 2 ½ inches apart through both pieces. This creates the holes for the adjustment of the table and the support systems. At the top of the telescoping portion, a 20 by 10 sheet of aluminum is welded perpendicular allowing for the attachment of the table. Another
piece of sheet aluminum 30 by 28 inches is attached to the \([\text{[]}]\)-frame across the cross bars. It is positioned flush with the first 26 inch extruded aluminum cross bars. This makes it possible to attach the foot platform and make angle adjustments using a wedge. Also it adds stability and safety to the design by increasing the amount of surface area. All the aluminum pieces are welded together with TIG welds. In addition to the strength of the welding, gussets are added to the two by two extruded aluminum telescoping piece and to the sheet aluminum for the table. Each contains three gussets. The gussets eliminate most of the stress and strain of the telescoping portion. Two stationary and two swivel locking casters are attached with bolts to allow for the transportation of the apparatus. Due to the design and materials used for the base structure, it gives a strong, safe and transportable foundation to build upon.

The second part is the foot platform. The foot platform is constructed out of poplar wood with dimensions of 12 by 18 inches at one inch thickness. On top of the platform, square wood rails are fixed at the toe and heel. These two rails keep the child’s feet from slipping off the platform. The foot platform also contains two side square wood rails that are adjustable. Pegs are attached to the rails and three sets of holes are drilled into the platform. This adjustability enables a snug fit around the foot. It also keeps the child’s foot straight. In addition to the rails, a pad is fixed in the center of the platform. The pad’s main purpose is to sustain the child in a proper stature. When the feet are shoulder width apart, it allows the reaction forces on the ankle joints to be reduced. The pad is constructed out of four by nine inch plywood with a four inch thick polyprothene foam piece attached to it. The pad is upholstered with a vinyl fabric. The assembled platform is attached to the aluminum sheet metal of the base by a piano hinge on the front section. This type of arrangement allows a wedge (18 by one inch

Figure 22.2. Structural Base Support.
at one inch thickness) to be inserted under the platform. The purpose of the designed wedge is to accommodate children with tension stress ankles. The foot platform is designed to adjust for different foot widths, maintain proper stature, and relieve stress on the ankle. All three purposes will help the child increase muscular strength around the ankle region.

The third part of the apparatus is the knee support. The main structure of the knee support is an aluminum bi-bended sheet with dimensions of 26 by four inches with 1/8 inch thickness. Two bends are made four inches from both ends. This creates a rigid U shape structure. The longer portion of the U-shape aluminum sheet serves as an attachment point for the front knee pad. The knee pad is assembled by a piece of plywood 26 by four inches and a four inch thick foam pad. The piece was then upholstered with a vinyl fabric. The shorter ends of the U-shape aluminum sheet serve as the attachment area of side support pads. The side support pads are constructed in the same manner as the knees support but contained the smaller dimensions of 8 by 4 inches. The side supports also allow for adjustment by the insertion of spacers. The spacers are light weight polystyrene blocks of both two and three inch thicknesses with the dimensions of six by four inches. The spacers are covered with black industrial tape. The side support pads and spacers both contain industrial strength Velcro for easy attachment to the aluminum. The whole knee support is attached to a six inch piece of two by two inch extruded aluminum which in turn is attached to two aluminum sliding rails. The two aluminum sliding rails fit snug around the telescoping portion of the base structure. With a corresponding hole drilled through the sliders, the knee support is easily adjusted using a pin. The knee support offers the children a chance to strengthen their leg muscles with the additive safety support at the joint. It also offers safety by restricting the outward movement of knees.

The next part of the apparatus is similar to the knee support. The hip support contains the same bi-bended aluminum sheet, the same dimensional front hip pad as the knee pad, and the same adjustment system. The difference is found in the side supports which are 16 by four inches. Since the hip support must contain a back pad support which is 28 by four inches, a notch system was needed for adjustment. The side supports are constructed out to polypropylene plastic sides that contained three notches. The polypropylene sides also contain Velcro for the attachment of spacers and side pads. The back support pad made out of plywood contains one set notches that fit secure with in the side support notches. The back support also contains foam padding upholstered in vinyl fabric. The hip support permits the operator to adjust the position of the child and arrange the appropriate padding. It also helps the lower back muscles to strengthen. The notch system enhances the safety factor by lowering the torque present on the support.

The final part is the table. The table is constructed out of poplar wood with dimensions of 24 by18 inches. It is designed to resemble a high chair with elbow rest. The elbow rest provides an area for the child to rest a portion of their upper body weight. The table is stained and coated with polyurethane to create a hard smooth surface. The table also contains three ridges on the front and one on each side to set writing utensils and/or stop toys from rolling off. The table also comes with a chalk board insert that sits on top of the table. The table is bolted on to the top of the aluminum sheet attached to the telescoping portion of the base structure. This supplies the table with a secure attachment providing a safe and weight bearing feature. The table also encourages the child to use their back muscles to support themselves. Overall the design of the apparatus offers safety while developing the child’s muscle strength.

Certain safety considerations were taken while designing the apparatus. Maximum support is applied to the main body joints: ankle, knee, and hip. Another safety factor considered was the tipping of the apparatus. The design balances the weight of the apparatus by making the child in the center of the apparatus the weight focus. Other safety considerations were taken with the construction of the pads making sure the child had enough padding to reduce pressure sores. The edges of the apparatus are coated with plastic to ensure the safety of children around the apparatus. Along with safety, reliability of the apparatus was considered. The material was chosen to withstand the wear and tear that the child may cause. The apparatus is designed to last several years without replacement of any parts.

The total cost of parts and labor was $660.
Figure 22.3. Triple Knee Support.

Figure 22.4. Quadruple Hip Support.
INTRODUCTION
A client agency was in need of a device to aid its clientele in a simple sorting task. The sorting task was being performed manually in a piece-by-piece approach. The drawbacks of the manual method were loss of wages and lack of time efficiency, due to fact that the clients possess fine motor disabilities. The device was required to function such that a decision was required by the user when performing the sorting task.

To aid in the effectiveness of these clients, an electro-mechanical sorting machine has been designed. The system is comprised of a hopper and a conveyor belt. The hopper is a gumball machine that has been altered to dispense objects onto the conveyor belt. The user activates a mushroom button switch, causing the gumball machine to dispense one object. The conveyor belt is driven by an adjustable speed motor operated by a potentiometer. There are three sorting bins placed alongside the conveyor belt. Each sorting bin has its own lever-arm, operated by a reversible motor. The lever-arms are activated by a matrix of mushroom buttons. The user presses an appropriate button and the lever-arm rotates into place, causing the object to be redirected into the bin. It is important to note that the design requires decision-making of the client.

SUMMARY OF IMPACT
The design team was successful in meeting all of the requirements for the sorting machine. The product increases the efficiency and also requires decision-making by the user. The feedback received from the client coordinator and users of the machine indicated that all were satisfied with the function and usability of the device.

TECHNICAL DESCRIPTION
The conveyor belt system is driven by a 50 RPM, twelve volt DC Dayton geared motor, inline with one spindle. It is approximately four feet-six and a half inches long and six inches wide. The spindles are five and a half inches in diameter. One spindle is driven and one is slave. The belt is supported by two aluminum plates and P4000 series Unistrut. Along one side of the conveyor belt is a six-inch by six-inch by 48 inch cable trough that runs the length of the belt. This trough provided a location to securely mount all of the motors and house the circuitry. The material used for the belt is canvas. Canvas provides the amount of friction between the oak spindles and also provides durability. The power for the conveyor belt is supplied by a regulated twelve volt DC power supply. It is used for the entire system.

The arm mechanisms are driven by an 8.75 RPM, twelve volt DC motors. The arms are ten inches by one-inch by a half-inch. Double pole double throw (DPDT) latching relays are incorporated to power and reverse the motors. This process is very similar to the method by which a garage door opener works. Upon a button being pressed the motor continues to run until a limit switch is hit. This limit switch cuts the negative side of the motor and drops power. Once the reset button is pressed, the motor reverses until it comes into contact with the rear

Figure 22.5. Handi-Sorter.
limit switch which drops power to the motor in a similar fashion as before.

The arm motors are reversed by the control of only two buttons, the arm button and the D/R Button. The actual circuit includes three-arm motors and a dispensing motor all controlled in similar fashions. Any intersection of two wires without a node dot is simply two wires crossing one another. By energizing the A coil, the contacts move to the A side. This creates a potential difference between the two common leads. The motor receives power until the forward limit switch is pressed and the negative side is broken, cutting power. Once the B coil is energized, the contacts are moved to the B side, reversing the polarity on the common terminals of the relay and reversing the direction of the motor until the reverse limit switch is activated. The buttons are heavy-duty sixty mm/2.25-inch momentary mushroom buttons.

The buttons themselves are not attached permanently to the device. They are mounted in four; four-by-four junction boxes, which are screwed together. This creates a control panel that is attached to the device by a removable lanyard. The lanyard is created by the use of snake skin. In doing this, the user may operate the machine from the safety of their wheel chair, while well removed from the danger of any moving parts. The buttons are color coded for easier use of the machine. The dispensing button is black, and contrasting the black button is a white sticker on top. The other three buttons are red, yellow, and green. These coordinate with the three lever-arms.

The hopper for the design is an adapted gumball machine. The hand crank that typically operates the machine is replaced with a fifty RPM, twelve volt DC Dayton geared motor. The circuitry involved in providing one full rotation of the nine pin gearwheel is a simple 555 timer IC along with a debouncing circuit. The circuit provides a 760 ms time pulse, which allows for the rotation to produce one gumball out of the hopper upon each depression of the dispensing/reset button. The bottom of the machine was removed, where the gumballs typically rest after being dispensed. This allows the objects to fall directly onto the conveyor belt with no added kinetic energy. The machine sits on a wooden shelf, constructed for elevating the hopper over the conveyor belt. The gumball machines are made for distributing any type of candy and the removable sifting plate will allow a user to change the size of the object they distribute.

Some of the safety considerations involved are the use of a conveyor belt and the electrical components. The design of a lanyard was produced to prevent fingers from becoming pinched if they had interaction too close to the machine. The lanyard itself is four feet in length. The user is never closer than four feet from the system. The electronic components are incased in an electric trough and the voltage used is twelve volt DC. This voltage is quite safe for humans.

The total cost of parts and labor was $810.

![Figure 22.6. DPDT Latching Relays for Controlling Arm Mechanisms.](image-url)
COMMUNICATION LEARNING PROGRAM

Designers: Kimberly Fowler, Faridal Matalib, and Erin Tewksbury
Client Coordinator: Marilyn LaRocco, Gorman Elementary School, Dayton, OH
Supervising Professor: Dr. Thomas Hangartner
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INTRODUCTION

Communication plays a key role in allowing individuals with disabilities to achieve the greatest degree of independence. All of the children in the client’s classroom have some degree of language impairment, and three students are nonverbal. In the classroom, cards featuring Mayer Johnson Inc.’s Picture Communication Symbols (PCS) are used to help develop communication skills. With thousands of pictures available in numerous languages, the PCS symbols provide a universal communication system.

The COMLED AV and Communication Learning Program constitutes an integrated package of both hardware and software elements that form a computer-based communication learning device designed to help 10- to 12-year-old children with disabilities practice valuable communication skills, such as picture identification and telephone usage. Because many of these children are nonverbal, the software features a library of Picture Communication Symbols (PCS) developed by Mayer-Johnson, Inc. The program allows a teacher to choose four or 16 PCS symbols to display on the computer screen. She may then input a target answer using the computer keyboard. After the teacher poses a question, students may select an answer from the displayed symbols using either one or two button switches, depending upon their physical abilities. The computer then provides both audio and visual feedback based upon the student’s answer. Additionally, the device features an actual telephone for practicing telephone usage; however the button switches are also functional in this mode. As with the picture identification mode, the teacher inputs the correct telephone number via the computer keyboard, and the computer then provides feedback based on the student’s input.

SUMMARY OF IMPACT

The client requested a device that would give her class a fun way to distinguish pictures used in communication. The COMLED AV and the Communication Learning Program fulfilled all of the required needs. After a two-week evaluation period, the client stated, “The students designed a program that will be an effective tool in my classroom. They assessed the special needs of my students and creatively used switches they were familiar with. Thanks for a terrific project.”

TECHNICAL DESCRIPTION

The COMLED AV black box allows the input devices, the jellybean button switches and the telephone to interface with the computer. The button switches are connected to the COMLED AV box via monoplug cables, while the telephone is connected using a standard telephone cord. This design provides additional protection for the circuitry; if a cable is accidentally pulled, it will simply detach from the black box without harming the internal circuitry. The box houses a touch-tone
In order for the telephone to produce actual touch-tones and still be used as an input device, a touch-tone decoder circuit is necessary. For this purpose, the Ramsey Electronics TT-7 has been chosen. This circuit demodulates and identifies the tones produced by the telephone. The circuit has twelve individual output pins, one for each touch-tone, that are held high at 5V; when its corresponding button is pressed on the telephone, a particular pin drops to 0V. Additionally, the circuit features a trigger pin that increases from 0V to 5V when any tone is generated by the telephone.

At the heart of the COMLED AV box lays the Parallax BASIC Stamp 2 (BS2). Powered by the 9V AC adapter that also supplies power to the telephone, this microcontroller contains an internal 5V voltage regulator, which, in turn, is used to supply power to the touch-tone decoder and Jellybean button switches. The BS2 serves to generate ASCII output based upon the telephone button or jellybean button pressed. The Communication Learning Program software uses this ASCII output. The BS2 contains sixteen input pins, fifteen of which are utilized. Twelve pins are connected to the output pins of the TT-7, one pin is connected to the TT-7 trigger pin, and two pins are connected to the jellybean button switches. Using PBASIC, the BS2 is programmed to continually monitor the TT-7 trigger and Jellybean button input pins. If the BS2 detects a signal from the TT-7 trigger pin, it then scans the remaining input pins to determine which number was pressed. The corresponding ASCII code is then transmitted to the serial port of the computer via the RS-232 cable. If the BS2 detects a signal from the jellybean button switches, the appropriate ASCII code is transmitted to the serial port of the computer. In either case, the program then resumes monitoring the three previously mentioned input pins immediately after outputting the appropriate ASCII code.

The Communication Learning Program is written in Visual Basic version 6.0. The design of the program consists of nine different forms. Of these nine forms, only seven are considered important and essential to the program. Of these seven forms, two are associated with the 4-picture mode, two with the 16-picture mode, and the remaining three with the telephone mode. The other two forms are the simplified manual and the splash screen. The program then can be divided into three different modes: the four-picture mode, the 16-picture mode, and the telephone mode.

Seven folders are included on the Communication Learning Program CD. The folder with the program in it is entitled COMLED. This folder is the only one necessary to run the program. To install the program, the teacher must simply copy the entire COMLED folder onto the C: directory of the computer. The teacher can then execute the program by clicking the executable file inside the COMLED folder. No pictures need to be added if the teacher is content with her choice of 626 pictures. Also included on the CD are the picture library, the Companion Metafile program, and Universe font. These folders are used in the process of adding new pictures to the program. Source code and the PBASIC editor and code have been included in case any modifications need to be made. Finally, an electronic version of the manual is provided in the CD.

The total cost of parts and labor is $565.
INTRODUCTION
The client coordinator from a school requested that a toy garage be redesigned so that students with disabilities may play with it. The students range from four to six years old and have a combination of cognitive and physical disabilities. The resulting device is a garage with push button activation of the doors which allows for easy operation by a variety of students. At the bottom of the ramps, there is a circular track for the cars so that they do not roll off the table. The entire unit is designed so that the structure and any free parts are contained within a small area. Some students exhibit aggressive behavior, so the designed toy is sturdy with durable parts. The toy garage leads to increased stimulation and fine motor learning for the children in the classroom.

SUMMARY OF IMPACT
All design goals were achieved. The client was satisfied with the resulting design and function of the toy garage. Testing of the toy garage with a four-year-old child confirmed the design was durable enough and simple enough for young children to operate. The subject thoroughly enjoyed herself while playing with the toy. The toy garage brought

Figure 22.9. Toy Garage in Use.
stimulation and enjoyment to the targeted audience of young children with disabilities.

**TECHNICAL DESCRIPTION**

This toy is operated from a Basic Stamp Board of Education microprocessor. When the child presses the switch the microchip is activated and the double doors open. The interior of the garage is arranged with an angled ramp so that the car rolls smoothly out of the garage. The car then rolls down the ramp and come to a stop within the pen area. Once it rolls out of the garage, the Basic Stamp is programmed so that the doors will automatically close. If the child wishes to play with the car and garage again, all they have to do is lift the car and place it in the slot carved into the garage’s top surface, and the cycle starts over again.

The Basic Stamp microprocessor is placed between the inner walls of the two garage units. Its dimensions are as follows: height: 3.25 inches, width: 4.5 inches, depth: one inch. The Basic Stamp is selected to simplify the circuit design and provide the servo with a set number of pulses required in opening and closing the doors. When the switch is activated, the Stamp sends out a set number of pulses to the servo with a value corresponding to a location preset within the servo. Once the door reaches its complete open position, the servo pauses and then sends a series of pulses in the same manner as the opening routine which closes the doors.

The garage is constructed from MDF, oak wood, and balsa wood and the ramps are made out of plastic. The dimensions of the entire unit are as follows: height: 1’ 7 ¼ inch, width: two feet, depth: two feet.

There are three main engineering principles applied to this design. First, using the servo mechanism is a mechanical decision made after considering the angle at which the doors open. In the design, the radius of movement of the servo control arms and the connecting piece on the doors was considered. Using the foot switch interface is an electrical application. Within the input pins on the Basic Stamp, there is a 400 mV floating voltage. In order for the program to work correctly, a 1KΩ resistor is added. Finally, programming the Basic Stamp microprocessor enables further development of the design team’s computer programming skills and the opportunity to learn a new programming language.

Given that children would be operating the toy, safety is a major consideration. Even though wood is used in the construction of the product, there is no splintering due to its finish. Also, the speed at which the doors open is not fast enough to injure someone. The reliability of the product is also a major consideration. The children operating this toy are rough and aggressive in their play habits. The toy is built to be sturdy and durable, with all the electrical components covered.

The total cost of parts and labor is $735.
INTEGRATED EMERGENCY ALARM SYSTEM

Designers: Michael Kahelin and Christian Stray
Client Coordinator: Jane Swickard, United Rehabilitation Services, Dayton, OH
Supervising Professor: Dr. Chandler Phillips
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Wright State University
Dayton, OH 45435-0001

INTRODUCTION
A client agency requested an improved design for their panic alarm system. This system consists of four alarm activators with corresponding alarm indicators. The problem arose from the fact that the indicators are only effective in a small vicinity. There are often only a few people in the building to respond to an emergency, and the previous alarm system did not reach enough of the building to notify help. The objective was to design alarm indicator banks that can be placed at strategic locations around the building to notify help during emergencies.

The solution consists of the four alarm activators which are wired to a hub. From the hub, the alarm activator wires are split four ways and run to each of four indicator banks. These banks have five lights on each of them and two different sounds. Four of the lights indicate alarms for each of the four corresponding areas and the fifth light is room for expansion should they install an alarm in a different location. The system is also equipped with a power alarm which sounds if the in-wall transformers are unplugged. This power alarm is based around a 555 timer. This design will help staff respond more quickly to emergencies.

SUMMARY OF IMPACT
The design has met all the requirements of the client. The coverage area of the system was almost doubled. In addition to a larger coverage area, a more strategic placement of the indicators increased the probability that a staff member would be alerted to an emergency. Upon evaluation, the client noted, “[the] system will be a real asset and greatly enhance safety”.

TECHNICAL DESCRIPTION
The four alarm indicator banks that are installed are 298 millimeter cylinders with a 40 millimeter diameter. They are mounted via three mounting bolts. These are bolted to the drop ceiling supports. The units weigh 0.34 kilograms and consume 3.9W of power. The driving circuit (transistor switches) and power failure alarm are housed in six by four by two inch PVC boxes. The activator buttons are connected to the hub with 22 AWG wire and the hub is connected to the indicators via 28 AWG telephone wire. The system’s function is very passive from the user’s perspective in that there are no changes to the user’s normal routine to achieve the desired benefits.

The system has numerous safeguards incorporated into the design. First, the displays are fused at 1A. This ensures that if there is a short to ground, the fast-acting fuse will burn before the ceiling of the building. The system is transformed down to 24V to ensure that it would not have to tie into the 120V electrical system. Another safety and reliability consideration is the continued function of the
existing system, independent of this design in the event of a system failure. Due to the fact that the existing system provides only enough current to switch the transistors, major current leakage is not an issue. Also, the existing system runs on about 400mA. If something were to go wrong, this relatively huge current would simply burn out the transistor and stop the short. The system is also very reliable due to the power failure alarm. If power is interrupted, the staff will be alerted and can plug it back in. In addition, the driving circuit and wiring is hidden above the drop ceiling. This greatly reduces the possibility of the unit becoming damaged, which contributes to the reliability.

Before installation of the system, the effective area of the existing system was analyzed. Effective area was defined by two criteria: direct line-of-sight to the indicators and minimum sound level of 70 dB. The reason this level was chosen was because 40 dB is considered the normal noise level for an office and for an alarm to be guaranteed to be heard, it should be 30 dB over the background noise. The total effective area of the original system was approximately 5022 square feet. After installation, the effective area was 10014 square feet. This was a 99.4% increase in effective area of the alarm system. Area was not the only consideration in assessing the effectiveness of the system. The placement of the new indicators was more effective than the old ones. One indicator was at a receptionist desk which was staffed continuously throughout the day. The other indicators were all in hallways, which were very high traffic areas, and were likely to attract attention.

The total cost of parts and labor was $980.

Figure 22.12. Circuit Schematic.
SENSORY STIMULATION STATION

Designers: Adrienne Bolds and Becky Ruskowski
Client Coordinator: Mandy Arnold, Five Points Elementary School
Supervising Professor: Dr. David Reynolds
Biomedical, Industrial and Human Factors Engineering Department
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INTRODUCTION
A sensory stimulation station was built for children with disabilities to help encourage interaction, increase attention span, and provide entertainment during free time. The station needed to be constructed for easy mobility and transportation, and to be sturdy enough that the students did not cause the station to move at an inappropriate time.

The resulting device is the Sensory Stimulation Station for Students with Multiple Disabilities. The goal of the station is to stimulate as many of the five senses as possibly in a creative fashion. Tactile stimulation is incorporated by the use of various materials and switches. To integrate auditory and visual stimulation, a sequence of LEDs and music are used. Olfactory stimulation is achieved by a series of atomizers.

SUMMARY OF IMPACT
The final design is a child safe stimulation station in which a student can be entertained while stimulating his or her senses. The final product has components which stimulate four of the five senses (auditory, visual, olfactory, and tactile). The client coordinator is satisfied with the final product design. The students are able to use the station with no difficulty and are entertained while using it. The station is successful in attaining the main goal developed for the station, sensory stimulation.

Figure 22.13: Student Using the Sensory Stimulation Station.
TECHNICAL DESCRIPTION

The entire station consists of three box-like panels constructed out of plywood. The two side panels are each two by two feet and six inches thick. The middle panel is also six inches thick but is two by four feet. The back of the panels are attached to the front by a hinge on the bottom and Velcro along the top, making the inside components such as batteries for the electronic components and the scents of the atomizers easily accessible to the teacher. The legs of the station are constructed of metal and can be adjusted vertically from 17.5-25 inches. They contain a series of holes in which a button is latched to the desired height. The entire station is covered in blue felt to eliminate the chance of the student getting injured by the surface and edges of the plywood, and to increase attractiveness of the station for young students.

The right panel contains the black light and the 8-LED running light system. The black light and the running lights are operated by separate switches. The switches are similar in appearance and activate the desired component by pressing the switch. When the black light is triggered by the student, the beads begin to glow to induce a distinctive visual experience. The running lights are operated by the use of two separate buttons. When switch one (green oblong button) is pressed once it turns the LEDs on in a sequential fashion. If the switch is pressed again it causes several LEDs to light up at the same time at an increased fluctuation rate. The second switch (big blue button with a horn imprint) turns the system off. When the second button is pressed again it resets the system so that it can be repeated. The goal of this switch is to help the student learn the pattern required to produce the visual stimulation.

The middle panel contains the system of four atomizers and the tactile board. The ball for each atomizer is a relatively large ball that resembles a basketball; this is for the convenience of students with limited dexterity. By squeezing the ball the student releases a spray from the cap of the atomizer. The four different scents are rose, freesia, pear, and raspberry. It is hoped that the different scents will trigger various reactions in the student, eventually making a connection between the stimulus and response. To prevent the possibility of spray entering the student’s eyes the height of the atomizers was strategically placed above eye level. The tactile board has four different types of textures.

The total cost of parts and labor was $760.
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