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ENGINEERING SENIOR DESIGN PROJECTS TO AID PERSONS WITH DISABILITIES

Edited By
John D. Enderle
Brooke Hallowell
NATIONAL SCIENCE FOUNDATION

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FOREWORD

Welcome to the sixteenth 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 sixteenth year of this effort, 2003-2004. 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

---

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.
supervising principal investigator. An index is provided so that projects may be easily identified by topic. Chapters on best practices in design experiences, outcomes assessment, and writing about and working with individuals who have disabilities are also included in this book.

It is hoped that this book will enhance the overall quality of future senior design projects directed toward 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. Moreover, the new technologies used in these projects will provide examples in a broad range of applications for new engineers. The ultimate goal of this publication and all the projects built under this initiative is to assist individuals with disabilities in reaching their maximum potential for enjoyable and productive lives.

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

Sincere thanks are extended to Dr. Allen Zelman, a former Program Director of the NSF BRAD program, for being the prime enthusiast behind this initiative. Additionally, thanks are extended to Drs. Peter G. Katona, Karen M. Mudry, Fred Bowman, Carol Lucas, Semahat Demir 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. Andrew Macfarlane for technical illustrations, and Ms. Genie Preisch, Julie Lundy, Elizabeth Enderle and Rebekah Enderle for editorial assistance. Also, thanks are extended to Stephanie Haapala and Martha Nye for the final proofing of the book. 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. Brooke Hallowell is Associate Dean for Research and Sponsored Programs in the College of Health and Human Services and a faculty member in the School of Hearing, Speech and Language Sciences 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 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
John Enderle and Brooke Hallowell

Devices and software to aid persons with disabilities often require custom modification. They are sometimes prohibitively expensive or even nonexistent. Many persons with disabilities have limited access to current technology and custom modification of available devices. Even when available, personnel costs for engineering and support make the cost of custom modifications beyond the reach of 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 members 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 past years include laser-pointing devices for people who cannot use their hands, speech aids, behavior modification devices, hands-free automatic telephone answering and hang-up systems, and infrared systems to help individuals who are blind navigate through indoor spaces. The students participating in this program are richly rewarded through their activity with persons with disabilities, and justly experience a unique sense of purpose and pride in their accomplishments.

The Current Book
This book describes the NSF supported senior design projects during the academic year 2003-2004.
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 five 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 modification is usually included. Next, a technical description of the device or modification is given, with parts specified in cases where it may be difficult to fabricate them otherwise. An approximate cost of the project, excluding personnel costs, is provided.

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

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

**Engineering Design**

As part of the accreditation process for university engineering programs, students are required to complete a minimum number of design credits in their course of study, typically at the senior level. Many call this the capstone course. Engineering design is a course or series of courses that brings together concepts and principles that students learn in their field of study. It involves the integration and extension of material learned throughout an academic program to achieve a specific design goal. Most often, the student is exposed to system-wide

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analysis, critique and evaluation. Design is an iterative decision-making process in which the student optimally applies previously learned material to meet a stated objective.

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

or

(800) 227-0216.

More information about this NSF program is available at:

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

**Specifications**

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

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

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

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

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

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

- Electrical parameters (including interfaces, voltages, impedances, gains, power output, power input, ranges, current capabilities, harmonic distortion, stability, accuracy, precision, and power consumption)
- Mechanical parameters (including size, weight, durability, accuracy, precision, and vibration)
- Environmental parameters (including location, temperature range, moisture, and dust)

**Paper Design and Analysis**

The next phase of the design is the generation of possible solutions to the problem based on the specifications, and selection of an optimal solution. This involves creating a paper design for each of the solutions and evaluating performance based on the specifications. Since design projects are open-ended, many solutions exist, solutions 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 often to build the device module by module. By building the project in this fashion, the student is able to test each module for correct operation before adding it to the complete device. It is far easier to eliminate problems module by module than to build the entire project and then attempt to eliminate problems.

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

After the project has undergone laboratory testing, it is then tested in the field with the client. After the field test, modifications are made to the project, and then the project is given to the client. Ideally, the 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 may handle the problem. If the repair or modification is more extensive, another design student may be assigned to the project to handle the problem as part of his or her design course requirements.

**Documentation**

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

Most universities require that the final report be professionally prepared using desktop publishing software. This requires that all circuit diagrams and mechanical drawings be professionally drawn. Illustrations are usually drawn with computer software, 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 web-based approach and in distance learning, in a collaborative arrangement with Ohio University.

Duke University

The Devices for the Persons with Disabilities course is offered as an elective to seniors and graduate students through the Biomedical Engineering Department at Duke University. The course has been supported since September 1996 by 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 are focused on basic principles of engineering design, oral and written communication, and ethics. In addition, guest lectures cover topics such as an overview of assistive technology, universal design, ergonomics and patent issues. Field trips to a local assistive technology lending library, and to an annual exposition 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 oriented towards the disadvantaged community. The instructor chooses a number of students to serve as CEOs of their company. The remaining students must present oral and written resumes and participate in interviews.

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

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

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

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

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

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

Early in the course, potential capstone projects are presented; students are required to review current and past projects. In some semesters, potential clients address the class. Representatives from agencies have presented their desires and individuals in wheelchairs have presented their requests to the class. Students are required to begin the process of choosing a project by meeting with potential clients and assessing the problem, defining the needs, and making a decision as to whether or not they 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 design. Once a project has been chosen, the student must begin the process of generating a written technical proposal. This document must clearly indicate answers to the following questions:

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

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

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

**Texas A&M University**

The objective of the NSF program at Texas A&M University is to provide senior bioengineering students an experience in the design and development of rehabilitation devices and equipment to meet explicit client needs identified at several off-campus rehabilitation and education facilities. Texas A&M has participated in the NSF program for seven 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 members at Texas A&M University involved with the rehabilitation design course have worked in collaboration with the local school districts, community rehabilitation centers, residential units of the Texas Department of Mental Health and Mental Retardation (MHMR), community outreach programs of Texas MHMR, and individual clients of the Texas Rehabilitation Commission and the Texas Commission for the Blind. Appropriate design projects are identified in group meetings between the staff of the collaborating agency, the faculty, and the participating undergraduate students enrolled in the design class. In addition, one student is employed in the design laboratory during the summer to provide logistical support, and pursue his or her own project. Each student is required to participate in the project definition session, which 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 duration. To meet the broad spectrum of needs, simpler projects are accommodated by requiring rapid completion, at which point the students move on to another project. More difficult projects involve one or more semesters, or even a year's effort; these projects are the ones that typically require more substantial quantitative and related engineering analysis.

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

Throughout each phase of the project, a faculty member 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. The design team meets as a group to discuss design ideas and project progress, and to plan further visits to the agencies.

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

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

Feedback from participating students is gathered each semester using the Texas A&M University student "oppinionaire" 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 ten 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, 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
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device is then fully tested, and after approval by the senior design faculty advisor, the device is given to the client. Each of the student design teams receives feedback throughout the year from the client or client coordinator to ensure that the design meets its intended goal.

Each design team provides an oral presentation during regularly held seminars in the department. In the past, local TV stations have filmed the demonstration of the senior design projects, and broadcast the tape on their news 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. An additional five-year grant was awarded in 2005. These NSF projects are a pronounced change from previous design experiences at UConn, which involved industry sponsored projects carried out by a team of student engineers. The new Biomedical Engineering Program at UConn has now replaced the ESE Dept. in this effort.

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

Each year, 25 projects are carried out by the students at UConn. Five of the 25 projects are completed through collaboration with personnel at Ohio

University using varied means of communication currently seen in industry, including video conferencing, the Internet, 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 who has 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 web-based approach is used for reporting the progress on projects. Students are responsible for creating their own Internet sites that support both html and pdf formats with the following elements:

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

**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 determiners for success in teamwork are positive interdependence and individual accountability. Positive interdependence, or effective synergy among team members, leads to a final project or design that is better than any of the individual team members may have created alone. Individual accountability, or an equal sharing of workload, ensures that no team member is overburdened and also that every team member has an equal learning opportunity and hands-on experience.

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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 timelines were used and general project goals were discussed throughout the two semesters. A teaching assistant was used in the course as an assistant coach to help the students in whatever manner was necessary. In general, multidisciplinary teams were not formed since the student backgrounds were not the criteria used to select team members.

Procrastination, a lack of enthusiasm and poor planning were common themes among the students. Most teams encountered significant difficulties in completing projects on time. Conflict among team members was more frequent than desired, and in some extreme encounters, physical violence was threatened during lab sessions. Many students complained that the projects were 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 a 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, 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 manufacturing of a PC Board (without soldering of components), the planner may assign a half-day to that task. All durations are assigned without regard to linking.

The next step is task linking. Here the planner determines the order in which tasks must be completed. Microsoft Project allows linking with simple keyboard commands. The planner links all tasks together, with a final completion date being noted. It is in this step where the planner must make certain decisions in order to schedule a satisfactory completion date. Tasks may be altered with respect to their duration or scheduled as concurrent items. The critical path is also delineated during the linking exercise. Once a satisfactory completion date has been scheduled due to these alterations, the planner can 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 web site. Weekly report structure for the web page includes: project identity, work completed during the past week, current work within the last day, future work, status review, and at least one graphic. The client and/or client coordinator uses the web reports to keep up with the project so that they can provide input on the progress. Weekly activities in Design II include team meetings with the course instructor, oral and written progress reports, and construction of the project. As before, the 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

“MEANINGFUL” OUTCOMES ASSESSMENT OF DESIGN EXPERIENCES

Brooke Hallowell

During the past ten years, the Accrediting Board for Engineering and Technology (ABET)\(^\text{13}\) has worked to develop increasingly outcomes-focused standards for engineering education. This chapter is offered as an introduction to the ways in which improved foci on educational outcomes may lead to: (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.\(^\text{14}\)

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

Cognitive/Affective/Performative Outcome Distinctions
To stimulate our clear articulation of the specific outcomes targeted within any program, it is helpful to have a way to characterize different types of outcomes. Although the exact terms vary from context to context, targeted educational outcomes are commonly characterized as belonging to one of three domains: cognitive, affective, and performative. Cognitive outcomes are those relating


to intellectual mastery, or mastery of knowledge in specific topic areas. Most of our course-specific objectives relating to a specific knowledge base fall into this category. Performance outcomes are those relating to a student's or graduate's accomplishment of a behavioral task. Affective outcomes relate to personal qualities and values that students ideally gain from their experiences during a particular educational 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
- Demonstrated means by which certain assessments, such as student exit or employer surveys, may be used to make strategic program changes.

These assessment practices may be used to a program's advantage in negotiations with administration (for example, to help justify funds for new equipment, facilities, or salaries for faculty and supervisory positions)\(^1\)

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\(^1\) provides direction in areas that are essential to assess in order to monitor

17 Accrediting Board for Engineering and Technology. Criteria for Accrediting Engineering Programs. ABET: Baltimore, MD.
the value of engineering design project experiences. For example, the following are considered "fundamental elements" of the design process: "the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation" (p. 11). Furthermore, according to ABET, specific targeted outcomes associated with engineering design projects should include: development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, production processes, concurrent engineering design, and detailed system descriptions. The accrediting board additionally stipulates that it is essential to include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impact. ABET's most recent, revised list of similar targeted educational outcomes is presented in the Appendix to this chapter. We encourage educators, students and consumers to consider the following questions:

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

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

Basic terminology related to pertinent assessment issues was presented earlier in this chapter. Brief descriptions of cognitive, performative, and affective types of outcomes 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 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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Athens, OH 45701

E-mail: hallowel@ohio.edu
APPENDIX: Desired Educational Outcomes as Articulated in ABET's New “Engineering Criteria 2000” (Criterion 3, Program Outcomes and Assessment)\textsuperscript{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 accreditation. Given that most students in the NSF-sponsored Senior Design Projects to Aid Persons with Disabilities programs are already in their fourth year of college-level study, it is critical to recognize that previous formative writing instruction is essential to their continued development of writing skills during the senior year. Model strategies for improving writing presented here in light of senior design projects may also be implemented at earlier stages of undergraduate learning.

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

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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.

\(^{20}\) 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>2/2</td>
</tr>
<tr>
<td>10 point size type throughout the manuscript</td>
<td>2/2</td>
</tr>
<tr>
<td>Margin settings: top =1&quot;, bottom=1&quot;, right=1&quot;, and left=1&quot;</td>
<td>2/2</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>1/2</td>
</tr>
<tr>
<td>Text single spaced</td>
<td>2/1</td>
</tr>
<tr>
<td>No indenting of paragraphs</td>
<td>1/1</td>
</tr>
<tr>
<td>Blank line inserted between paragraphs</td>
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<tr>
<td>Identifying information includes: project title, student name, name of client coordinator(s), supervising professor(s), university address</td>
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</tr>
<tr>
<td>Appropriate headings provided for Introduction, Summary of impact, and Technical description sections</td>
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<tr>
<td><strong>Total points for form and formatting</strong></td>
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<tr>
<td><strong>B. Images</strong></td>
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</tr>
<tr>
<td>Photographs in black and white, not color</td>
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</tr>
<tr>
<td>Photographs are hard copies of photo prints, not digital</td>
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</tr>
<tr>
<td>Line art done with a laser printer or drawn professionally by pen with India (black) ink</td>
<td>2/2</td>
</tr>
<tr>
<td>Images clearly complement the written report content</td>
<td>2/2</td>
</tr>
<tr>
<td>Photographs or line art attached to report by paperclip</td>
<td>1/1</td>
</tr>
<tr>
<td>Photographs or line art numbered on back to accompany report</td>
<td>1/1</td>
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<tr>
<td>Figure headings inserted within the text with title capitalization, excluding words such as “drawing of” or “photograph of”</td>
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<tr>
<td><strong>Total points for images</strong></td>
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Chapter 4: Using NSF-Sponsored Projects To Enrich Students’ Written Communication Skills

C. Grammar, spelling, punctuation, and style

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<td>Consistent tenses throughout each section of the report</td>
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<tr>
<td>Grammatical accuracy, including appropriate subject-verb agreement</td>
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</tr>
<tr>
<td>Spelling accuracy</td>
<td>2</td>
</tr>
<tr>
<td>Appropriate punctuation</td>
<td>2</td>
</tr>
<tr>
<td>Abbreviations and symbols used consistently throughout (For example, “or” or in. throughout for “inch;” excludes apostrophe for plural on abbreviations, such as “BMEs” or “PCs”)</td>
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</tr>
<tr>
<td>Uses the word “or” rather than a slash (/) (For example, “He or she can do it without assistance.”)</td>
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</tr>
<tr>
<td>Numbers one through 9 spelled out in text; number representations for 10 and higher presented in digit form (except in series of numbers below and above 10, or in measurement lists)</td>
<td>1</td>
</tr>
<tr>
<td>In lists, items numbered, with commas between them (For example: “The device was designed to be: 1) safe, 2) lightweight, and 3) reasonably priced.”)</td>
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</tr>
<tr>
<td>Consistent punctuation of enumerated and bulleted lists throughout the report</td>
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Total points for grammar, spelling, punctuation, and style /15

D. Overall content

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

Total points for overall content /15
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
The World Health Organization (WHO) has launched worldwide 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.

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

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

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

Resources

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

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

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

Another valuable source is the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) http://www.resna.org/. This is a transdisciplinary organization that promotes research, development, education, advocacy and the provision of technology for individuals with disabilities. In addition, by using the technical assistance project link on the home page, one can 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
ARIZONA STATE UNIVERSITY

College of Engineering and Applied Sciences
Bioengineering Program
Department of Chemical, Bio & Materials Engineering
Tempe, Arizona 85287-6006

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jiping.he@asu.edu
SHARK FIN ORTHOTIC HAND PADDLE

Designer: Rachel Galvan
Supervising Professors: Dr. Vincent Pizziconi and Brian Glaister
Arizona State University
Ira A. Fulton School of Engineering
Harrington Department of Bioengineering
Tempe, AZ 85287-9709

INTRODUCTION
In the United States alone, an estimated 12 million people suffer from spastic paraplegia. Spasticity is most commonly associated with several neurological disorders such as Multiple Sclerosis, Stroke, Cerebral Palsy, Spinal Cord and Brain Injuries, and Neurodegenerative Diseases. Spasticity is a condition in which certain muscles are continuously contracted causing stiffness and/or tightness of the muscles. Due to this problem, people who suffer from spasticity are encouraged to become involved in aerobic activity that exhibits minimal pressure and force on the body such as swimming. Swimmers who suffer from hand spasticity have desired a hand paddle specially designed to alleviate pain and discomfort on the hand while providing wrist support. The SHARK FIN orthotic hand paddle was designed and developed to meet the needs of this population.

The SHARK FIN orthotic hand paddle is a device that is intended for use as an exercise component to be used in conjunction with swimming. This device was designed to redevelop muscles and/or restore motion to joints as well as reduce stress and strain on the hand and wrist of the user. Lastly, the purpose of the device is to provide sufficient water resistance while swimming. This device was specifically designed for a disabled swimmer with hand spasticity.

The design of the orthotic hand paddle includes a large paddle that is used to provide resistance
through the water and includes Neoprene padding secured in an indented region in the center of the paddle. The paddle is secured to the hand of the swimmer with latex tubing. By pulling the latex tubing through small circular holes placed around the perimeter of the indented region and small extension arm the paddle is securely fastened to the user.

**SUMMARY OF IMPACT**
The device relieves pain and discomfort often felt by those using presently-available hand paddles. The client using the device reports that the paddle is comfortable, stable and provides an excellent amount of resistance through the water. By using this device, the client is able to train and exercise for greater amounts of time.

**TECHNICAL DESCRIPTION**
The design of the orthotic hand paddle includes a large high-density polyethylene paddle that provides resistance through the water. It includes Neoprene padding secured in an indentation in the center of the paddle. The paddle is secured to the hand of the swimmer with latex tubing. By pulling the latex tubing through small circular holes placed around the perimeter of the indentation and small extension arm, the paddle is securely fastened to the user.

The cost is approximately $3.00.

Figure 6.2. Shark Fin Orthotic Hand Paddle.
WHEELCHAIR MOBILE ARM SUPPORT

Designer: Anjali Gupta

Client Coordinator: Tedde Scharf, ASU Disability Resource Center
Supervising Professor: Dr. James Abbas
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INTRODUCTION
The mobile arm support is a custom design for an individual with muscular dystrophy to assist her in activities of daily living. Growing progressively weaker in her arms, she requested mobile supports to support the forearm while allowing her to move her arms in specified directions.

Muscular dystrophy (MD) is a disease that affects the neuromuscular junctions, the terminal between the motor neuron and the muscle fiber. The motor neuron allows nerve impulses to travel to the muscle fibers causing contraction in the muscles. When degeneration of the neuromuscular junction is evident, the way the muscle receives impulses from neighboring sites is affected.

The disease causes a weakening and the degeneration of muscles. Individuals with MD can experience weakening of the limbs along with trouble in the heart and respiratory muscles. Research is being done to find a possible cure for muscular dystrophy but until a permanent cure is developed to fight muscular dystrophy, MD patients can use assistive devices to help perform activities of daily living.

SUMMARY OF IMPACT
The device will allow the client to perform important tasks, such as turning on the room lights, grabbing objects and reaching for the telephone, more easily. She is able to lift her arm vertically and horizontally with an increased range of motion. This decreases her dependence on other individuals.

TECHNICAL DESCRIPTION
The overall device (shown in Figure 6.3) is made of aluminum links and electrical components. Aluminum was chosen for its high strength to weight ratio. It provides the basis for the mobile arm support. The links are made of aluminum rods cut to the proper lengths, which are designated according to the size of the individual’s forearm.

The device is actuated by two toggle switches attached to the right side of the wheelchair. One switch controls movement of the arm to the left and the right of the user, while the second switch controls movement up and down. An external switch is also attached to turn the motor’s power on and off. This will prevent draining of the battery when the device is not in use.

Commercially-available motor drives are used to control two commercially available motors designed to function in the directions described above. The power source is the motorized wheelchair’s own battery pack. The motor speed is set at a slow constant rate to ensure safety. Mechanical stops are also incorporated into the support to prevent dangerous movements.

The mobile arm support attaches to a clamp under the current arm rest. The arm support runs parallel to the arm rest. The device is portable and can be detached from the wheelchair at any time.

The cost is approximately $500.
Figure 6.3. Mobile Arm Support.
PARKING REACHER

Designer: Karen Lewis
Supervising Professors: Dr. James Abbas and Brian Glister
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INTRODUCTION
The Parking Reacher was designed for an individual with osteogenesis imperfecta, who had difficulty when reaching out the window of an automobile to access things such as toll booths, parking garage entrances and ATM machines.

SUMMARY OF IMPACT
The objective of the Parking Reacher (shown in Figures 6.4 and 6.5) is to daily assist those with limited reaching ability. Parking garages and entry gates for vehicles are designed with the assumption that drivers can reach two to three feet out of their window. The Parking Reacher extends to address reaching problems. The Reacher fits securely and compactly in the vehicle, close to the driver.

TECHNICAL DESCRIPTION
Several design concepts were considered for the Parking Reacher, including complex springs and telescoping materials to activate the grip. The compatibility factor also had several design variations throughout development, including folding and telescoping. The final design was partially chosen for its simplicity and ease of repair. It consists of a trigger, two acrylic tubes and a handle, which reduce coupling and finger mechanism. All components of the device are made of polypropylene. The acrylic tubes fit inside one another to allow for telescoping and snap buttons hold the device at the desired length. The trigger activates the grip by pulling an interior cable, which closes the grip.

Since the Reacher is intended to be used in a vehicle to open gates and structures, it is designed with those scenarios in mind. The gripping mechanism is designed to be able to push small buttons such as those found on keypads or ATM machines. The gripping mechanism is also dipped in vinyl to allow for the grabbing of parking tickets or paper.

The device costs $20.00.
Figure 6.4. Parking Reacher.

Figure 6.5. Client with Parking Reacher.
MOBILE ARM

Designer: Chad R. Price
Supervising Professor: Dr. Kristine Csavina
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INTRODUCTION
The mobile arm (shown in Figures 6.7 and 6.6) was designed to provide assistance to people with muscular dystrophy or similar upper extremity disabilities. Activities that may be impaired include writing, reaching, answering phones, using the computer, and shaking hands. The mobile arm device supports the client’s forearm and assists the client in accomplishing tasks that require arm movement, such as extension of the arm. The device attaches to the wheelchair and allows the user to extend his arm to shake hands and answer phones by the use of a simple switch.

SUMMARY OF IMPACT
The design of the mobile arm was defined by the needs of the user, who works in a business setting. In this type of setting, using telephones, computers, and shaking hands requires speed and efficiency. Upper extremity disabilities are an obstacle in accomplishing these daily tasks in a timely manner. The mobile arm decreases the time it takes to move the arm into an extended position. The user has control of the mobile arm and can extend or retract the device when desired.

TECHNICAL DESCRIPTION
The mobile arm was designed to fit the client’s Permobil Chairman 2K wheelchair armrest. The design integrated the wheelchair armrest and some of the mounting components to attach the mobile arm device to the wheelchair.

The prototype used a power window motor to drive the device. The rack was taken from the window lift mechanism of a car power window. The rack is mounted to the armrest using two rivets to hold it in place.

The mobile arm is guided by a linear drawer slide (3 piece, ball bearing). The slide is attached using four $\frac{1}{4}$" bolts. A C-beam was used as an interface between the device and the wheelchair. It was cut down to mount the motor and the slide, as well as to attach the device to the wheelchair. Holes drilled in

Figure 6.6. Mobile Arm Used for Answering Phone.
the sides of the C-beam allowed the two attachment components from the wheelchair to be integrated with the device for mounting to the wheelchair.

The mobile arm is powered by one of the 12 Volt batteries the wheelchair utilizes. The speed of the motor is reduced by a drop in the voltage supplied to the motor. A voltage divider is used to drop the voltage to 5 Volts. The voltage drop results in a linear speed of approximately 2.5 cm/s. This can be adjusted to the user’s preference of speed. A three-position switch controls the direction of the mobile arm, with middle position off.

Sixteen gauge stranded wire was used to handle the nearly two amps of current that is drawn by the motor. A limit switch was placed near the armrest to stop the power to the motor when the arm extended to nine inches, maximum extension.

The mobile arm device was designed with size in mind. The motor of the device is not wider than the wheel width of the wheelchair. This allows the user to have access to entering through any doors that they have always been able to enter.

The cost of parts/material is approximately $150.

Figure 6.7. Shaking Hands using Mobile Arm.
INTRODUCTION
The light bulb changer (LBC) (shown in figure 6.8) was designed to enable elderly individuals to change light bulbs in fixtures high above the ground. Light bulb changers exist on the market today but fail to account for the needs of those who are elderly. They usually have sleek designer poles that cannot be gripped easily or twisted to change light bulbs. The LBC consists of a rubberized crank handle, a telescoped pole, and a bulb gripper. The finished device was given to an 80-year-old woman who lives by herself. She has frail arms, is uncomfortable on ladders, and has problems grasping objects.

SUMMARY OF IMPACT
The LBC allows people with weak hands, people who can’t generate much force, or people who are afraid to stand on ladders to change high light bulbs in their house. The LBC eliminates the necessity of waiting for someone to come over and change a light bulb in a dark area of the house. Now the client can change light bulbs according to her own schedule, not that of another person.

TECHNICAL DESCRIPTION
The frame of the light bulb changer is made from PVC. This material was used because it is lightweight, inexpensive and readily available. The crank, the most important element of the device, was placed at a 90-degree angle relative to the pole. The crank allows the user to expend less energy changing light bulbs than other bulb changers on the market. This concept is based on the root equation $T = F \times r$. The torque that is needed to unscrew a light bulb is equal to the cross product of the force and the length. In this case, the length is indicative of the length of the crank on the device. Thus, the crank allows the user to use less force when changing light bulbs.

A five-inch crank was placed on the device. This length allows the user to stand in one place while operating the device. If the crank handle were too long, the device would have to be operated by walking around the crank. The five-inch crank was also selected because it allows the user to fully utilize the muscles in the biceps and shoulders while operating the device.

The crank is also coated with a rubber friction material called Plastidip. This material allows the user to grip the device with ease. Both the crank and the crank handle are coated with this material so that both hands can grip the device well.

The claws of the end effector are made from spring steel that actually wraps around the entire bulb to secure it to the device. This is done via a circular spring that expands and contracts based on the force applied to the spring.

The device is telescoped so that it can be used on incandescent lights up to 12 feet off the ground. When not in use, the device can be compacted to four feet for easy storage. All sharp parts have been filed to ensure that it is safe.

The total cost of the parts and materials was approximately $100.
Figure 6.8. Client Using Device.
CHAPTER 7
DUKE UNIVERSITY

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ENVELOPE INSERTING AIDS

Designers: Shin Y. Ong and Shin R. Ong
Client Coordinator: Judy Stroupe, Orange Enterprises
Supervising Professor: Larry Bohs
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INTRODUCTION
Four devices have been developed to help workers with physical disabilities insert documents into envelopes of different dimensions. Each device holds an envelope in a position for receiving documents, and aligns paper prior to insertion. Envelope insertion is then achieved through single-hand pushing actions. The devices are relatively inexpensive, portable, easy to operate, and suitable for use by individuals who lack fine motor control.

SUMMARY OF IMPACT
The client is a non-profit agency that meets the employment needs of individuals with physical disabilities by subcontracting mailing and packaging services. Employee salary is a function of competence in areas of mail preparation, such as document collation and envelope stuffing. The Envelope Inserting Aids will allow some workers to perform an additional task in the workplace. The client coordinator commented that the inserting aids will "increase production rate and pay, boost independence, self-esteem and confidence, and allow them to do much more of the job".

TECHNICAL DESCRIPTION
Four aids (shown in Figures 7.1 and 7.2) were designed to accommodate the following envelope sizes: 10" x 13" (Fig. 7.1), 9.5" x 12.75" , 9" x 6," and 9" x 4." Each device consists of an aluminum aligner tray mounted on a plywood base. The tray has perpendicular, or angled, edges to align documents. Some perpendicular edges have an additional lip to ensure that documents stay on the tray.

The tray and its edges extend a few inches beyond the plywood base. A ledge is mounted over the tray extension, and the gap between the ledge and the tray forms a channel for documents to go into the envelope. The envelope is opened by pulling the envelope itself over the channel and is then secured with a clip. The clip’s purpose is to secure the envelope so that it does not become displaced with any pushing action. The top piece of the channel extends further into the envelope to provide stability and aligns documents properly. The tray extension is shorter so that documents will not remain in the channel upon envelope removal.

The shape of the channel is customized for each envelope. For business envelopes with triangle flaps (Fig. 7.1), the channel’s top piece has a triangular cut in the middle to enable the client to reach deeper and insert documents completely. The 9" x 6” aid requires a trapezoidal channel with a wider bottom to accommodate snug-fitting documents. The channel is elevated from the work surface by the plywood, so that envelopes can be inserted without moving the device.

The smooth continuous tray extends into the envelope, which minimizes snagging of documents. Documents on the aligner tray are pushed into the envelope through the channel. Aluminum edges are smoothed and rounded to ensure they do not cut the documents. Edges without a lip are fitted with
rubber hoses to minimize stress injuries to the wrist. A piece of Dycem is attached to the underside of each device to secure it to the table surface during operation.

After testing the devices with the clients, we determined that aligner edges were effective in keeping paper in the tray. Physical discomfort during envelope insertion was minimized because thin edges of the aluminum (without a lip) are padded. The static and kinetic friction between paper and aluminum is minimal but increases with contact pressure. Therefore, the most efficient manner to use the device is to push papers against the tray lightly.

The cost of parts for the four envelope inserting aids is approximately $100.
CUSTOM CANES AND BRACKETS

Designers: Lindsay Boole and Hudson Levy
Client Coordinator: Christina Lomax
Supervising Professor: Larry Bohs
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INTRODUCTION
The goal of this project was to provide forearm canes with shock absorption to an active woman with osteoarthritis. Also, brackets were designed to mount the canes to a client’s powered scooter.

SUMMARY OF IMPACT
After using the devices (Figure 7.3), the client commented, “The shock absorbers have already made such a difference. I already don’t think I could go back to the regular canes. [The new canes] just take the impact so nicely and make my shoulders feel so much better. Being able to mount [the canes] on my scooter will make getting around so much easier, especially when I’m with [a child].”

TECHNICAL DESCRIPTION
The shock absorption component was developed by modifying the spring mechanisms from commercial shock-absorbing trekking poles. The commercial spring shock absorbers were composed of a threaded top stopper, a spring, a long hex screw, and a plastic molding. The poles were smaller in diameter than the client’s Guardian cane shafts, so custom parts were designed to fit the commercial shock absorbers into the Guardian canes.

An aluminum top stopper was affixed with screws into the Guardian cane shaft, and a machined plastic sleeve was fit around the commercial shock absorber to increase its diameter. Custom washers were designed to fit between the top stopper and the spring, as well as between the spring and the molding, to minimize the wearing effects of continuous use.

During initial tests, the torque exerted by the forearm canes caused the cane tips to rotate, loosening or tightening the shock absorber spring. To prevent this rotation, a setscrew was attached through the top stopper and into the long hex screw.

The screw was tightened at a level of shock absorption comfortable for the client.

To attach the canes to the client’s powered scooter, commercial EZGrip brackets were attached on the rear fenders, and custom U-shaped guiding brackets on the front fenders (Fig. 7.4). Both were secured with screws through aluminum plates, to evenly distribute the screws’ forces across the plastic surfaces of the scooter. The client can mount the custom canes on her scooter by placing the bottom end of the shaft in the guiding bracket, then pressing the top of the shaft into the EZGrip bracket. The seat
of her scooter rotates so that she can mount one cane on each side of the seat. The cost of parts is approximately $75.
INTRODUCTION
A set of devices has been developed to aid the client, a 13-year-old boy with cerebral palsy, in common kitchen tasks. These devices provide support for mixing foods, spreading condiments, opening jars and soda cans, and cutting food. The devices have been modified from commercially available products to provide more stability, grip and easier movement control. Each device is attractive, relatively inexpensive, and easy to assemble and operate.

SUMMARY OF IMPACT
The client can now be more involved in the kitchen, relying less on his mother, and improving his independence in some tasks: mixing salad and recipe ingredients, making his own sandwiches, opening jars and soda cans, and cutting food items such as lemons and sandwiches. His occupational therapist said "I feel [the devices] will make him independent with tasks that he normally wouldn't be. Independence is something that he needs, especially at this age."

TECHNICAL DESCRIPTION
The Kitchen Helpers (Fig. 7.5) consist of a mixing bowl (upper left), a jam stamp and Spreadboard (The Wright Stuff, Grenada, MS) (upper right), a jar opener (lower left), and a cutting board (lower right) (Figure 7.6) that functions both as a jar holder as well as a knife mount.

The mixing bowl assembly is used for mixing a salad or recipe ingredients. It consists of an 8 qt. stainless steel mixing bowl, an 8” diameter turntable and a gum rubber gripping ring. The bowl secures to the turntable using Velcro. The rubber ring fits tightly around the lip of the bowl, creating a good grip for turning and holding the bowl. The turntable allows our client to turn the bowl while mixing, eliminating the need to stir in a circular motion. The heavy base of the mixing bowl and turntable assembly makes it less likely for it to tip over. Rubber mats attached to the bottom of the turntable and a Dycem mat for the kitchen counter prevent the assembly from sliding.

The jam stamp and Spreadboard are used to spread different condiments evenly onto bread. The Spreadboard and squeeze bottles are available commercially. The jam stamp is adapted from a potato masher by welding a 4.5” diameter stainless steel plate to the bottom. The upright handle allows for easy movements of the jam stamp without bending the wrist. The large surface area allows the condiment of choice to be spread evenly with minimal movement.

The jar opener was modified from a commercial device (Good Grips Jar Opener, OXO International, NY) by attaching magnets to the underside, a finger hold to the top, and a brass weight to help stabilize the front.

The cutting board, which was modified from a commercial device (Swedish Cutting Board, Westons Internet, West Sussex, England), holds jars, and stabilizes a knife for cutting. Without the knife
mount, the cutting board serves as a jar holder with jars fitting tightly between a sliding panel and two square pegs. Two commercial quick-adjust bar clamps secure the cutting board to the countertop to prevent rotation. A custom aluminum knife mount allows foods to be cut safely with the Ergonoma chef knife (Grip Advantage, Inverness, FL) by bringing the knife down in a chopping motion. A custom guard surrounds the knife to further protect hands and fingers. The guard attaches to the knife with a small spring, so that the knife only drops below the guard when food is being cut, and only drops to the depth of the food. A spring pin in the knife mount allows quick removal of the knife for cleaning.

The cost of parts is approximately $250.

Figure 7.6. Client with Cutting Board with Knife.
SENSORY PLAY STATION

Designers: Lauren J. Matic and David J. Rodrian
Client Coordinator: Michelle Hoffman, Durham County Schools
Supervising Professor: Larry Bohs
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INTRODUCTION
The goal of this project is to provide a play station with sensory activities. This device allows children with and without various disabilities to interact, learn academic concepts, and develop motor skills. The device includes an adjustable height table and adapted sensory toys. The completed play station allows children of different abilities and differing heights, and children using wheelchairs, to interact with others at eye level.

SUMMARY OF IMPACT
The client coordinator commented regarding the Play Station: “All of the kids, even older kids, want to play with the sensory station. It's a great success here.... The dumping bin is the favorite for most of the kids.”

TECHNICAL DESCRIPTION
The Sensory Play Station is shown in Fig. 7.7. The table frame is constructed from commercially available aluminum framing and connectors (Bosch-Rexroth Inc.), making the table sturdy, lightweight, and weather resistant. The table is 25.5” wide by 37.5” long -- small enough to fit through a doorway though large enough to allow multiple children to interact together. Two inexpensive, commercial plastic bins with lids fit into the top of the play station frame. These bins are removable to allow the sensory medium such as sand or water to be changed. A Movotec Lift System (Suspa Inc.), bolted to the legs of the frame, allows the table height to be adjusted from 25” to 37” by turning the crank of a hydraulic pump. To prevent the crank from becoming accessible to children, a cable lock is mounted on the frame. To improve mobility of the table, locking casters are mounted to the table legs with custom aluminum brackets.

Several sensory activities promote interaction between children and provide exposure to academic concepts. Two custom-designed toys are permanently mounted to the frame (Fig. 7.8). The first, called the tipsy toy, consists of a bucket attached to a string. When a large ring on the end of the string is pulled, the bucket tips over, pouring its contents into one of the activity bins. This activity helps improve motor skills and encourages teamwork while addressing the academic concepts of cause and effect, and gravity.

The second custom toy is a teeter-totter. The teeter-totter is constructed out of weatherproofed wood with plastic containers secured to each end using Velcro. Since the toy is centered over the table, a student can fill one container while another student fills the other container. This activity addresses the academic concept of heavy vs. light and more vs. less. In addition, several commercial sensory toys were purchased to add fun and educational elements to the play station.

The cost of parts is approximately $750.
Figure 7.8. Custom Toys: Tipsy Toy (background) and Teeter Totter (foreground).
LIFTING ASSIST FOR WHEELCHAIR

Designer: Paul A. Lisi and Andrew D. Steinberg
Client Coordinator: Nancy Curtis
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INTRODUCTION
The client is a 17-year-old girl with cerebral palsy. She cannot transfer into her motorized wheelchair comfortably without the assistance of others. The goal of this project was to build a device that allows her to get into her wheelchair as independently as possible. A lift was constructed. It attaches to her wheelchair and uses the seat-height actuator as a lifting mechanism. The device lifts her about 8" off the ground to make sitting in the wheelchair easier; it also serves as a footrest when the wheelchair is in use.

SUMMARY OF IMPACT
The client’s physical therapist said, “The finished product will enable only one person to assist instead of two because they will not have to lift her. Also, more people will be able to assist – for instance, her sister who is smaller than her mother, and other friends who don’t have special training. It will also give [her] more independence in the future [when she is] away at college and in a more independent living situation in a dorm or apartment. It will also assure that those helping her will not have to risk back injuries.”

TECHNICAL DESCRIPTION
The Lifting Assist (Fig. 7.9) uses the seat-height actuator of the powered wheelchair as the lifting force. The operational sequence is as follows: First, the client stands on a platform with the wheelchair seat in the lowered position. Second, the seat actuator is extended, causing the wheelchair seat and platform to rise by about 8". Third, the platform is locked into place vertically. Fourth, the seat actuator is retracted, lowering the seat to its minimum height. At this point, the client is approximately 8” closer to the seat vertically than she was on the ground. Finally, the client sits down with minimal assistance.

The final design comprises a mounting component, a linear stabilization component, a platform, and a locking system. The mounting component consists of a rectangular plate, connected by two ¾” square insertion rods to the footrest attachment sleeves below the wheelchair seat. Two shaft clamps and a vertical lock bar attach to the front of the rectangular plate.

The linear stabilization component includes two 25-mm diameter shafts, the tops of which are secured to the shaft clamps. Two pillow-block linear bushings slide freely on the shafts, and attach to the rear of the
platform, allowing it to move vertically. Locking collars mount on the shafts below the bushings, causing the platform to rise as the seat actuator extends.

The platform base has a trapezoidal shape, 12” on the end nearer the wheelchair, 14” on the other end, and 11.5” deep; these dimensions give the client maximum space given the constraints of the wheelchair. The base is covered with a piece of non-slip rubber. The rear of the platform is 12” horizontally by 6” vertically. The platform sides taper from 6” at the rear to 1” at the front, providing rigidity and maximum foot visibility for the client.

The locking system includes two spring pins attached through the platform’s rear wall. The first spring pin locks into a vertical stationary bar on the wheelchair, originally intended for stationary platform mounting. A custom square rod attaches to the vertical stationary bar, extending its height. As the seat rises to maximum height, this spring pin locks into a hole in the vertical stationary bar extension, fixing the vertical height of the platform. When the chair is lowered to its minimum height, the second pin locks into the vertical bar attached to the rectangular plate of the mounting component. If the client tilts her chair, this latter spring pin holds the platform in the proper position while the first spring pin slides out from its hole in the stationary bar extension. To get out of the chair, an assistant pulls on the rings of the lock pins, which allows the platform to slide back down to floor level.

The cost of parts was approximately $1000.
LITERACY TENT
Designers: Russell Blaise and Marie Schroeder
Client Coordinators: Luanne Holland and Joanna Clark, Durham County Schools
Supervising Professor: Larry Bohs
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INTRODUCTION
The Literacy Tent provides a literature-based, inclusive environment for use in a school. The tent includes a series of multisensory stimuli corresponding with a book's text, making the book accessible to both children with and without disabilities. A series of stimuli are mounted to the frame of the enclosure, for use with any book. For individual books adapted for tent use, book kits with specific stimuli are provided. The Literacy Tent provides opportunities for learning on many levels, from literacy to cause and effect to basic socialization.

SUMMARY OF IMPACT
The literacy tent is an enjoyable and educational asset available to the educators at the client school. One supervisor hopes to establish a lend-out procedure for tent use in regular and special education classrooms. She stated, "they could set up a literacy area around the tent. We'll put a few beanbag chairs on the floor and designate the area as a place for students to go and read. Then I can bring my students, and we can bring regular and special education students to the tent, set up the stimuli, and read an adapted book together."

TECHNICAL DESCRIPTION
The Literacy Tent (Fig. 7.10) includes three parts: a tent structure, a sensory environment, and kits containing stimuli tailored to specific books.

The tent structure is constructed from 1¼" furniture grade PVC, connected in a 5' x 5' x 5' cube, with a 2.5' high peak added to the roof. For portability, the frame fittings allow the cube walls to fold to the back and create a 5' x 5' vertical square. The frame can be completely assembled or disassembled in five minutes or put into storage in one minute. The structure's walls are made of fabric, affixed by industrial strength Velcro. The outer walls feature pockets sewn into the fabric, 2.5' off the ground, 6'

Figure 7.10. Literacy Tent.

wide and 4' to a side, to provide storage for stimuli not being used. The tent structure is stored in a 6'x1' ski bag.

The sensory environment consists of switches and switch-activated stimuli. The stimuli are generic in nature, so they can be incorporated into the reading of various books. Four custom switches were built to activate a tape recorder, a bubble machine, a fan, an aromatic fan, and Christmas lights. These switches were built by removing the light bulbs from push-on lights and providing 1/8" output jacks for controlling the stimuli. All switches and sensory
devices are mounted to the tent structure with industrial strength Velcro. The switch-activated tape recorder plays a book recording via a latch or timer mechanism.

Three book kits were developed; each provides smaller, specific stimuli to reinforce subjects in a given book. Each kit contains a tape of the book to be read, a laminated copy of the book, a curtain 2’ in length, made of book-themed fabrics, and book-specific stimuli. For the adapted book On Halloween Night, the curtain was created from two Halloween-print fabrics, and stimuli include parts of a witch’s costume, a bell, pumpkin scent, and chocolate candy. The kits for the books In the Tall, Tall Grass and Looking Great follow the same concept.

The cost of parts for the Literacy Tent was approximately $800.
INTRODUCTION
Our client was a two-year-old girl with athetoid cerebral palsy. To build head and neck strength, her parents and therapist wanted a device that would support her in a prone position that she could tolerate and would also allow her to crawl. The Toddler Crawling Positioner allows the client to be supported at a maximum angle of 45 degrees, which she can currently tolerate, down to 0 degrees, which will allow her to crawl once she builds adequate strength.

SUMMARY OF IMPACT
The Toddler Crawling Positioner will help the client develop strength by providing greater variety in therapy sessions. The client’s mother noted that, “It is an achievement in itself to have her happy in an assistive device. She seems to tolerate it just fine, which is remarkable.”

TECHNICAL DESCRIPTION
The Toddler Crawling Positioner (Figs. 7.11 & 7.12) includes a base, adjustment bar, connector piece, pommel, and torso support.

The base is composed of five extruded aluminum segments; four 2”x2”x12” square tubes comprising the legs, each coming off of the 2”x2”x28” spine at 60 degrees. The legs are outfitted with swivel caster wheels attached via lock collars and the spine is designed to mate with the adjustment bar. The entire base has been anodized in red and gold colors to give it vibrant, lasting color.

The adjustment bar connects the base with the torso support and is the mechanism for angle adjustment. It mates with the base via rounded teeth that oppose the load of the client, therefore locking it into place and eliminating the risk of becoming dislodged while the client is in the device.

The base is also connected to the torso support via the connector piece. This piece is a 2” by 13” extruded aluminum channel, fixed to the base by a pin joint and to the underside of the torso support by three wood screws. The connector piece also accommodates the pommel via a 0.25” wide milling, which allows for vertical adjustment of the pommel. The pommel is made of high-density closed cell foam over steel tubing, and is adjusted via a wing nut and bolt through the connector.

The torso support is made of a hardwood frame, upholstered with foam and waterproof vinyl. It is comprised of three pieces, connected via width-adjustable brackets and thumbscrews. Also provided are three sets of colorful, pre-washed Elmo-themed cover sheets to increase aesthetic appeal.

The cost was approximately $300.
Figure 7.12. Toddler Crawling Positioner with Client.
INTRODUCTION
The client is a professional dancer who has post-polio syndrome. She wanted a device to lessen the weight on her legs while onstage. The Dancer Assist consists of a lightweight mobile frame with a harness attached via a spring suspension. This device allows the client to perform jumps and other aerial maneuvers she could not perform before, while the support frame glides with her onstage. The Dancer Assist can be disassembled within minutes by hand, and is readily portable for the client.

SUMMARY OF IMPACT
The client commented that the device, “has really gone above and beyond my initial expectations. I think that the aerial dancing capabilities that I hadn’t expected have really expanded my repertoire as a dancer and I look forward to exploring these possibilities as I continue to work with [the Dancer Assist] in the future.”

TECHNICAL DESCRIPTION
The Dancer Assist (Fig. 7.13) contains three components: harness, frame and suspension system.

The frame is constructed of materials purchased from 80/20 company (Columbia City, IN). It consists of extruded aluminum struts, which are strong and lightweight. The door-frame design features three components: one "U" piece overhead and two "T" pieces for the wheel base. These three pieces are easily assembled using a slide-in joint on each side and secured by hand with a wing nut, all under two minutes.

The suspension system includes two springs, a safety spring and a heavy spring, connected in series. The safety spring is intended to support loads of up to 50 lbs, which is the amount of support that our client wanted while standing. When the client requires more support for jumping and full-body suspension, the safety spring is fully extended and the heavy spring incorporates. The springs connect to the harness by a pulley and cable system, which offers a smooth and secure connection to the two-point attachment at the waist, and allows the client to rotate her body even while fully suspended in the air. The design also features a ball-bearing swivel to anchor the suspension to the frame, which offers smooth and complete rotational freedom. All moving parts are enclosed inside a protective denim sleeve to prevent pinching or abrasion.

Finally, a lashing system, constructed from plywood, L-brackets and wood screws, holds the frame pieces securely together when disassembled for ease of travel.

The cost of parts for the Dancer Assist was approximately $825.
Figure 7.13. Dancer Assist with client.
DARKROOM MODIFICATIONS

Designers: Jenny Mao and Zach Novak
Client Coordinator: Faye Tripp
Supervising Professors: Richard Goldberg and Kevin Caves
Department of Biomedical Engineering
Duke University,
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INTRODUCTION
Our client, a professional photographer, had a traumatic brachial plexus injury leaving her right arm paralyzed. To support her passion for photography, two major additions were made to her darkroom. The Developing Station gave her the ability to develop her own 35 mm film, while the Cassette Loader allowed her to load efficiently twelve large-format, 4"x5," film sheets into six cassettes. One design challenge is that most of the operations must be completed in total darkness with only the left hand.

SUMMARY OF IMPACT
The client commented, “My attempts at handling film one-handed resulted in dropped film, frazzled nerves, and wasted time and energy. The two pieces of darkroom equipment designed for me... have restored my ability to easily handle film, which means the loading of sheet film into holders and the rolling of 35 mm film onto reels for developing are once again simple chores rather than major obstacles that take the fun out of photography.”

TECHNICAL DESCRIPTION
The Darkroom Modifications (Fig. 7.14) include a Developing Station and a Cassette Loader. The Developing Station is constructed of ¼” Lexan, and it has several custom components that facilitate one-handed operation for developing 35 mm film: a bottle opener on the side to open the film canister, a scissors to cut the film leader, and a custom fixture to hold the film reel. The entire station is attached to the table using a clamp that is easily operated with one hand.

The most difficult aspect of the design was determining the best method to accurately, easily, and safely cut off the leader of the film at a 90-degree angle. The client inserts the film into a guide slot, which ensures that the film is positioned correctly every time and holds the film in place once inserted. Then, she cuts the film leader using a pair of scissors with the handles removed, which are attached to the developing station, perpendicular to the guide. Since the scissors handles are removed, the client opens and closes the scissors by grabbing a thumbscrew that is attached to the bottom blade. In this manner, the client can hold the film while cutting the leader, while using one hand.

The Cassette Loader is designed to assist the client in loading 4” x 5” sheet film into commercial film cassettes. The design is based on that of a commercial CD storage stand. The client can load up to six empty film cassettes into slots on our device. This holds the cassettes in place so that she can easily load the film each one, turning the unit upside down to load both the top and bottom side. The cassette loader is constructed of ⅛” and ¼” Lexan pieces, connected using an acrylic adhesive. Lycra-covered neoprene on the front allows tension to be applied to the front of the cassette, and also helps keep the exposure door open when loading the film. A handle helps the client turn the device over, which is necessary for cassette loading.

The cost of parts was approximately $150.
Figure 7.14. Client with Darkroom Modifications.
DYNAVOX MOUNTING SYSTEM FOR HORSEBACK RIDING

Designers: Nicolas Buraglia and David Franklin
Client Coordinator: Lisa Reynolds, PT, Director of Heads Up! Therapeutic Riding Program
Supervising Professor: Kevin Caves and Richard Goldberg
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Durham, NC 27708

INTRODUCTION
The client is a ten-year-old girl with Cerebral Palsy who enjoys therapeutic horseback riding. To allow her to communicate with the instructors and the horse, we developed a mount that attaches her DynaVox communication device to her English saddle. The mount consists of two parts: an adjustable saddle clamp, and a DynaVox attachment bracket. The mount allows her to see and use the touch screen surface, giving her more freedom to make decisions and communicate while on the horse.

SUMMARY OF IMPACT
The DynaVox Mounting System allows a non-verbal rider to communicate with others while riding. The rider now has the capability to express where she wants to go. The client coordinator commented, “It’s so simple! That’s when you know you done a good job. This is huge for us. We’ve been trying to do this for years but we couldn’t find anything I was comfortable with putting an $8000 piece of equipment on.”

TECHNICAL DESCRIPTION
The DynaVox Mounting System (Fig. 7.15) consists of a saddle clamp, quick release attachment, and upper mount. The saddle clamp attaches from the front to the rear of the saddle, with a threaded rod linking either end. This rod resides under the saddle, where a gap provides about an inch of clearance between the saddle and the horse’s spine.

Both end pieces are machined from brass. The front piece is threaded to accept the rod, while the rear piece has two sidewalls with a groove between, where the rod protrudes. A large knob with a tapped opening works like a wing nut to tighten the saddle clamp to the saddle.

The quick release attachment consists of two parts. The first contains a slot with dimensions 0.75x0.25x2.5”, which is welded to the front piece of the saddle clamp. The second part includes a rectangular brass rod that fits snugly in the slot. A T-handle spring pin holds the two parts together, and a lanyard attached to the upper mount prevents the pin from getting lost.

The upper mount was made by modifying a commercial cymbal stand with two pivot joints. One pivot joint is welded to the front end of the rectangular brass rod. A ribbed bar extends 4” from this joint. At the end of the bar is the second joint to which attaches a vertical tube to hold the DynaVox. The tube connection includes two 90 degree welded joints to center the DynaVox over the saddle. By adjusting the two pivot joints, the DynaVox can be positioned for safety and convenience. The Dynavox itself is attached to the upper mount using a commercial part from DaesSy (Daedalus Technologies, Richmond, BC) made specifically for these devices.

The cost of parts was approximately $300.
Figure 7.15. Dynavox Mounting System.
**MORSE CODE TRAINER**

*Designers: Ann Hundley and Stephen Wu*

*Client Coordinator: Juli Trautman, SLP, CCC*

*Duke University Medical Center*

*Supervising Professors: Kevin Caves and Richard Goldberg*

*Department of Biomedical Engineering*

*Duke University, Durham, NC 27708*

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**INTRODUCTION**

For people with limited mobility, Morse code is an attractive alternative to computer access because it involves only two keys, dash and dot, as opposed to the more complex traditional keyboard. We designed a device to help ease the transition from more traditional means of interfacing with a computer to Morse code. The Morse Code Trainer is portable, provides audio and visual feedback, is accessible to a wide variety of clients, and incorporates variable timing to facilitate the learning process.

**SUMMARY OF IMPACT**

The client coordinator commented, “The Morse Code Trainer will allow my clients without the physical access skills for computer use, to investigate Morse code as a computer access option. Commonly, people have a misconception that Morse code is overly complicated and, therefore, they are reluctant to pursue this option, despite its advantages over switch scanning… By allowing my clients to take the trainer home and practice this technique, they will be able to make a more educated decision, and hopefully understand Morse code’s potential to allow for efficient and effective computer access for people without adequate hand control.”

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**TECHNICAL DESCRIPTION**

The Morse Code Trainer (Fig. 7.16) uses a 16F876 PIC microcontroller (Microchip Inc., Chandler AZ), programmed in C to interpret user input. Two 1/8” mono jacks allow the use of any commercial switch for entering dots and dashes. Pressure switch jacks also provide for sip and puff input.

The Morse Code Trainer includes features to make it accessible to clients with a variety of disabilities. For visual accessibility, a high contrast LCD shows the character or characters entered. This LCD has an always-on yellow backlight, and blue background. It also has a large character mode for users with visual impairments. A speaker generates tones of different frequencies to indicate a dot or a dash. With a headphone jack, the device to be used in a room where other noises might be distracting. Variable controls are provided for end-of-character time and repeat time.

The device is powered by AA batteries, and is lightweight for portability. Although every function that may be entered into a computer (including mouse movements) can be encoded in Morse code, only the codes for the alphabet, numbers, the “enter” and “space” bars, and period were implemented for simplicity.

The cost of parts was approximately $225.
Figure 7.16. Morse Code Trainer.
INTRODUCTION
The use of pedaling as a therapeutic exercise is beneficial for children with a variety of physical disabilities because it develops better muscle tone, as well as improved left and right coordination. The goal of this project was to develop a stationary tricycle that could be used by a physical therapist working in an elementary school, during therapy exercises. The final design is a stationary tricycle that attaches to a classroom chair via a clamping system, and that adjusts to accommodate children of differing sizes and disabilities.

SUMMARY OF IMPACT
The client coordinator, commented, “as a pediatric physical therapist, I have longed for a therapy tool that would enable my preschool patients to work on reciprocal pedaling. The problem is that many physically-challenged children lack trunk strength and balance to sit on a standard tricycle while concurrently pedaling. There was no existing product that allowed pediatric patients to sit in a supported seat while practicing pedaling. Creation of this device will, without question, have impact on physically challenged children I interact with. It expands the repertoire of movement experiences I can offer these children to promote motor development. Best of all, it is colorful, stable and fun. It is a clinician’s dream to offer children a therapeutic activity that is also fun.”

TECHNICAL DESCRIPTION
The main body of the Stationary Tricycle (Fig. 7.17) was adapted from the front of a commercial tricycle that was designed for toddlers, and had a mechanism to adjust the seat-to-wheel distance.

A custom wheel mount lifts the front wheel off the ground so it rotates freely while the child pedals, providing interest and motivation for the child. The mount is constructed of 1” thick solid oak that is painted red. Rubber on the bottom, and on the interface between the mount and the tricycle, prevents slippage.

The chair attachment system (Fig. 7.17) securely attaches the tricycle to a classroom chair, and provides both vertical and horizontal adjustment to accommodate children of various sizes. The system consists of four separate components: the horizontal adjustment, the vertical adjustment, the hinge component, and the clamping system.

The horizontal and vertical adjustment tubes have a series of holes to allow for length adjustments using lock pins, which are attached with lanyards so that they will not be misplaced. The distance from the seat to the pedal is altered using the horizontal adjustment, which also serves as the connection between the tricycle and the chair attachment. The distance from the handlebars to the seat is altered by the vertical attachment. The angle at which the aforementioned pieces are connected changes the angle of the handlebars, which moves them closer or further from the child.

The hinge component serves as the connection between the adjustment pieces and the clamping system. It provides 180-degree rotation to accommodate both vertical and slanted chair legs. The clamping system consists of two metal slabs, which are pulled together by a screw and knob mechanism.

A bookstand, which was adapted from a collapsible music stand, attaches to the front of the tricycle with a threaded ring clamping system and knobbled screws. The physical therapist can place a book on the stand and have the client pretend to ride to different places pictured in the book. This provides added motivation for the client. The bookstand can also be easily removed when not needed. The pedals were adapted from commercial wheelchair pedals by painting them red and attaching foot cups to help children keep their feet engaged. Two
different size foot cups are included, and they are large enough to accommodate a child’s feet, with his or her shoes on.

The cost of parts was approximately $150.

Figure 7.17. Stationary Tricycle.
CHAPTER 8
MICHIGAN TECHNOLOGICAL UNIVERSITY

College of Engineering
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ADJUSTABLE MOUNTING DEVICE FOR READING

Designers: Cris Braganza, Stephanie Deziel, Nathan Leatherman, and Megan Schaller
Client Coordinators: Kathy Penegore and Joan Pavlowich, Copper Country Intermediate School District
Supervising Professor: David A. Nelson, PhD.
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INTRODUCTION
A child with a progressive motor disease and severe visual impairment, who uses a wheelchair, requires a device to allow him to read on his own. The student must be able to adjust the device so that he can read easily with proper posture. The reading surface has three degrees of freedom so that the student will have proper posture when reading. The device (Figure 8.1) is freestanding and portable so that the weight of the device is transmitted to the ground instead of the wheelchair.

SUMMARY OF IMPACT
Prior to using the device, the student had hunched posture while reading books. The device will help the client immensely by helping him maintain an erect posture, as shown in Fig. 8.2. The strain in his neck will be greatly reduced due to better posture, and the lighting source on the device will allow him to read at night. The adjustability of the device will allow for the reading of books of different shapes and sizes, and will also allow the device to adjust to the client as he grows.

TECHNICAL DESCRIPTION
Fig. 8.3 shows a three-dimensional schematic of the adjustable mounting device along with side and front view drawings. The device can be separated into three sub-assemble parts: 1) the base; 2) the telescoping poles; and 3) the box, which contains the control system and reading surface.

The base of the device was constructed from steel tubing and fits underneath the client’s wheelchair. Swiveling wheels were attached to the base to allow easy movement. A counterweight was added to the base to prevent tipping during storage. During use, the device is attached the wheelchair.

Two telescoping poles equipped with linear actuators were used to provide motion in the horizontal and vertical planes. The poles are made out of an aluminum rod and aluminum tube, which
move with respect to each other. Teflon bushings were added to decrease the friction and to prevent the aluminum from binding. The linear actuators (Motion systems) have a stroke of eight inches for the vertical plane and a stroke of four inches for the horizontal plane.

The telescoping poles were welded to the aluminum frame of the box and reading surface. The reading surface is 20 inches wide and 16 inches tall so that the client is able to read material of various sizes.

The box has an aluminum frame and panes of Plexiglas®. Plexiglas® was used because it is clear and will not obstruct the student’s line of sight. A linear actuator with a stroke of 12 inches was placed inside a channel attached to the reading surface to enable angular motion of the reading surface. The reading surface can achieve a maximum angle of approximately 80 degrees.

The total cost of parts is approximately $1250.

Figure 8.3. Drawings of Final Design.
CAUSE AND EFFECT LEARNING ENCLOSURE

Designers: Bethany Hemphill, Rhyan Hongisto, and Amanda Läde
Client Coordinators: Lisa Sporbert, Copper Country Intermediate School District (CCISD)
Supervising Professor: David A. Nelson, Ph.D
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INTRODUCTION
Cause and effect learning is fostered in a client classroom for children with multiple physical and cognitive disabilities. This classroom currently uses cordless switches, receivers, and a control box for cause and effect learning. When a button is pressed, the signal is transmitted to the receiver to activate a device that is receiving power from the control box. The students learn that when the button is pressed (cause), the item of interest is activated (effect). The school requested that the system be improved to decrease set-up time, reduce the number of battery changes and prevent the students from tampering with the controls. The device also must be accessible to students who use wheelchairs.

SUMMARY OF IMPACT
This device will aid the classroom instructors by reducing the time they spend setting up and maintaining the individual control systems. With the new device, set-up time is five minutes, compared to 20 minutes with the individual components. It is expected to help engage the students’ interests, since multiple devices can now be selected. All students in the classroom are now able to use the device, and the instructor will be creating a learning station so that the device can be used at any time by any student.

TECHNICAL DESCRIPTION
The final design incorporates two sub-systems, as shown in Fig. 8.4. The Transmitting system contains three switches (seen on the bottom of Fig. 8.4). The Power and Receiving system incorporates the control units and receivers (seen on the top of Fig. 8.4). The two sub-systems can be independently positioned so that all students in the classroom can utilize the device. A polycarbonate enclosure was constructed to house each sub-system to limit the students’ access to the vital controls of each system. The enclosures have snap-on lids which can be removed by the teacher for easy access to the interior to allow for battery changes and control adjustments.

The Transmitting system contains three Cordless Big Switches (AbleNet, Minnesota) that were rewired to one rechargeable battery source. The 9-volt battery connectors in the switch were wired in parallel to a single 9.6-volt rechargeable RC battery. This rewiring eliminated three batteries, allowing for simpler battery changes and longer periods of use between changes. The switches were placed in the polycarbonate enclosure and a lighted on/off switch was added to the outside of the enclosure to turn the switch module on and off.

The Power and Receiving system contain two PowerLink units (AbleNet, Minnesota) and the receivers for the Cordless Big Switches. The receivers were converted to AC power by cutting the wires leading to the battery housing, and reconnecting them to a 1/8” panel mount jack. Three 1/8” mono plugs were wired parallel, inserted into each receiver and wired to an AC/DC converter to complete the conversion to AC power. A single power strip provides power to the two PowerLink units and AC/DC converter. Then the

Figure 8.4. Cause and Effect Learning System.
entire Power and Receiving system was placed into the polycarbonate enclosure.

The finished device is able to transmit and receive signals when the subsystems are separated by up to 20 feet. This is an improvement over the Cordless Big Switches as received from the manufacturer. Initial testing showed that signals were able to be received and transmitted up to nine feet. It is possible that increased amperage is being transmitted to the receivers, which may cause a circuit in the receiver to overheat and malfunction at some point in the future. The device is able to activate one item of interest at a time. The classroom teacher desired to have multiple items activated at once, but this is not currently possible. Despite these weaknesses, the device meets all requirements of the teacher utilizing the device, and will be used extensively in the next school year.

The total cost for parts for the device is $820. Additionally, two PowerLink units (AbleNet, Minnesota) and three cordless Big Switches and Receivers (AbleNet, Minnesota) were purchased by the client for an additional cost of $90.
ASSISTED BALL THROWSING DEVICE

Designers: Megan Ballard, Miranda Fry, Brandee McMichael, Erin Sturgell
Client Coordinator: Traci Steele, Gwinn High School
Supervising Professor: Dr. David A. Nelson, PhD
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INTRODUCTION

Students with multiple physical and cognitive disabilities would like to participate in ball throwing activities in gym class. While there are ball throwing devices on the market, these are designed specifically for one type of ball, such as a tennis ball or baseball. These devices are also not controlled with switches that the students are able to operate. The goal was to design a device that could throw multiple types of balls for the students at the push of a button. A picture of the final device is shown in Fig. 8.5.

SUMMARY OF IMPACT

When introduced to the device, the students showed enjoyment at being able to throw a ball. The device allows the opportunity for students with physical disabilities the ability to participate in games with their peers, and gives them opportunities for more positive feedback from their fellow students. There were, however, requests for improvements such as decreasing the weight and allowing for throwing angle adjustments. The device fulfilled the original requirements. Future work will address these new needs.

TECHNICAL DESCRIPTION

The throwing mechanism of the machine consists of two vertically aligned wheels placed one above the other, as shown in Fig. 8.6. The wheels are powered by two identical motors that are held by upper and lower motor mounts. The lower mount is stationary and the upper mount is held in place by two support rods and an acme threaded rod. This can be turned by means of a hand crank to raise and lower the upper wheel to accommodate different sized balls. The speed of the motors is adjustable through the control panel, which also contains the power switch for the motors. Power to operate the motors is provided via a 12 volt rechargeable battery connected to the control panel.

A chute and gate, shown in Fig. 8.7, feed the ball into the throwing mechanism. The chute consists of polycarbonate sheets placed in a v shape that slants down from the ball entrance to the throwing wheels. The gate mechanism consists of an aluminum gate attached to the bottom motor mount’s anchoring plate. This gate is held at an angle of approximately 15 degree angle from the horizontal by a spring and acts to stop the ball at the base of the chute. The gate is lowered by means of two solenoids: one pulls up on the end of the gate and a second pulls down on the opposite side. This gate mechanism is triggered by pushing the large yellow button that completes the circuit connecting the battery to the solenoids. The device is reset by the action of the spring once the button is released, cutting off power to the solenoids. A wiring diagram for these components is shown in Fig. 8.8. When the gate is lowered, the
ball is fed by gravity into the throwing mechanism which, when powered, launches the ball.

The entire device is anchored to an aluminum base plate and enclosed by polycarbonate at the side the ball enters and Plexiglas on the other three sides and top, as shown in Fig. 8.9. This enclosure is held in place by aluminum framework with plastic connectors. Two wheels located on the bottom of the frame, and a handle on the enclosure (not shown) permit easy movement of the device to the desired location. The battery is held in a toolbox that is bolted to the base. Holes in the toolbox permit the wiring for the control panel, motors and solenoid to pass through.

A drawing of the entire design with portions of the enclosure removed is shown in Fig. 8.9. It performs as required with the ability to throw balls ranging in size from a tennis ball to a basketball at ten different speeds. The gate functions could be improved by making it stronger and less likely to stick. The adjustable throwing mechanism works well, but the enclosure protecting the device should be adjusted to allow slightly larger balls to pass through and have increased strength to avoid cracking during use.

Figure 8.6. Drawing of Throwing Mechanism.

Figure 8.7 Drawing of the chute.
Figure 8.8. Circuit Diagram for Solenoids

Figure 8.9. Enclosure diagram

Figure 8.10. Diagram of entire device without outer housing so that detail is shown.
CHAPTER 9
NORTH CAROLINA STATE UNIVERSITY

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INTRODUCTION
An adjustable chair was requested by the client for an 18-month-old child with cerebral palsy. Overall, the goal was to allow the child to be more interactive with other children while being comfortably supported. The chair was to: (1) have a range of motion of two feet; (2) support the head, legs, and torso; (3) support a weight of 30-100 lbs.; (4) have a tilting tray; (5) roll easily along carpet, wood, and grass surfaces; (6) have adjustable straps; (7) be comfortable for the child; and (8) be easy to use and safe for the faculty and children. The center in which it will be used currently has several chairs that are insufficient in terms of support, comfort, and mobility. The proposed solution should overcome these limitations.

SUMMARY OF IMPACT
One of the most important design considerations for the adjustable chair (Fig. 9.1) was to enable the child to interact better with peers in various settings and for longer periods of time. This is the reason that having a wide range of motion available was so important to the design. The chair was designed to support the head, legs, and torso. Furthermore, the adjustable straps and large capacity for weight will allow the chair to grow with the child. A tilting tray was important because it accommodates the lack of muscle control in the neck and varying line of vision. The tray design makes it easy for a child to view, and concentrate on, materials placed on the tray. All-terrain wheels were necessary so that the child would not be limited to indoor activities. As a result, the child can now safely experience all kinds of environments, including the sandy playground. Before this new design, children at the center were limited to 15-minute intervals in the existing seating devices.

TECHNICAL DESCRIPTION
The frame of the chair was constructed from one-inch square steel tubing and subsequently covered with pipe insulation to ensure safety. To achieve a range of motion from the floor to two feet, drawer sliders were attached to the seat frame. Additionally, a pulley and winch system was secured to the back of the chair frame to make raising and lowering of the chair safe and simple. A plastic cover was placed over the winch to prevent injuries. Leg rests were fabricated to keep the child’s legs in proper position through the entire range of motion. The tray has five different positions within a range of 0 to 60 degrees.

The total cost for parts and labor of the adjustable chair was approximately $560.
Figure 9.1. Adjustable Chair.
INTRODUCTION
The Pony Walker™ is a device that promotes and assists walking in children with developmental disabilities. This device provides vertical support for the child, who is not strong enough to place full weight on his legs and is unable to balance. The Pony Walker™ is commonly used for children with cerebral palsy. For this specific project, the clients’ grandchild has cerebral palsy and uses a Pony Walker™ frequently. However, even with using the pony walker, he is not yet strong enough to initiate walking movements alone. Therefore, his caretakers must push or pull him while he is in the Pony Walker™. Currently, the Pony Walker™ does not have a handle, which places the caretakers at high risk for developing back injury because they must bend over to push or pull the Pony Walker™. The problem is exacerbated in this child’s case because his caretakers are elderly.

The goal of this project was to design an attachable handle that would be: (1) safe; (2) strong; (3) lightweight; and (4) easy to manufacture. In the initial stage of the design process a team of three parties were included to ensure a clear understanding of the problem: the two grandparents; and a contact person at the Charlie Gaddy Center. The team decided that the best approach would be to modify an existing handle made for the Pony Walker™ that is sold as a separate component. The handle fit the team’s requirements with respect to weight and strength, however it was made to attach to the back of the Pony Walker™ as opposed to the front. This design did not coincide with the grandparents’ original request to have the handle placed on the front. The modification entailed altering the handle so that it could be attached to the front as well as the back.

SUMMARY OF IMPACT
The clients stated that having a handle attached to the Pony Walker™ saves their backs from added stress. Having a handle allows for easier navigation of the Pony Walker™ and gives them more control of the device without having to exert more force when pushing or pulling. This modification to the device will help the child initiate walking movements (by moving his feet and legs) because the clients will be more likely to use it. The clients conveyed their desire to assist the child while maintaining eye contact in order to enhance the child’s motivation for walking. Furthermore, they wished to maintain a position that allows them to see if the child’s feet start to drag. Frontal placement of the handle addresses their needs. Rear placement would make falling over obstacles less likely by allowing the clients to have a clear line of sight which promotes the safety of the child and the clients. Having a handle that can be attached to the front or back allows the user to assess all risks and benefits of handle placement and decide which location is best suited to their needs.

TECHNICAL DESCRIPTION
The first step in manufacturing the device was to purchase a handle from the Snug Seat® company. The most important design constraints were the ability of the handle to interchange locations between the front and back of the Pony Walker™ and a design modification that would not interfere with the warranty of the walker. The only way to avoid voiding the warranty was to make a design that would not require any direct modification to the Pony Walker™ itself. Modification began by cutting the handle off the original mounting base. The modification to the mounting base that allowed for maximum stability and met the design constraints was the addition of a channel with a lip (see Fig. 9.2).
The channel was made to fit over the center bar of the Pony Walker™ (see Fig. 9.3).

The lip, which was a critical component of the channel, acted to prevent rotational movement. The center bar of the Pony Walker™ was held tight against the inside of the channel by a threaded knob. Strips of adhesive backed plastic were attached to the inside of the channel and to the bar of the Pony Walker™ to prevent wear of the bar by the ends of the threaded knob and channel. The final product consisted of five parts (see Fig. 9.4) with a total cost of $186.

Figure 9.2. Channel Design with a Lip.

Figure 9.3. Mounting location of handle.

Figure 9.4. Pony Walker™ with handle attachment.
INTRODUCTION
The client requested the construction of a multipurpose game board to support bowling, shuffleboard, and a putting green for senior citizens in an adult daycare facility. The client requested it to be 12 feet long by 30 inches wide, and have the ability to fold to fit into a storage space. The client also requested that it have wheels to provide easy movement. There are systems for bowling or shuffleboard, but not bowling, shuffleboard, and golf altogether. Most of the existing systems also did not have wheels or folding capabilities.

SUMMARY OF IMPACT
This project is designed to keep elderly people physically active during their activity time in the adult care facility. The project will also improve the adults’ hand and eye coordination from playing the three different activities available: bowling, golf, and shuffleboard. It is easy to set up and store. The design is lightweight and allows the 12-foot board to fold up to six feet, which is convenient for storing purposes. The wheels assist in taking the portable game system in and out of the storage area. Therefore, the adults can effortlessly take out the board and fold it down to start playing the games. It will be a great addition to the daily activities of the adults at the facility.

TECHNICAL DESCRIPTION
To create an acceptable design, several factors had to be considered. Weight was a main concern, as the existing equipment was very heavy and cumbersome. Wood was used to construct the frame of the board with a layer of Formica on top to make the surface smooth for bowling and shuffleboard. Two by four braces were placed on the underside of the board to provide support for the surface. Instead of gutters for bowling, bumpers were put on the sides to keep the ball on the board. This was done to save space and keep the design light. Cove molding was placed at the juncture of the bumpers and the Formica for aesthetic reasons. The board was made to fold once in the middle, bringing the final height to approximately six feet. When the board is lying flat, the middle is lifted upwards until the two sides meet. Four wheels were mounted on the bumpers so that, when the board folds up, the wheels are on the four corners of the game system. The outside of the board was painted green, and red dots were placed on the Formica for bowling pin placement. Styrofoam was glued to a putting surface to make the putting green insert. A box was made to be placed at the end of the game board. The holes for the putting surface are there, and it is also used to catch the bowling ball and the shuffleboard disc when they reach the end of the board. The design works well to give the staff at the adult care facility an easier and more compact way to use and store the games.

The approximate cost of the Portable Game System was $600.
Figure 9.5. Photo of Portable Game System.
ASSISTIVE SEATBELT DEVICE

Designers: Brian Patnode, Daniel Reames, and Preston Watkins
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INTRODUCTION
An assistive seatbelt device was designed to aid persons who are obese or have cerebral palsy to fasten their seatbelt with little or no difficulty. Limited fine motor skills, poor coordination, and low vision prevent some people from placing the belt latch into the standard receptacle. This device was designed to act as a funnel to help latch the belts. A secondary problem was that the back seat receptacles were poorly supported causing more of a problem with latching than the front seat receptacles. A device was designed that can attach to the funnel portion of the assistive device and support the receptacles in the back. Existing seatbelt apparatuses do not provide a large enough area to insert the latch, nor do they typically provide support for receptacles in the rear seating areas. This is the first device to incorporate an extended funnel design to aid in the fastening of seatbelts.

SUMMARY OF IMPACT
This design helps persons with certain physical disabilities to fasten their seatbelt with ease and confidence. This will result in safer passengers because more people will be buckling their seatbelts. This design will also result in a more independent person who will no longer have to be aided by someone else when buckling his or her seatbelt. Traveling may become easier and more enjoyable for those persons who previously had trouble fastening their seatbelts.

TECHNICAL DESCRIPTION
The assistive seatbelt device is constructed primarily of a plastic material known as Aquaplast®. This material is traditionally used for splinting and needs to be placed in water heated at 170°F to become moldable. A wooden model of the funnel was constructed for use in molding the plastic material. Mounting sleeves were then stitched by hand using a sewing awl. Two-inch webbing was stitched together forming a pocket for the mounting arms of the funnel to slide in to. Hook and loop Velcro® was then placed on both ends of the sleeves to provide easy attachment and adjustability. This harness allows for universality of the design product.

In order to attach the device onto nearly any top release seatbelt receptacle, the arms of the funnel must first be inserted into the sleeves on the harness. Once the funnel and the harness are working together as a single unit, the funnel can be positioned over the receptacle, and the straps of the harness can be fastened around the body of the receptacle. For back seat installation where the receptacle is not supported, the final piece can be inserted into the harness for support. It slides into the rear part of the device from the bottom and the other end of the support slides in between the top and bottom portions of the rear seat. Once the device is set up properly, an easily accessed funnel provides guidance into the receptacle while the support provides stability for the entire receptacle (See Fig. 9.6).

The approximate cost of the Assistive Seatbelt project was $130.
Figure 9.6. Assistive Seatbelt Device.
INTRODUCTION
The client is a five-year-old boy who has been diagnosed with sensory integration dysfunction (SID). SID is a pediatric neurological disorder that is manifested by difficulty in processing sensation from the environment. He was in need of equipment at his home to help him gain more stimulation from his environment. The client attempts to gain sensory input from his surroundings, often leading to hyperactivity. The goal of the project was to create equipment to develop the child’s perspective and vestibular systems. He likes the sensation of being up high and tries to satisfy this need by jumping on his bed. The project incorporated the client’s need into a sensory center where many different activities were available to him. His bed was lofted in order to give the positive feeling for the client of being up high and so that he could jump into a pile of foam pillows. Under the bed was a quiet place for the client to swing back and forth, play in beans, draw on a whiteboard with scented markers, and listen to music. In addition, an outdoor rock-climbing wall was constructed to give the client a sense of being elevated and allow him to sharpen his motor skills and strength. Existing solutions for SID include attendance at occupational therapy and smaller-order sensory devices.

SUMMARY OF IMPACT
The client will be exposed to therapeutic equipment on a more regular basis as opposed to only once per week at occupational therapy. By being able to participate in activities to supplement his therapy, the child has a greater opportunity to develop his proprioceptive and vestibular systems more quickly. As his body adapts and he learns more, the client should be able to attend school with minimal difficulties. The provided equipment will aid the parents of the child as well. The parents found it difficult to calm the child at times that were necessary, such as bedtime. The equipment will allow the child to be both excited and calmed during the appropriate time, which meets the parents’ needs and avoiding conflict with the child. The project will be useful for the child for as long as he needs therapy.

The main design consideration was the length of the loft railing. The group designed it so that it could be removed during the daytime to allow the child to jump down onto the pillows and reattached at night while he slept. The railing was made to be less than half the length of the bed because the child was 42” in length and the group decided that protection of his upper body was sufficient in the event of a fall. Upon delivery of the project, the father of the child showed appreciation by stating, “He is enjoying and exploring his new loft and rock wall. He loves jumping off onto the pillows, playing with the car rug, and practicing his writing on the white board while sitting in the bean pit.”

TECHNICAL DESCRIPTION
The main structure of the indoor sensory center was a loft constructed of non-treated lumber. It is 52” tall, 81” long, and 40” wide. The loft is tall enough so that the client can stand up beneath it, but it is low enough to the ground to allow the client to sit up in the bed and to safely jump down onto the large pillows. A removable safety railing is built to sit on the edge of the mattress frame of the loft. The back of the loft is supported by two diagonal cross-braces. Horizontal boards at each end of the loft serves as supports and as steps. At one end of the loft, the stairs are covered with carpet. The four upper corners of the loft, where the mattress frame attaches to the leg posts, are supported by small diagonal supports. Privacy curtains were made and hung from tension rods around the perimeter of the loft underneath the mattress frame. A hammock
swing was made using heavy-duty canvas fabric and rope and was hung underneath the loft structure from one corner to the middle of the other side of the loft. A dry-erase drawing board was mounted to the back of the steps. A pocket organizer curtain was hung near the drawing board. Next to this organizer was a set of small shelves. These shelves, along with a compact radio/CD/cassette player, comprised the music center. A 35-gallon plastic container, with lid, was filled with 125 pounds of dried pinto beans. This bean “bucket” provided therapeutic body pressure when the client sat down in the beans.

The outdoor rock-climbing wall, measuring 86” tall and 60” wide, was constructed of treated lumber (see Fig. 9.7). Exterior paint combined with sand was applied to the wood to give it a rock-like appearance and texture. Rock climbing holds of various types and sizes, which were donated by a local rock-climbing facility, were secured to the wall. The rock wall was hung at the client’s home using eight adequately sized galvanized carriage bolts.

The approximate cost of this project is $680.

Figure 9.7. Outdoor Rock-Climbing Wall.
INTRODUCTION

Children with motor learning disabilities and visual impairments have special requirements in toy function. The idea of a sensory toy is to incorporate multiple senses to stimulate learning and motor activity and to develop a sense of empowerment. To combine various senses into one device, sights, sounds, and textures were implemented into a simple pushbutton design as requested by the client. The toy is geared towards children between the ages of one and five years old. Visuals are clear and contrasting in color. Sounds are pleasant and evoke positive emotions, and textures are varied and encourage exploration. The buttons are designed so that they must be pushed with one finger, furthering motor hand-eye coordination.

SUMMARY OF IMPACT

The device challenges children with sensory disabilities to control their actions by holding down a button to elicit a response. They learn that each button relays a different response and that buttons can be combined together to receive multiple responses. The toy can be easily cleaned and is movable, allowing easy set-up and maintenance for supervisors. The size of the toy allows children to play with it on the floor, tabletop, or trays. The power button allows adults to control the use of toy, and the toy can be easily recharged via the charger that is connectable at the back.

TECHNICAL DESCRIPTION

The main body of the toy is made of 3/8” PVC plastic (Fig. 9.8). The plastic sheet was cut, and the enclosure was constructed using a PVC welding process. The electrical workings are diagrammed in Fig. 9.9 below. The circuit board is housed in a project box affixed to the bottom of the toy, and button circuitry is attached to the underside of the top of the toy. A wire ribbon connects the two circuit boards. The top of the toy is secured using screws. Artistic designs were created using a variety of fabrics, paper, and decorations. The design is very simple and easy to construct. The materials are all readily available and easily machined.

The schematic was analyzed to ensure that none of the components is overloaded during application. All the resistors are quarter watt resistors. The power through each resistor is well below one-fourth watt. The current and voltage through each of the components were also calculated to ensure that the toy runs at a low current and is not a shock hazard.

The approximate cost of all materials was $523.
Figure 9.9. Schematic of Sensory Toy.
INTRODUCTION
This device was created for a young boy with cerebral palsy. He is nonverbal, has limited use of his hands and legs, and uses a wheelchair. He is home-schooled and uses a Vanguard computer system to communicate and learn language. The Vanguard system is connected to the Tracker 2000, which acts as a sensor. As he moves his head, the Tracker receives a signal from a special sensory metallic dot placed on his forehead. The signal is sent to Vanguard, which then verbally expresses the client’s desires.

The project was to determine a solution that would allow the client to temporarily disable the Tracker so that he could accomplish other tasks, such as using the computer, watching television, or socializing. Previously, the Tracker system created a disturbance when the client wished to take momentary breaks from his system because it continuously signals Vanguard even if the client does not want to communicate.

SUMMARY OF IMPACT
This modification of the Tracker 2000 allows the client to connect with those around him more effectively by giving him additional control over his environment. It gives him the ability to turn his communication system on or off without having to rely on a caretaker.

TECHNICAL DESCRIPTION
A radio-signaling device was developed to allow manual joystick control of a black flag to block the sensory input to the Tracker. The entire device is battery operated, and both the power to the device and the functionality can be controlled. After considering many other designs, this solution was selected as the most efficient due to the minimal amount of external wiring and the relative ease of use.
back and forth, the cover will go up and down thus allowing the client to control the Vanguard.

The cost of the parts and materials was about $340.

Figure 9.10. Tracker 2000 Device.
HAND BRAKE CONTROLS FOR TRACTOR

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INTRODUCTION
The client is a man with paraplegia who needed a hand-controlled brake for his John Deere 4100 tractor. Since he has the use of his upper body only, he has been limited to controlling the tractor by use of the forward and reverse travel pedals, for which he had installed a mechanical linkage. This arrangement was suitable for most of his activities on the tractor, but he requested a braking mechanism in order to shift gears while traveling uphill, and to serve as an extra safety measure. The client was adamant that the control not be obviously visible to others, such that any addition should be in a form that looked similar to existing controls. Also, he wanted the tractor to be able to be driven in a typical fashion by any other user.

Although there are several existing designs for hand controls, there was not one that met the client’s needs. A shaft mounted over the brake pedal with a lever rotating about it could be used to depress the brake pedal, but this would be both obvious to a viewer and interfere with normal usage of the pedal. More complex systems, such as the fingertip braking mechanism, would have been difficult to complete within the project’s timeline.

Because of the client’s previous modifications to the tractor, combined with the cumbersome clutter of original controls, there was little room to install a rigid mechanical linkage. Therefore, a cable was selected. One end of the cable was attached to a brake lever mounted on the fender of the tractor, while the other end was connected to a metal rod. This rod was welded to a plate, which was clamped to the shaft about which the brake pedal rotates.

SUMMARY OF IMPACT
This project will help increase the client’s independence and personal productivity. Having this hand brake system for his tractor allows the client to safely operate his tractor in low and high gears on his home property, which has hilly land environment that demands the full use of his tractor’s capabilities. Without this feature, the client would have had limited use of his tractor. The client states “it’s great to have the ability to safely shift from low to high range.” Most importantly, this project empowers the client to be more active in his daily life. By extending him the capability to use another component of his tractor, this project has helped his day-to-day productivity.

TECHNICAL DESCRIPTION
In order to rotate the brake shaft of the tractor, the brake cable must be connected to the shaft. To accomplish this, a clamp was manufactured. The design of the clamp consists of two U-shackle clamps welded to a rectangular steel plate (see Fig. 9.11). Four holes were drilled through the steel plate to fit the shackle screws. A steel cylinder was welded to the bottom piece of the steel block at the center. The sides of the steel cylinder were flattened half way from the bottom, and five holes were drilled from the side so the brake cable could be attached to the clamp. A handle was needed in order to control the brake cable. The brake cable had to be attached to the handle at the position above its pivot point so that a pulling action would result in a pulling of the brake cable. To do this, a small hole was drilled through the lever arm so that the cable could be attached. The brake handle was mounted on the fender of the tractor by bolting it to the frame. A steel plate was bolted between the handle mount and the fender to create additional stability. The brake cable was secured to the underside of the tractor using metal U-shaped electrical conduits. The conduits were placed over the cable and bolted to the fender and the underside of the tractor. Furthermore, additional mounting
brackets were placed at each end of the brake cable to hold the cable tightly in place.

The manufactured parts were modeled using the Pro/Engineer graphic design software. These drawings were used to communicate the design ideas to the research shop for manufacture. To determine the amount of torque required to turn the brake shaft, the amount of force needed to activate an existing brake pedal attached to the shaft was measured. Then the length of the pedal for the radius of the moment was measured. Dividing the force value of 50 pounds by the radius value of one foot gives an estimation of 50 ft-lb of torque needed to rotate the shaft. To ensure there was no bending in the fabricated metal clamp, stress calculations were used to estimate a correct thickness. Using a safety factor of three, a necessary plate thickness of one centimeter was calculated. These calculations give the amount of force the device would need to supply and ensured that the design would not fail under the given loadings.

The approximate cost of all materials and outside labor was $523.

Figure 9.11. Clamp for Tractor Brake.
INTRODUCTION
A client with cerebral palsy who uses a wheelchair had difficulty maneuvering around his workplace, a plant nursery where the terrain is level, but mainly mulch. Small obstacles, such as garden hoses and tools, often lay in his path. While in his wheelchair, the wheels often sunk into the mulch and made it impossible for him to propel himself around the workplace. In order to move at work, co-workers needed to push or pull him, often a tedious and time consuming experience.

The available solutions that had previously been considered all involved motorized wheelchairs of some sort. While a motorized wheelchair would improve the client’s mobility and allow him to travel independently around the worksite, it would also be less cost efficient and would disrupt the terrain of the nursery. Additionally, the client was adamant about being able to power himself in the wheelchair.

To cater to the client’s requests and the problem’s demands, the client’s previous wheelchair was modified. Changes were made to the width and type of the wheels and to the handle used when others push or pull the wheelchair. The major modification, however, was in designing a more efficient way for the client to transfer his pushing power to the wheels.

SUMMARY OF IMPACT
The final modified wheelchair should greatly improve the quality of life of the client, especially at the workplace. Previously, he was limited to working with the direct assistance of his co-workers and was relatively immobile under his own power. Because of his inability to move around the worksite, his actions were limited to what he could do while sitting behind a table, stationary for hours at a time. Because of the large amount of effort necessary for others to move the wheelchair in the mulch, each transporting activity (arriving, departing, bathroom trips, etc.) took significant amounts of time away from his workday.

After implementation of the modified wheelchair, the client should be able to maneuver himself around the mulch worksite using his own power to fuel the wheelchair’s movements. This will not only free up the work time of his co-workers, but also enable him to work more hours during the week. The increased mobility and decreased dependence on co-workers at the worksite will also enable the client to assume more job responsibilities, such as plant watering or fertilizing. Increasing his work opportunities at the nursery will also contribute to his ability to work more often during the week.

The most important effect of the modified wheelchair, however, will be the improvement in the client’s quality of life. The solution not only allows the client to accomplish more work and become more independent of others, he will also adhere to his requirement that a motorized apparatus not be part of the solution. By extending his independence, the wheelchair will allow him to enjoy working and gain more personally from positively contributing to his workplace.

TECHNICAL DESCRIPTION
The old wheelchair that the client allowed to be modified was a Quickie II model, with serial #Q2-0201635. The first modification made to the wheelchair was the replacement of the standard narrow wheels and tires. All-Star Bike Shop (Raleigh, NC) was consulted and custom-made wheels and tires were ordered from The Aftermarket Group (Beltsville, MD) with 24” x 2.125” dimensions (the standard wheels were 24” x 1 3/8”), aluminum handrails, and ½” bearings for quick release axles. These tires were not only wider
than the original tires, but were also air-filled (the standard tires had a hard rubber core) and had knobbier tread. Since the replacement tires were wider, it allowed for an increased surface area to be in contact with the ground, reducing the average force per area of contact with the ground. With less pressure under each tire in the mulch setting, the effect was that the replacement tires sunk significantly less than the originals, and maneuvering was now possible with relative ease.

Although larger tires were a significant improvement, there were no elementary changes in the design of the original wheels. An additional device was then designed which modified the method of applying force to turn the wheels. Large handles were manufactured out of 1” square aluminum tubing. The handles were designed so that they would attach and pivot at the axle. Brass door holders (sku # 196721) purchased from Lowe’s Home Improvement (Cary, NC) were then attached and positioned to act as pawls. With this design, each push of the handles would transfer a force to the outside of the tire via the door holders. The torque applied to the wheel is equal to the force applied times the distance away from the axle that the force is applied. With this design, not only was the torque increased due to the increased distance (height the handles were held vs. the radius of the tire), but the amount of force applied was also increased (pushing handles at chest height vs. pushing handles at wheel height). In addition, a U-shaped push handle made of out 9/10” cylindrical steel tubing was attached to the original push handles to reduce the amount of force required to push the client. By increasing the distance between the axle and where someone could push the wheelchair, the movement was increased, which would thereby decrease the amount of force needed to push the wheelchair.

The total cost of this modified wheelchair project was $630.
CHAPTER 10
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INTRODUCTION
The proximity switch allows persons with physical disabilities to activate a button without physical contact. The device is designed to be 1) portable, 2) small, 3) easy to use, and 4) reasonably priced. Most switch-operated devices are compatible with, and easily adapted to, the proximity switch. The proximity switch operates as a momentary, or latching style, switch to fit a necessary application. Changing between the two settings is accomplished by changing a jumper setting inside the button enclosure.

There are several similar no-touch buttons available. Some are operated using a photo eye and, when the light in the room changes, the button needs to be recalibrated. The new design allows the user to control the device in a hidden manner by placing it under a bed tray, table, or almost any other material up to 1.5" thick. This causes the button to operate more safely in situations where the user or button could be harmed. The switch has adjustable sensitivity which can be set for a switch activation of 0.75" away, down to a firm touch on the button's surface.

SUMMARY OF IMPACT
The button allows for an effortless way for clients to use items in their daily life, thus improving the overall quality of life for the user. Practically any switch-operated piece of equipment can be modified to work with the button. The dimensions of the proximity switch are approximately 4" in diameter by 1" thick. The device is simple to attach to a modified piece of equipment.

A completed device, shown in Fig. 10.1, is currently in use by the client coordinator. He has expressed satisfaction with the device and feels that the button will help improve the lives of many people. He is currently using several of the devices and plans to incorporate more into his facility.

TECHNICAL DESCRIPTION
As shown in Fig. 10.2, the proximity switch is composed of five component blocks: 1) a proximity chip, 2) a button touch pad, 3) a relay, 4) an output jack, and 5) power.

The heart of the device is the QT140, a proximity chip made by Quantum. The chip is responsible for sensing a near touch and activating the output. The chip operates by sending repeated groups of five volt pulses, at 10 MHz, to the button pad. It then senses the variation in the signal which causes a change in output. The change occurs when the body is close to the touch pad surface; it essentially acts as a grounding source. When the chip determines a valid switch it activates a five volt on the output pin, which drives the solid state relay. The solid state relay activates the equipment by closing the loop.

A standard 9-volt battery powers the entire system. The button has a power switch to turn the button on and off as it is needed. There is also a jumper accessed through the battery cover, which allows for the changing of momentary to latch style switching.
The device has moderate production difficulty, with the designed system cost of about $45 per unit. This price is significantly less than comparable products.

Figure 10.2. System Block Diagram.
INTERACTIVE PUPPET STAGE

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INTRODUCTION
The existing puppet stage of a center’s for children with disabilities is improperly suited for the needs of the children who attend class there. It is not interactive and does not provide wheelchair access. The client center wants a puppet stage that can accommodate one or two wheelchairs and also provide sound and light stimulation for the students.

SUMMARY OF IMPACT
The new puppet stage allows more interaction for children with limited movement of their entire bodies. The two important senses of sight and sound are stimulated with flashing light emitting diodes (LEDs) and programmable sound effects. The new stage allows multiple puppeteers and audience selection of puppets. The goal of better interaction between the children and the stage is met with the new stage. The completed puppet stage is shown in Fig. 10.3.

TECHNICAL DESCRIPTION
As shown in Fig. 10.4, the stage consists of four component blocks: 1) microprocessor; 2) light system; 3) sounds system; and 4) interface controls. Additionally, the entire system is powered by a 120 volt AC to 5 volt DC converter.

The brain of the stage is the PIC16F876A microcontroller chip. The chip controls the blinking lights and sound chip. When a user pushes one of three buttons, light control signals are sent from the PIC to 8-bit serial to parallel shift register (74HC595). Sixteen modular printed circuit boards are cascaded to provide 128 LED light outputs. Each modular board contains eight LEDs: two red, two blue, two green, and two yellow. The shift registers are connected to three pins on the PIC. Each of the boards is connected in series to produce various light patterns and effects.

Aside from controlling the 128 LEDs, the PIC16F876A also controls sound effects. On start-up, the PIC checks to see if the stage is in record or playback mode. A toggle switch on the outside of the stage determines record or playback, which is controlled by the teacher. If the stage is in record mode, the student chooses one of three buttons to record one of three messages. When the button is pressed and held, the chipcorder (ISD2560) records through an attached microphone circuit. Releasing the button ends recording. In playback mode, students press buttons to select and play from three available recordings.

The ISD2560 Chipcorder is capable of recording 60 seconds of sound. The 10 address pins on the chip can be configured to start playback or record at 600 locations. This design divides the 60 seconds of sound up into three equal lengths of 20 seconds. If button one is pressed, the chip begins record or play at 0 seconds. If button two is pressed, playback or record begins at 20 seconds. If button three is pressed, playback or record begins at 40 seconds. There is a possibility that if a sound is longer than 20 seconds it can record over the next sound. In order to eliminate this from happening, the PIC only...
allows a user to record for 20 seconds. When a signal is recorded an end of message bit is placed. When playback begins for this sound the chipcorder will play until it sees the end of message. To obtain the best quality of sound, the highest sampling frequency of 8 kHz is used.

The total cost for the stage was $834.00. Major costs include professional manufacture of 16 printed circuit boards and 128 high output LEDs. The stage frame was donated.

Figure 10.4. System Block Diagram.
WIRELESS INTERCOM SYSTEM

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INTRODUCTION
The wireless intercom system is designed to provide a direct communication link between two adjacent SVEE rehabilitation homes. The motivation for designing the intercom system is to allow convenient communication between any two of five devices or between all the devices using a broadcast feature.

SUMMARY OF IMPACT
The client requested a simple interface to accommodate all users. The units are designed with very few buttons and low interface complexity; this way any user can learn how to use the device in a short amount of time. The intercom system is a cost effective and relatively easy to use solution that meets client requirements for point to point or broadcast communication.

TECHNICAL DESCRIPTION
The central building block of the system is a PIC microprocessor, as illustrated in Fig. 10.5. Its high versatility allows flexibility in the design and operation of the unit; it also has a simple instruction set, easy-to-use USART, and A/D capabilities for sampling and sending vocal information.

The system is a bi-directional, half duplex, wireless intercom, such that it can communicate between the houses. Each Linx transceiver unit comes FCC pre-certified and with an approximate transmission range of 150 feet. The intercom units are built using in-house fabricated printed circuit boards which are encased in custom built Plexiglas enclosures. Address and talk buttons, volume control, exposed speaker, microphone slots, and LED indicators are on the front of the enclosure, as shown in Fig. 10.6. The back of the case is removable to facilitate repairs or replacements. The system is powered by a 120Vac to 5Vdc wall converter, and plugs into a jack on the lower right side of the case.

The unit is designed to allow private talking between two units or broadcasting to all units. By pressing the intended address button (1, 2, 3, 4, or broadcast,) the system sends out an identification byte. The receiving units decode the byte. If the address byte does not match, the unit disregards all audio processing and turns on an “in use” display.
LED. If the address byte does match, the unit turns on an “in use” LED, decodes the incoming audio data, and sends it to the speaker.

A software compounding technique is implemented to achieve an acceptable sampling rate for the given system transceiver bandwidth. The compounding encoder is a binary logarithmic scheme used to sample and then transmit two samples per byte. The scheme works by taking an 8-bit sample and assigning it a 4-bit number logarithmically spaced from a DC offset value. After a second sample is encoded, the two 4-bit data samples are concatenated and sent out as a single byte, exemplified in Fig. 10.7. The receiving side then takes each 4-bit number and recovers an approximate 8-bit value. Because data transmission is digital, the system acts as a simple information encryption scheme for privacy where only the proper software decoder is able to properly decrypt the information.

The total cost of parts and materials per unit is $148.13.

Figure 10.7. Data Flow Block Diagram.
INTRODUCTION

When a muscle contracts, blood volume in the muscle is reduced. Additionally, oxygen is needed to fuel a contraction, so changes in the amount of oxygen present can also indicate a muscle contraction. These principles of muscle contractions are the basis of a system designed to control a prosthetic device.

SUMMARY OF IMPACT

This project demonstrates that low-cost optical-based sensors can control a prosthetic arm. Further research is needed to develop an improved method of incorporating a control system from the LabVIEW program used for this project. LabVIEW provides a researcher with an algorithm that can be easily modified during the research process. Once the control algorithm has been fully developed, LabVIEW can be replaced with a small, low-cost microprocessor. With further research, this project can provide a user with a stable, reliable, and low-cost method to control a prosthetic device.

TECHNICAL DESCRIPTION

Fig. 10.8 presents the block diagram for the overall system. The project uses optical sensors to detect muscle contractions for the control of a robotic arm. Red- (660nm wavelength) and infrared- (870nm wavelength) light emitting diodes (LEDs), along with a photo-Darlington transistor, were used to detect muscle contractions. The wavelengths chosen are well suited for determining changes in blood volume and oxygen content.

Fiber optics are placed on the skin and then connected to the LEDs. When a contraction or extension of the muscle occurs, different intensities of light are reflected back from the muscle and into the fiber optic. A voltage is created across the photo-Darlington transistor as a result of the light that it detects. The voltage is sent through an amplifier and then filtered to increase the signal and reduce noise. Fig. 10.9 shows a schematic of the sensing unit.

Digital processing is accomplished using LabVIEW, a computer software program. LabVIEW is used to analyze and manipulate the signal input sent into the computer through a data acquisition (DAQ) card. LabVIEW is chosen for research flexibility but will be later replaced by a low-cost embedded microprocessor.

LabVIEW takes samples of the input analog signal to produce a sampled waveform. The program looks for a change in the voltage signal to determine if a contraction or extension has occurred. If the voltage level crosses a certain threshold, an output signal is sent to the robot. It continues sending the ‘on’ signal until the threshold level is crossed again.

Every person is different and has different contraction strengths based on the muscle being observed. Muscle fatigue plays a role in the contraction strengths observed. When a muscle is fatigued, a smaller threshold level is needed because the strength of a contraction is less. The threshold levels can be manually changed on the LabVIEW front panel to meet the requirements of the specific user.

The outputs from the LabVIEW program are then sent to an H-bridge IC. The H-bridge is a simple, reversible drive circuit. Using the two outputs from Labview, the circuit’s logic allows for forward, reverse, stationary and braking motion of the motors. The H-bridge circuit is shown in Fig. 10.10.

The robotic arm, OWI-007, has five DC servo motors that control five different axes of motion. These motions include: 1) hand gripper; 2) wrist rotation; 3) elbow bending; 4) shoulder bending; and 5) base rotation. These motions are similar to the motions a prosthetic arm requires. For this project, only the first three motors mentioned are used.
For three sensing units, H-bridge IC and a robotic arm, the total cost is approximately $160.00. The LabVIEW license and PC cost several thousand dollars, but are not required for a final commercial device.

Figure 10.8. System Block Diagram.

Figure 10.9. Sensing Unit Schematic.

Figure 10.10. H-bridge Circuit.
INTRODUCTION
The Hands-Free Seatbelt system is designed for a person who lacks the upper body mobility necessary to fasten a conventional automotive restraint system. The newly-designed system allows the user to operate a lap belt by using his feet to control the tightness and looseness of the belt. A motor, controlled by a lighted paddle switch, drives the seatbelt spool. A 12V battery powers the system and is recharged by the automobile’s power through the power port. In an emergency, a solenoid may be activated by a push button disengaging the seatbelt on the right side. An original equipment inertial locking mechanism locks the seatbelt spool providing the stopping force in the event of a collision. Fig. 10.11 displays the complete system.

SUMMARY OF IMPACT
After years of searching, the client is very excited to finally be secured in a seatbelt while at the wheel of an automobile. The client is now better protected during vehicle operation and is able to comply with existing seatbelt regulations. Although this system is intended for a specific client, the design is universal and can be utilized by a larger group of individuals.

TECHNICAL DESCRIPTION
A system block diagram is given in Fig. 10.12. The central block is the printed circuit board (PCB), which consists of the motor directional control relays, emergency release solenoid relay, and the battery maintenance circuit. Connections to the PCB include: 1) power from the vehicle power port which supplies power to the charging circuit; 2) the emergency release solenoid relay; 3) the seatbelt spool drive motor; 4) the battery, which is the main source of power for the system; 5) a momentary pushbutton that activates the emergency release mechanism; and 6) a paddle-style toggle switch that controls the direction of the spool.

The battery charger circuit is biased, using resistors, to have a steady 13.5 V in the float state which is recommended by the battery manufacturer and a 14.5 maximum charge voltage. The maximum charge current is 3.6 Amps, and 2N1038 transistors limit the current to approximately 1.4 Amps.

The development cost of the hands-free seatbelt system is approximately $750. Much of that cost is
required to meet safety concerns. The system would be considerably less expensive without components such as the solenoid, which activates the seatbelt release in an emergency, and the battery, which is present in case of power failure.

![System Block Diagram](Image)

Figure 10.12. System Block Diagram.
INTRODUCTION
The Wireless Volleyball Scoreboard is designed specifically for a local Special Olympics tournament to reduce the number of tournament officials required at the volleyball matches. By creating a wireless remote controlled scoring system, the need for an off-court scoring official is eliminated. This device is designed to allow multiple units to function simultaneously in the confines of a gymnasium or sports arena. Additionally, the device is designed to be portable, durable, and easy to use.

Although similar commercially available scoring systems do exist, these products are typically expensive and are not designed for specific use as a volleyball scoring system. Thus, the new device offers significant advantages over existing devices.

SUMMARY OF IMPACT
By reducing the number of volunteers required to officiate volleyball matches, the Special Olympics’ volleyball tournament coordinators can better serve its participants. At 18” x 12” x 8”, the device is small enough to be portable yet large enough to be easily read. Because the device is powered by batteries, it poses no safety risks due to power cords. A very simple, yet attractive, design allows for easy operation and promotes device usage. Additionally, the display unit is designed to work with multiple remote units in the event of a lost or damaged remote, which further ensures the durability of the entire unit.

TECHNICAL DESCRIPTION
The Wireless Volleyball Scoreboard is composed of two devices: a handheld (remote) unit and a display (scoreboard) unit. Fig. 10.15 shows the block diagram for each device.

The user interface at the remote unit consists of four buttons: increment home score, decrement home score, increment away score, and decrement away score. Resetting the score is achieved by simultaneously pressing both decrement buttons.

When one of these buttons is pushed on the remote unit, the processor sees a low-to-high transition on a corresponding input pin, triggering a series of internal commands at the processor ending with a signal being sent from the processor to the transceiver. The processor’s universal asynchronous receiver transmitter (UART) registers then transmits the signal through a transceiver to the scoreboard unit. The information transmitted includes a “barker” to alert the scoreboard unit that a message is coming, an address number unique to the remote unit which sent the data, a byte indicating which
button was pushed, and a checksum byte for error checking. Fig. 10.13 shows a graphical representation of the transmitted data signal.

The user input at the scoreboard unit duplicates the four buttons on the remote unit. Additionally, three two-position dip switches are also included. The dip switches are used to match the scoreboard unit to the remote unit’s address (the address of the remote unit is set in software). The processor on the scoreboard unit receives input either from the user input buttons on the scoreboard or from the transceiver. The buttons on the display unit operate identically to the buttons on the remote unit; when one of the buttons is pushed, the processor sees a change on one of its input pins and changes the score according to which button was pushed. When the processor receives a signal from the transceiver through the processor’s UART register, the processor first checks the address to ensure the data is from the correct remote unit. Next, the error checking byte is analyzed to ensure no errors have occurred in transmission. Finally, the byte identifying which button was pushed at the remote unit is received, and the processor updates the display accordingly.

The display at the scoreboard is comprised of four seven-segment numbers; each segment consists of five light emitting diodes (LEDs). Four eight-bit shift registers with output latches are used to control transistor circuits which drive the LEDs. The two shift registers that control the home and away scores are connected in series such that data is input through the first shift register to the second. Through the processor’s serial peripheral interface (SPI) two eight-bit numbers are output, one after the other, to both the home and away scores simultaneously. The score is updated by updating the latches of either the home or away shift registers separately.

The remote unit is powered by two size AA batteries and the scoreboard unit is powered by six size D batteries. When the units are not in use, switches are available to power down both units. Fig. 10.14 shows the completed system.

The overall cost of the device with minimal production is approximately $400. With moderate production levels, the cost would drop substantially.
BOCCE BALL SCORING SYSTEM

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INTRODUCTION
The game of bocce ball is played all over the world and is enjoyed by people of all ages. To begin play, a target ball, called the palina, is thrown onto the playing field. Each team rolls four bocce balls in an attempt to get closest to the palina. At the end, the bocce ball closest to the palina ball scores a point for that team. Fig. 10.16 shows a typical bocce ball and the circuit board to be encased inside.

The bocce ball scoring system enables judges at the Special Olympics to determine which bocce ball is closer to the palina ball by using a wireless system. Following play, a hub unit is placed on the palina ball. When triggered, the hub communicates with the bocce ball to determine the winner. Once the winning ball has been determined, eight light emitting diodes (LEDs) on the winning bocce ball are illuminated.

SUMMARY OF IMPACT
The bocce ball scoring system accelerates and simplifies the judging process. The scoring system provides volunteers of the Special Olympics with an efficient and reasonably accurate method to determine a bocce ball winner. The device correctly determines the winning ball approximately 95 percent of the time. System accuracy may be improved with additional system testing and calibration. The addition of flashing lights to indicate a winner adds a new level of excitement and participation to the game.

Representatives from the Special Olympics are enthusiastic about the design concept, eager to continue system testing, and willing to continue cooperative development. In researching prior designs, no similar systems appear to exist.

TECHNICAL DESCRIPTION
The bocce ball scoring system has three primary design requirements: 1) the hardware must fit inside the 107 mm bocce balls; 2) alterations must not affect the trajectory of the bocce balls; and 3) the hub should fit into or over the 57 mm palina ball. Custom circuit boards fit within the bocce balls and surface-mount components to help conserve space. Due to the smaller size of the palina ball, hub hardware needs to be placed over the palina ball once it is played onto the field.

All scoring operations are controlled by the hub, a block diagram of which is shown in Fig. 10.17. Hub operations are controlled by a PIC 16F876 microcontroller. To begin, the hub sends a message using a LINX radio frequency (RF) transmitter to clear timing counters at each of the bocce balls. Next, the hub produces a 3.5kHz audio sound. Given the relatively slow propagation of sound in air, nearby bocce balls detect the tone earlier than distant bocce balls. Once the tone is detected, individual bocce balls stop their timing counters and wait for the hub to request information.

Once sufficient time has elapsed for all bocce balls to detect the tone, the hub individually polls each ball requesting their counter values. All information is again transmitted using the LINX RF transceivers.

Figure 10.16. Bocce Ball and Circuit Board.
Once all bocce balls have reported their counters, the hub determines the nearest ball by finding the smallest counter value. Lastly, the hub communicates to the winning bocce ball and instructs the winner to illuminate its LEDs.

Fig. 10.18 presents the block diagram of the bocce ball circuitry. Again, operations are controlled using a PIC microprocessor. The microphone, amplifier, and band-pass filter circuitry are used to detect the 3.5kHz audio tone generated by the hub. A LINX transceiver, identical to the hub’s transceiver, is used for RF communication.

The cost of the completed system is approximately $850, which includes circuitry for the hub and eight bocce balls.
INTRODUCTION
This in-room security system (IRSS) is designed to provide notification to group home staff members when a person with special needs attempts to leave his quarters without permission. The IRSS provides a non-intrusive means of monitoring a client with special supervision needs. It is the goal of the client group home to provide its residents with an environment that is as comfortable and non-disruptive as possible. Since loud alarms are disruptive to residents, the silent alarm of the IRSS appeals to the group home.

SUMMARY OF IMPACT
The design criteria for the IRSS were defined by the client contacts and caregivers. The primary requirements were that the system be: 1) capable of alerting caregivers; 2) non-intrusive; and 3) mobile. Some residents of the home require constant one-to-one supervision from a caregiver. Since it is not realistic to dedicate a staff member to one resident for the entire day, it is necessary to assign a resident to what is called in-room time, during which the resident is not permitted to leave his room. With the IRSS, a caregiver can adequately monitor the special needs resident while tending to other residents’ needs. With the tendency of some residents to cause disruption by initiating an alarm state purposely, the silent alarm of the IRSS is well-suited for the application.

TECHNICAL DESCRIPTION
The IRSS consists of four independent units including two sensors, a base station, and a pager. The units communicate wirelessly to make the system easily relocated. The system’s block diagram is shown in Fig. 10.20. When one of the magnetic sensors is activated, either by a door or window being opened, the corresponding sensor unit transmits to the base station. In the event that the sensor unit is activated, the corresponding sensor unit transmits to the base station. In the event that the base station is not reset in less than one minute, the base station sounds a backup audio alarm. When the pager receives the signal, it activates a vibrating motor to alert the caregiver.

In the sensor units, magnetic switches are used to activate the sensor circuits when either the door or window opens. Each sensor circuit is composed of a PIC microcontroller, a transmitter, and an antenna. The microcontroller continually checks to see if the sensor is activated. Once an open door or window is detected, it transmits a signal to the base station and pager units. Linx transmitters and antennae are used for modulation and transmission from the sensors. Four AAA batteries supply power for each sensor unit.

In the base station unit, Linx transmitters and antennae are again used, as well as Linx receivers for demodulation of incoming signals. A PIC microcontroller processes incoming signals and generates outputs. An AC/DC converter supplies power to the base station. The unit requires 5V DC, which is stepped down from a 120V AC wall-outlet.

In the pager unit, the same wireless components and microcontroller are utilized. The pager is powered by three AAA batteries. A voltage divider circuit is used to convert the 4.5V battery supply to the 2.6V (1.3V per motor) required by the vibrating motor.
Resistor values are chosen to ensure that the motors’ 130mA rating is not exceeded. A toggle switch is present in the pager to conserve battery life, since the microcontroller draws current whenever the unit is powered. The finished unit is shown in Figure 10.19.

The total cost of parts and material for the entire system is approximately $700.

Figure 10.20. System Block Diagram.
INTRODUCTION
The wander alert system allows greater freedom of movement for residents of a local group home, while still monitoring their location. This system tracks the location of a person, and reports back necessary information. When the person walks outside of a given range, an alert is sent. The administrators at the home are alerted by a discreet pager-like device. The tracking device uses GPS to monitor the individual, and a wireless transmission system to send information.

There are current commercial devices that operate using the same principles as this device but they are designed to cover a larger area and use satellites to transmit information. While effective, these systems are expensive and incur monthly charges.

SUMMARY OF IMPACT
The wander alert system assists the staff and residents of the SVEE home in a comfortable and reliable way. The homes do not have the time or the staffing to watch individuals as they walk every day. If an individual walks away from the home while using the wander alert system, this information is quickly sent to the administrator. An early alert reduces the time taken to search for a lost or missing resident. The system can be worn at all times, is portable, and does not hinder the wearer. The wander alert system frees the administrators from worry, and opens more time for other tasks.

TECHNICAL DESCRIPTION
The wander alert system is a two part system: 1) the tracking system; and 2) the alert system. As is seen in Fig. 10.21, both components are portable, operate independently, and communicate using a radio link.

The Global Positioning System (GPS) tracking system is based on the LassenSQ chip made by Trimble Navigation Limited. This chip connects to

Figure 10.21. Wander Alert System Block Diagram.
an embedded antenna made by Trimble, and receives and decodes the GPS data. The Lassen SQ is chosen due to its small size, and relatively low cost. The data from this chip is sent over a serial data line at 9600 baud using the Trimble Standard Interface Protocol to a Microchip processor.

A PIC16F876 processor receives the serial data from the GPS and translates the information. It determines if the user is in or out of the set boundaries. The PIC controls the transmitter and sends information serially at 2400 baud to a radio transmitter. There are three different codes that can be sent by the tracking device: 1) in range; 2) out of range; and 3) no GPS signal. When coordinates are available, the in range and out of range signals are sent once every three seconds. The code for no GPS signal is sent when the updates from the GPS have not contained coordinates for approximately 15 seconds. This signal helps determine when the connection between transmitter and receiver is working.

A Linx TXM-433-LC is used to communicate with the receiver system. This single chip transmitter only requires power, input, and an antenna to operate. It sends data at rates up to 5000 baud. This chip is designed to fit within Part 15 specifications of the FCC rules and transmit 300’ or more. A one-quarter wavelength loop type antenna is used for its good directionality and small size.

Each component in the transmitter is picked for low power usage. The batteries selected are all AA rechargeable with an output of 1.2 volts. With all components at full power, the transmitting system’s batteries last at least 9 hours.

The alert unit is also designed to be portable and reliable. The receiver is the Linx RXM-433-LC, which complements the TXM-433-LC. It has similar specifications and requires only a power connection and antenna to operate. The receiving antenna is identical to the transmitting antenna.

The data received by the receiver is sent to a PIC16F876 processor. At startup, an LED displays the state being unknown. This state does not change until data is received from the tracking system. When an out of range, in range, or unknown signal is received, the corresponding LED is lit. The processor also monitors the time since last signal reception. When approximately 45 seconds have passed, it is assumed that the tracker is out of range, and an LED is lit.

Each component on the alert system is designed for extended use. At maximum power, the receiving system’s batteries last more than 36 hours.

The total cost for parts is approximately $140.
INTRODUCTION
The goal of this project is to aid people who are blind with certain everyday tasks through the use of an autonomous vehicle. For jobs such as delivering a package, throwing away trash or putting a dinner plate on a table, these individuals use techniques such as counting steps or guide sticks.

SUMMARY OF IMPACT
The autonomous vehicle can guide a blind person around his or her environment or deliver an item from one point to another. The autonomous vehicle is designed to search for a predetermined object, navigate to that object, and drop a package at that destination. The design, while not yet refined for real world use, lays the foundation for practical future development.

TECHNICAL DESCRIPTION
As shown in Fig. 10.22, there are five main blocks that play a role in the functionality of this robot vehicle: 1) vision system; 2) sensor system; 3) locomotion system; 4) power system; and 5) central processing system.

The vision system is controlled by a laptop and a camera. The camera acquires a picture which is saved on the hard drive of the laptop. Image processing techniques such as contrast enhancement and edge detection are calculated to discriminate changes of light or color. In order to recognize the target, recursive functions implemented in C detect the desired target. The pattern recognition techniques are size, rotation and distance invariant. Once the correct image is detected, the robot vehicle will drive to that object. This program runs from a laptop, which communicates with the camera through a USB port.

The sensor system involves the implementation of an ultrasonic sonar ranger. Transducers are used for collision avoidance, collision detection and surrounding area mapping. The microprocessor-
controlled ultrasonic ranger is attached to the front of the robot to calculate the distance between the robot and any object with a range between approximately 29 centimeters to five meters. The propagation time of the pulse and speed of sound are then used to calculate the proximity of any object with respect to the transducers.

The case, wheels, and motors provide locomotion for the vehicle. Two stepper motors (8V DC, 2 A) allow the vehicle to rotate at any angle and move forward or backwards. The overall dimensions of the vehicle are 79 cm x 35 cm x 60 cm (length, width, and height respectively).

The power supply is comprised of two 12V batteries connected in parallel. These 12 ampere-hour batteries provide ample voltage and current for the vehicle. Voltage regulators provide the regulated 5V and 8V levels needed to power the LED and TTL components.

The total cost of the autonomous vehicle not including the laptop is $743.
CHAPTER 11
SAN DIEGO STATE UNIVERSITY

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INTRODUCTION
A track and trolley system was designed for the B’Quest, a racing sailboat. The mechanical track (rail) system will be used to shuttle crewmembers who are quadriplegic and paraplegic around a circuit to each watch station in the cockpit. These watch stations include port and starboard jib sheeting winch, port and starboard mainsheet trimmer, navigator, and helm positions. The existing seats (shown in Figs. 11.2 and 11.3) will be mounted onto the rolling and rotating trolleys. A full-scale mock-up of the cockpit and aft decking has been constructed in order to test, evaluate, and modify the device before installation on the B’Quest. The mock-up is capable of being tilted at up to +35 to simulate maximum expected “heel,” or roll angle, while sailing “close hauled” (as far into the wind as possible).

SUMMARY OF IMPACT
The complete assemblage of track, trolley, and motorized drive mechanism (the latter described in the following article) will allow individuals who are paraplegic and quadriplegic to move from watch station to watch station without leaving their seats. This innovation will greatly increase both safety and comfort for all members of the crew.

During rough weather, the possibility exists that a crewman will be injured or even hurled overboard while changing positions. The new system will reduce this possibility, since the only time a crew member will be out of his or her seat will be when he or she is moving from the cabin, up the companionway, and into a seat immediately adjacent to the companionway, or returning to the cabin.

TECHNICAL DESCRIPTION
Goals and Constraints
Design decisions were based on the following goals and constraints:

1. The highest part of trolley must be no more than 3” above the deck on which it is mounted.

2. The traveler (mechanism on which seat rides) must negotiate helm arch, which adds 12” of elevation to the seat. The 62” width of the arch will include concave and convex radii, which the travel plate and bogeys must negotiate without interference.

3. The seat must rotate so that crewmembers can position themselves optimally with respect to duty stations. In particular, the seat must be properly positioned in relation to the foresail winch.

4. The seat must be held securely to the boat under at 35° of heel against dynamic loads of at least 500 lbs. The safety factor must be at least 3.0.

5. The apparatus must be corrosion-resistant and appropriate for a marine environment.

6. The apparatus must not have sharp projections or protrusions, which could either injure a sailor falling against them on a pitching deck or snare lines.

Tubular Track and Archway
The tracks (Fig. 11.1) are made of 1” tubing, since tubing can be easily bent and, with proper material selection, can exhibit high strength and stiffness while being relatively light. The arched track at the rear of the cockpit behind the helm (Figs. 11.1 and 11.3) has a 62” span with no support from the deck underneath it. Moreover, the helmsman and seat trolley weigh up to 250 lbs and can exert up to twice this force on the arch, as well as large twisting...
moments, due to pitching and heeling of the boat in rough seas. Therefore, the arch was designed with high safety factors. Each of the two tube rails is connected to two support tubes by welded gussets to form a truss with a right triangle cross-section (Fig. 11.3). The 9” spacing between the trusses accommodates the motorized drive mechanism and third tube rail along which the drive translates.

The 3” height restriction required that the rails be mounted as close to the deck as possible and still allow clearance for under-gripping vertical rollers. It was decided to weld stainless steel rails directly to 3/16” thick stainless steel mounting strips.

**Breakaway (Drop-Down) Track Section**

The breakaway section adjacent to the companionway at the front of the cockpit (see Figs. 11.1 and 11.2) gives crewmembers a clear pathway to get below deck without tripping over the rails. The ends of the tubes are slotted, and they mate with slots in the fixed rails. The breakaway section is secured by telescoping pins that engage the fixed rails. When dropped down, this track section is only 1¼” high.

**Trolleys and Bogeys**

The bogeys have both horizontal and vertical rollers to retain the trolleys on the track, even when the boat is pitching and rolling (Figs. 11.4 and 11.5). In order to meet the tight height requirement, the bogeys were recessed into the trolley plate as far as possible. The bogeys are retained in the travel plate by capture rings which mount on the bottom surface of the plate. In order to negotiate turns, the circular sockets in the base plate for the outboard bogeys were extended into ovals, allowing the bogeys to remain centered on the rails (Fig. 11.4). In order to more securely retain the trolleys on the track, stainless steel washers will be welded to the heads of the vertical shaft bolts for the side wheels (Fig. 11.5).

The base plate includes a front “wing” with a series of ½” holes spaced 15° apart (Fig. 11.4). This allows the rotating plate, which directly supports the chair frame, to rotate over a + or - 45° range. In order to lock the rotating plate into each position, a toggle device was designed to fit under the front lip of the travel plate (Fig. 11.6). It is essential that any device at this location not have protrusions of any kind, which would injure crewmembers’ legs, or snag clothing or lines. A spring-loaded throw-bolt rides on a ramp which, when pushed in one direction disengages the bolt from the rotating plate, and, when pushed in the other direction, allows the bolt to re-engage. A knotted cord operates the bolt, which is led through the holes in the chassis to the front of the travel plate. In this way, there are no parts extending into “sailor-space”.

The rotating plate is mounted to the travel plate by a 1.25” bolt within a Delrin-AF bushing (Fig. 11.4). The rotating plate is separated from the travel plate by a 1/16” thick Delrin-AF gasket that reduces friction for easy seat rotation. The bogeys are similarly isolated and supported by Delrin bushings and disks.

We determined that the concave radius in a 12” helm arch would create interference (Fig. 11.3), so the height of the arch was reduced to 9”, with consent of the client. The final design barely exceeds the 3” height requirement, as the total height to the rotating plate top surface is 3.125”.

Rail pairs are located 10” apart center to center. Turning radii are 5” and 15” at the stern and 10”, and 20” forward. Fitting prospective templates to the deck surfaces of the sailboat and finding the best fit for attaining the proper duty stations determined these dimensions. Model travelers were constructed to define the best compromise between bogey spacing on the traveler, and workable turning radius. During design iterations, the bogey spacing on the traveler had to be decreased in the side-to-side dimension from 10” to 7.5” in order to accommodate the turning radii.

**Brake**

A mechanical brake under the trolley base plate (Fig. 11.9) is used to slow or stop the seat trolley when the boat is pitching or rolling. The brake is similar to a bicycle brake, although it is significantly stronger, since it must exert at least 600 lbs of clamping force to generate enough friction to stop a trolley rolling down a 35° incline at maximum heel. Stainless steel springs press the rubber brake pads against the tube rail. The brake is normally engaged, and is released by a hand lever via a sheathed cable (Fig. 11.10) with a mechanical advantage of 30:1, meaning the crewmember must exert only 20 lbs force on the handle. The brake can be held open by a retaining pin which can be quickly released by tugging on a lanyard, to quickly arrest a runaway trolley. All
parts will be made of 304 rolled stainless cold, except for the brake pads.

**Materials**
The harsh conditions of exposure to the elements and seawater dictated that all components be corrosion proof. Hastelloy C-276, stainless steel alloys 304 and 316L, and Super Duplex (Zeron 100) stainless steel were considered. Since the B’Quest is raced, all components must be as light as possible. Super Duplex is three times stronger than 316L and more resistant to seawater corrosion, and is less dense than the Hastelloy C-276. Super Duplex is the material best suited for this application due to its strength, corrosive resistance, and cost (approximately $5.00/foot). Therefore Super Duplex (Zeron 100) will be used for the tube rails of the actual on-board article, while the prototype rails will be made of alloy 316L to demonstrate proof of concept.

The bogey housing and press fit horizontal axle for the upper roller were machined from 316L stainless steel. The two vertical bolts (axles) for the side rollers and the bolts connecting the bogey assemblies to the base plate are stainless steel 304 bolts modified to design specifications. Although stainless steel 304 is not as corrosion resistant as 316L, the yield strength of 304 is 160,000 psi, three times that of 316L, which is sufficient to withstand the dynamics forces with a safety factor greater than 3.

Anodized aluminum alloy 6061-T6 was used for the seat mounting plates and toggle assembly (the toggle assembly releases, and locks together, the plates to allow rotation of the seat). Aluminum 6061 combines relatively high strength, good workability, and high resistance to corrosion, and readily accepts coatings.

Delrin AF was used for the large, low friction washer sandwiched between the aluminum rotating plate and base plate, as well as for the washers and bushings for the bogeys, rollers, and “king pin” about which the rotating plate spins. Delrin AF is an acetal resin with PTFE fluorocarbon fibers distributed throughout, giving it the characteristics of Teflon. It exhibits low moisture absorption, high stiffness, low coefficient of friction, and it is easy to machine adapt.

**On-Board Article Versus Prototype**
The on-board system will incorporate modifications stemming from testing the prototype. One change has already been planned. The prototype for dry land testing has tubular tracks made of thick-walled stainless steel alloy 304, because it was readily available and donated by Valley Metals in San Diego. However, weight is an important consideration for a racing sailboat, so the actual article that will be installed on the B’Quest will employ thin-walled, lighter and stronger, “super duplex” stainless steel tubing for the tracks.
Figure 11.1. Twin Tubular Track Mounted on Cockpit.

Figure 11.2. Drop-down Portion (yellow) of Motorized Drive.
Figure 11.3. Arched Truss behind Helm (left), Check for Interference between Tube Rails and Bogeys of Trolley over Convex (middle) and Concave (right) Truss Sections.

Figure 11.4. Trolley Underside with four Bogeys that Retain Trolley on Tracks (CAD Model, left; Prototype Hardware, right).

Figure 11.5. (Left) Trolley Close-up. (Right) Rotating Bogey Close-up (green).
Figure 11.6. (Right) Bogey Riding on a Track Rail. (Left) Lock Pin for Rotating Plate.

Figure 11.7. (Right) Trolley Underside with Brake. (Left) Trolley Underside with Brake and Brake Handle (cream & tan box).
CREW OVERBOARD RETRIEVAL SYSTEM

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INTRODUCTION
Currently, there is no known dual-purpose system that will take a person who uses a wheelchair from the dock to a boat, or a way to rescue a person who has fallen overboard. For small boats there is no efficient means of rescuing a person out of the ocean, a process that proves more difficult if that person does not have the full use of his legs and arms. The purpose of our design project is to simultaneously develop a reliable and efficient mechanical system that will do both the above tasks, and not compromise the sailing efficiency of the boat.

The design has three major divisions. The first is the arch davit that serve as the support system. The second sub-division is the turret that is capable of rotating 360 degrees, and sits on the turret mounting plate. The third major component is a square tubular beam seven feet in length. The beam supports the shuttle that is able to transverse the length of the beam.

The device is designed to mount on the aft section of a boat, and be controlled by mechanical winches that are mounted onto the arch davit. The entire device is purely mechanical, and designed to be operated by persons of limited upper body strength.

SUMMARY OF IMPACT
This system provides a method for people with limited upper body strength to safely board a boat and to rescue an overboard person. See Figures 11.8 and 11.9.

TECHNICAL DESCRIPTION
The arch davit is stainless steel tubing shaped in a form of an arch with lateral support trusses. The top of the arch davit has a mounting plate to support the turret system. The turret system consists of two thrust bearings, an upper and lower plate, and a v-belt drive system. A square tube assembly with a shuttle attaches to the turret. The arch davit had to be designed with the following constraints: 1) it had to be built on the aft section of the boat using existing mounting holes, keeping in mind that additional holes will have to be made; 2) the davit had to clear existing structures such as the main boom, the helm chair, and the stanchions; and 3) it had to be designed with 303 stainless steel, 1 1/2” outer diameter tubing with 1/4” thickness to support the loads.

The turret system involves two thrust bearings with the arch davit mounting plate between the two bearings. With this configuration, the upper and lower bearing share the load equally and provide for more surface area for the bearings. The upper plate rests on the upper thrust bearing so that it is free to rotate. The plate has a 2” hole bored through the center to allow for the path of the pulley lines. There is a dovetail c-channel mounted on the rear of the upper plate to allow for the securing of the square-beam cable. There are also two rabbit-ear flanges mounted on the front of the upper plate to provide the pivot for the square beam assembly. See Fig. 11.9.

The square-beam assembly is reinforced with a gusset that is welded on it to provide lateral support. Each side of the square tubing is 2 1/2’ with 1/8” thick walls. Attached to the beam is an eye-bolt that is 2’ from the end and is used for the support cable. The square tubing provides a surface for the shuttle to ride on as well as provides for a path for the pulley lines to run through. The square beam was designed to hold a 1,000 pound static load and a 400 pound repeated load.

The shuttle is a U-shaped assembly that rides along the top and bottom surfaces of the square tubing. The sides of the shuttle are reinforced with flanges to keep the U-shape from spreading. A pulley is mounted under the shuttle to provide for the movement of the retrieval hook.

The two winches used on this project are off the shelf items. A 1:1 gear ratio winch is used for moving
the shuttle laterally. And a 50:1 gear ratio winch is used to lift up to 1,000 pounds from the water. A flexible drive shaft, another off the shelf item, is used to rotate the turret mechanism.

Figure 11.8. Functional Mockup of Extended Gantry Crane.

Figure 11.9. Turret and Furling Mechanism Close-up.
CENTER PEDESTAL GRINDER FOR RACING SAILBOAT

Designers: Clayton Holmes, Leonardo Flores, and Phong Phan
Supervisors: Albert Nguyen and Dr. Karen May-Newman
Mechanical Engineering Department
San Diego State University
San Diego, CA 92182-1323

INTRODUCTION

Winches are ubiquitous on sailboats, used for hauling in and tensioning a variety of sail handling and control lines. Traditional winches use a crank handle mounted directly to the vertical axis of the drum. This configuration requires substantial trunk and lower body strength to power the lateral motions required of the handle. This motion can pose ergonomic challenges for able-bodied sailors, and can be nearly impossible for sailors with physical disabilities or lower body strength limitations.

An improved device provides a pair of cranks rotating around a horizontal axis, using an opposing motion, like bicycle pedals. This configuration, often known as a pedestal or “coffee grinder,” is commonly found on larger sailboats. Larger sails lead to higher control line tensions, and larger crews allow crew members to be dedicated primarily to winch grinding. Gearboxes provide multiple speeds, and allow the power to be directed to different winch drums.

The goal of this project was to design a winch pedestal that could be rotated for use by a crewmember sitting on either the port or starboard side of the cockpit of a 40’ racing boat. A design variation looked at the feasibility of a lower, foot operated version for those with upper-extremity limitations or amputation.

SUMMARY OF IMPACT

The center pedestal grinder provides a method for crew members with limited lower or upper body strength and mobility to perform the task of raising and adjusting the sails of a boat.

TECHNICAL DESCRIPTION

The center pedestal winch grinder employs a “coffee grinding” mechanism that is mounted in the center of the boat’s cockpit, and connected to winches on either side of the boat. The pedestal grinder is typically operated with both hands while in a standing or crouching position. The students’ design enables crewmembers in a seated position to effectively grind with a powerful, bicycle-like hand motion at chest level.

The key components of the prototype center pedestal consist of a commercial gearbox and a locking rotation mechanism. The handles attach to the side shafts of the gearbox, inside which three bevel gears convert the handle rotation around a horizontal axis into rotation of a vertical center shaft inside the pedestal. The bottom of the gearbox is attached to concentric cylindrical components that allow for rotational positioning of the handles for different crew positions. This rotation mechanism employs a locking pin to rigidly fix the position of the gearbox at various locations. The rotation base mounts atop the shaft pedestal and uses two aluminum plates to bolt to the deck. Within the pedestal, the drive shaft interfaces with a standard below-deck drive system.
Figure 11.10. Center Pedestal Grinder Prototype.

Figure 11.11. Gearbox and Rotating Mechanism Assembly Drawing.
WINCHTOP GRINDER FOR RACING SAILBOAT

Designers: Devin McNeil, Nee Lee, Matt Caronna and Ryan Moriarty
Supervisors: Albert Nguyen and Dr. Karen May-Newman
Mechanical Engineering Department
San Diego State University
San Diego, CA. 92182-1323

INTRODUCTION

A winch is a mechanism that contains a drum on which rope is coiled, and can be tightened with a crank or handle that allows easier adjusting or hoisting of sails. Traditional winches, ubiquitous on boats, rotate (grind) in a horizontal plane and are not easily operated by able-bodied sailors, much less sailors who may use wheelchairs, have amputations, or otherwise have limited upper or lower body strength. An improved device rotates in a vertical plane using an opposing motion like a bicycle crank, and allows users lacking lower body strength and flexibility to operate them. The goal of this project was to design a mechanical adapter to an existing (traditional) winch, converting the winch from a handle-cranking device (operated on a plane) to a vertical, bicycle hand-rotating motion. This winch-top grinder must be designed for strength, ease of attachment/detachment, and corrosion resistance. The grinder must also operate both forward and reverse, in order to utilize the two-speed gearing of the winch.

The Challenged America sailing program is modifying a Tripp 40 racing sailboat to accommodate a primarily disabled crew. This program is located in San Diego Bay and currently has over 100 members. The winch-top grinder will be used by several of the regular crew members during pleasure, and competitive, sailing.

SUMMARY OF IMPACT

The winch-top grinder provides a portable device for crew members with limited lower body strength to perform the task of raising and adjusting the sails of a boat.

TECHNICAL DESCRIPTION

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

The winch-top grinder consists of handles attached to a commercially available gearbox, which is connected to a winch via a drive shaft. The gearbox is cast aluminum (Motion Industries) containing bevel gears with two input and one output shafts. Couplings and connectors are designed to attach to the handles and drive shaft, which terminate in the star spline socket in the winch top. The winch-top grinder is designed to withstand 80 ft-lb of torque. Testing of the grinder demonstrated that it could be moved from an old to a new winch in less than 5 seconds. This design can be used in a variety of sailboats and for individuals with limited mobility, such as seniors, as well as crew members with disabilities.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gear box</td>
<td>$260</td>
</tr>
<tr>
<td>Aluminum plating</td>
<td>$15</td>
</tr>
<tr>
<td>Coupling</td>
<td>$10</td>
</tr>
<tr>
<td>Shaft Collar</td>
<td>$35</td>
</tr>
<tr>
<td>Keys</td>
<td>$3</td>
</tr>
<tr>
<td>Total</td>
<td>$323</td>
</tr>
</tbody>
</table>

The final estimated cost is approximately $1000
Figure 11.12. Winch-top grinder in use on a racing sailboat.

Figure 11.13. Winch-Top Grinder: Fabricated Prototype (left) and CAD Assembly Drawing (right).
INTRODUCTION
The purpose of this project was to create a motorized drive mechanism to be integrated into a track and trolley circuit for moving crew seats around the cockpit of a Tripp 40 sailboat, the B’Quest. The motorized drive mechanism functions only on the rear portion of the track circuit (behind the wheel). Its function is to propel crew seats, that are mounted on trolleys, over an arch in the track that exists to enable the helmsman to see over the cabin. Only one of four seat trolleys is latched to the drive mechanism at any given time, since only one seat is on the rear portion of the track (i.e., the helmsman’s position) at any given time.

The motorized drive mechanism latches onto the bottom of the seat trolleys and runs along a third tube rail between the two tube rails that support the seat trolleys. The drive system consists of four polymeric drive wheels mounted in a stainless steel chassis. Attached to the chassis is a 24V DC motor of sufficient power and torque to transport a sailor seated on a trolley over the rear arch (across the cockpit) in 10 seconds. A chain drive is used to transfer power from the motor to the drive wheels. This system is controlled via an umbilical switchbox attached to the sailor’s seat latched to the drive mechanism. The power for the motor is supplied by the existing 12V DC electrical system on the boat.

SUMMARY OF IMPACT
There currently is a motorized helm chair on the B’Quest that translates left and right (port and starboard) behind the wheel, but a sailor with physical disabilities must be carried to, or assisted into, the seat. Moreover, the current device has several flaws: it is heavy (a distinct impediment for a racing sailboat), draws too much electricity from the boat’s batteries, and is unreliable.

The new motorized drive system will correct these deficiencies, will interface with the track-and-trolley system (see the previous article), and propel a seated crewmember along the arch in the track behind the helm that allows the helmsman to see over the cabin.

TECHNICAL DESCRIPTION
The motorized drive mechanism is designed to propel a sailor (who is disabled or able-bodied) sitting in a chair trolley over a 9” high arch in the tubular track behind the helm of the B’Quest. This device had the following requirements: 1) must translate the crewman and seat (250 lbs total) from one side of the cockpit to the other in 10 seconds; 2) must use the existing 12-volt power supply on the boat (lead-acid marine batteries); 3) cannot have any pinch points or other hazards; and 4) must be rugged, weatherproof, and reliable.

The motorized drive mechanism is illustrated in Figs. 11.14 and 11.15 below. Its components are also described below.

Chassis
The chassis houses the other components and must withstand the 600 lb clamping force needed to generate enough friction (300 lb) to propel a sailor and seat trolley. The chassis consists of a length of 2”x 4”x 0.25” wall 316L Stainless Steel rectangular tube. Holes were machined for the bearings, and holes were drilled and tapped for the screws for the retaining plates. An angle bracket is used to mount the motor.

Rollers
The rollers are the interface between the axles and the center drive rail and are cast, or machined from, polyurethane rubber. The inner diameter of the rollers is undersized to minimize slippage with the axles. The outer diameters are oversized to provide the necessary clamping force on the drive rail.
Axles
The four axles transfer the clamping force from the polyurethane roller to the chassis and transmit power from the sprockets to the rollers. The axles are made of type 15-5 PH stainless steel, selected for its combination of corrosion resistance and superior yield strength of 145 kpsi, which far exceeds the 25.4 kpsi stress required to achieve the proper clamping force. The axles were turned to the appropriate diameters on a lathe. The larger diameter accommodates the rollers, and the smaller diameter slips into the bushings, bearings, and sprockets. The large diameter section has channels machined in it to grip the polyurethane wheels to prevent them from slipping. There are two flats on the axle for the set screws in the sprockets.

Bearings
The bearings are used to support the axles. The bearings used are ABEC 1, R6, 440C Stainless Steel, double sealed bearings. The bearings are held in place by the bushings and retaining plates. The bearings are rated for a 750 lbf load.

Bushings
The purpose of the eight bushings is to keep the drive wheels centered in the chassis. The bushings are made of Delrin®. The material was rejected due to the required diameter on a lathe and drilled to accept the axle. These keep the rollers in proper alignment and reduce friction losses without lubrication.

Retaining Plates
The two retaining plates are used to capture the bearings in the chassis. The original design did not call for the use of retaining plates; instead the bearings were to be pressed into the chassis. The change was made to make the device more serviceable. The revised design requires only a regular screwdriver to completely disassemble the chassis, axles, and bearings. The plates are made of 16 gauge 316L Stainless Steel. The plates were cut to size and the appropriate holes were drilled for the axles and screws.

Sprockets
The sprockets are used to transfer motive power from the chain to the axles. The sprockets are for an ANSI 35 chain and are made of 304 Stainless Steel. The sprockets were drilled and tapped for two set screws spaced 90° apart. Size 8-32, Stainless Steel, cup point set screws are used.

Chain
A roller chain is used to transfer power from the motor to the sprockets on the axles. The chain is an ANSI 35, 300 series Stainless Steel, roller chain rated for 1440 lbs of tension. The chain can be routed in such manner that all four wheels are driven with the addition of two more sprockets not shown in Figs. 11.14 and 11.15.

Motor/Gearhead
A DC motor is used to provide the motive effort. The power required has been calculated and a motor was sourced. Initially, traditional 12 VDC motors were examined for this application, but the size of these motors was a problem, since motors that met the power requirements were typically 11” long x 6” diameter. The motor selected was a model TG2300 DC brushless motor from Thin Gap Motors, capable of providing 70 in-oz of torque at 2000 rpm using a 24V supply.

The increase from 12 to 24 volts allows for a more compact motor. A step-up voltage converter, normally used for solar power applications, was chosen. At its peak torque this motor draws 7.5A. The motor is internally sealed, and its dimensions suit the application, 3½” long x 3” diameter. A gearbox with a 20:1 reduction will be obtained from CGI to achieve the required torque and speed.
Figure 11.14. Assembly View.

Figure 11.15. Exploded View.
CHAPTER 12
STATE UNIVERSITY OF NEW YORK AT STONY BROOK

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INTRODUCTION
The hand-powered tricycle is a vehicle for use in physical therapy and recreation for people who have limited lower-body strength. The objective was to create a vehicle that is fun to ride and gives people with disabilities the joy of riding a tricycle while providing encouragement for them to participate in physical therapy. This vehicle requires the rider to have moderated upper body strength and control.

SUMMARY OF IMPACT
The hand-powered tricycle is made primarily for people who have limited or no use of their legs. These individuals will only need to use their upper body to power and steer the vehicle.

TECHNICAL DESCRIPTION
The hand-powered tricycle is a fully mechanical system. It uses a system of cables for the steering mechanism and a frame-enclosed sprocket and chain to perform the driving function. The vehicle is powered when the rider performs a bench press motion. This motion drives the chain, which is attached at the lower section of the handlebars downtube, and is contained within the frame. This pushing motion pulls the chain that goes around the sprocket, which is attached to the rear wheel, and this creates a forward motion of the vehicle. The chain will freewheel backwards due to a tension spring located at the other free end of the chain; this spring is anchored inside the frame.
The design of the steering mechanism allows the rider to steer regardless of the position of the forward stroke. This is accomplished by having the cable mounting points of the steering arms concentric to the pivot location of the handlebars downtube. The steering motion is actuated by a cable attached to the spindles and routed throughout the frame. The system consists of four cables, when a right turn is made, the front of the left spindle is pulled inwards and the back of the right spindle is pulled inward, and the opposite for a left turn.

6061 aluminum was used to fabricate the entire frame, due to its strength and light weight. Some of the tricycle’s features include Ackerman steering geometry for a better turning radius and vehicle control, disc brakes for all weather braking conditions and outstanding braking modulation, and a racing bucket seat for secure and comfortable seating.

The total cost of this project was $3,200.
INTRODUCTION
The Wheel-Stair wheelchair is an innovation that modifies a traditional wheelchair by enhancing its mobility and usage. The objective of the invention is to minimize the amount of input torque required to transport over a curb to allow greater mobility for persons with disabilities. This wheelchair is designed to be used indoors and outdoors on level or abnormal terrain.

SUMMARY OF IMPACT
This invention allows persons with limited upper body strength to have an increase in mobility through a reduction in input torque. This manually-powered wheelchair acts similarly to that of a traditional wheelchair but adds its own twist to conventional wheelchair mobility restrictions. The Wheel-Stair expands the terrain in which a wheelchair can function in normal operation with added mobility.

TECHNICAL DESCRIPTION
The design of this manually-driven wheelchair focuses on the tire. The tire is modified so that it aids the wheelchair in going over a curb. The tire is selectively compliant so that it holds shape and allows for smooth translation motion. It also deforms when it encounters a curb in order to minimize the required input torque. This is achieved by allowing the air pressure to increase in the tire. The tire is modified by dividing it into six equal sized and sealed off bladders. Coming out of each bladder and going into all other bladders is a hollow pipe. The pipe has attached to it a check valve which opens as the pressure increases over predetermined critical pressure. This critical pressure is achieved by the increase of pressure experienced by the bladder which makes contact with the curb at the time of its encounter. The air in that bladder chamber will dissipate to all other chambers, leaving that chamber flat, and deformable. This will allow the tire to conform to the curb. The flat chamber re-inflates as each other chamber makes contact with the ground. This will happen because each chamber now has a slight bit more air in it (coming from the deflated chamber). As each chamber makes contact with the ground the pressure increases and the check valve opens. Pressure naturally flows from high to low, so the air will flow into the flat chamber until the pressure of
all the chambers equalize. The wheelchair frame is made of steel, the tires and all its components are made of two-ply rubber and the tire rims are aluminum.

The total cost, excluding labor, is $331.

Figure 12.8. Engaged Tire.

Figure 12.9. Internal chambers.

Figure 12.10. Internal Chambers.
INTRODUCTION
The design objective is to design a manually-operated outdoor playground carousel for children with disabilities and able-bodied children. Design engineers met with teachers and administrators at a school for children with disabilities, and together the group concluded that this design would benefit the children by helping to improve muscle tone, circulation, motor coordination, goal-oriented group cooperation, and social skills.

SUMMARY OF IMPACT
The manual carousel is targeted for all children who are able to passively sit, although two or three of the eight passengers must use their arms to drive the carousel.

TECHNICAL DESCRIPTION
The Manual Carousel is a human-powered mechanical carousel. All components of the carousel are original designs and have been fabricated in the machine shop except the following: sprockets and chains, axle shaft and its protective frame, passenger seats, roller bearings, nuts, washers, and bolts. The frame is designed of 1018 hot-rolled steel, and is mostly welded. The frame houses the seats, wheels, shaft, chain drive, and connects to the central joint via a pivoted extension arm.

Power is transmitted manually from the hand crank to the drive sprocket through a standard roller chain. The drive sprocket transmits power to the axle, which transfers power to the drive wheel (outside wheel). The wheel transfers power to the carriage frame, which transfers power to the extension arm, which transfers power to the revolute joint (the joint is also an original design) causing it to revolve about the axis.

The shaft is a standard 5/8” diameter, 30” long shaft. It is mounted with a drive sprocket and is rested in a protective frame. The frame makes contact with the shaft in four places, and a roller bearing is implemented at each location. Two of the four are pressed in a factory made frame for the shaft. The other two are pressed in originally designed bearing housings.

Two 20” high traction tires are used, and support most of the passenger weight. A swivel wheel has been mounted on a footrest to prevent toppling of the carriage under the weight of the passengers. It is to be mounted on the frame.

The revolute joint implements a spindle design, in which four male pivots join to the extension arm of the carriage. Notice the Teflon bearings between the bottom surface of the spindle and the top surface of the post sleeve. There is Teflon bearing between the top surface of the spindle and the post cap as well. Also provided are pictures of the vertical support with the joint mounted.

A drive pin is mounted to the shaft to create one drive wheel, and was modified from its manufactured state for design purposes in two ways. The drive pin spacer was trimmed to increase exposed shaft surface area. The drive pin plate, a circular disk on which the pins are located, was trimmed to be flat in one area. This was done to allow the shaft to slide out of the assembly without hitting the vertical support beams of the carriage frame.
Figure 12.11. Manual Carousel.
AUTONOMY TOY

Designers: Vanessa Capanzano, Jesse Fite and Time Tebo
Client Coordinator: Thomas Rosati, Premm Learning Center, Oakdale, NY
Supervising Professor: Dr. Peisen Huang
Department of Mechanical Engineering
State University of New York at Stony Brook
Stony Brook, NY 11794-2300

INTRODUCTION
The Autonomy Toy was designed with a particular child’s size, fine and gross motor skill abilities and mobility type considered. The design can be modified for other children. Various sounds, motion and vibration, surface textures and lights can be incorporated.

SUMMARY OF IMPACT
The Autonomy Toy is designed to entice play, enhance cause and effect learning, and provide positive reinforcement while the child benefits from increased exercise. It was designed to allow the client to use the toy without assistance.

TECHNICAL DESCRIPTION
The final design for the toy is a multifaceted ball. The ball’s main feature is its programmed random motion and the element of cause and effect. Due to the constraints of manufacturing for the design team, the prototype will be a representation of the toy’s possible features. The drive mechanism for the design will include two motors and the use of a ring and pinion, and a rack and pinion to create 2-D motion. A controller will be used to program the motion and to control the interaction between the power supply and motor function. The primary goals for the final design are to incorporate two different programmed motions with reasonable complexity, and have corresponding initiation sites. These programs will be initiated with lighted buttons. Aesthetically the prototype will include a lighted surface with the use of LEDs. Secondary goals for the toy will be to incorporate a program to compensate for human intervention, or the incorrect orientation of the toy for proper use. Another secondary goal includes the compensation for encountering objects that will hinder the motion of the toy.

The final design is composed of many components, which contribute to a forward and backward, and a turning motion. The function of all inner mechanisms contributing the generation of motion, and all other component function and specifications are included in Table 1. Other subsystems of the design include rotating electrical contacts, epicyclic gear train, the ball and tube sensors, and micro switches. See Figs. 12.14 and 12.15 for sketches of the final design.
Figure 12.14. Left half of the toy.

Figure 12.15. Right half of the toy.
INTRODUCTION
This machine is a platform-type wheelchair lift capable of overcoming both vertical and inclined impediments to wheelchair traffic. Specifically, the lift is designed for a sheer elevation of up to four feet (such as a stage), and an inclined lift of up to five feet along an incline of 30 or 35 degrees (such as a short stairway). In addition to the lift’s versatility in service, the machine easily collapses into a storage and transport configuration of less than 12 square feet and a width of 30 inches for doorway passage. Another outstanding feature of this design is its potential compliance with the current national safety standard for platform lifts and stairway chair lifts (ASME A18.1-2003).

SUMMARY OF IMPACT
The client’s school has a population of mobility-impaired students who need a portable storable lift to transport students onto the gymnasium stage, and to use in the hall stairs when the stationary lift is out of service. This environment benefits from all three characteristics of the Compact Modular Wheelchair Lift: a vertical lift onto the stage, and an inclined lift along the hall stairs, both combined with the necessity of sporadic use and easy storage.

TECHNICAL DESCRIPTION
This machine is powered by a double-acting (roped) hydraulic piston powered by either 120 VAC outlet power, or by batteries. The hydraulic piston actuates the chain or cable (not shown) pulling the platform along the guide rails. The chain or cable is routed first to the primary bearing block (inside the guide rail supporting the hydraulic piston). From the bottom of the primary bearing block, the cable or chain is routed downward and across the machine on the cable bed/guide rail channel. Here, the cable or chain is directed upward along the outside of the guide rail, reversing direction at the top, and terminating at the bearing block in the far guide rail. The bearing block system operates with each bearing block having two v-wheels that ride on corresponding angle tracks inside the guide rails. The system provides resistance to moments both axial and radial to the axis of the v-wheels. This bearing system is neither unique to this machine, nor the only system which could be employed in this machine. Any number of commercially available linear motion systems, or custom designed bearing systems can be substituted for the current bearing block design, possibly with improved results. The machine is illustrated below in the

Figure 12.16. (a) Partial Prototype; (b) Vertical Configuration; (c) Inclined Configuration; (d) Storage Configuration.
vertical lifting configuration, but can be adjusted to the inclined configuration by setting the platform level (39) and the guide rail incline (33) to the appropriate station. Additionally, the machine is converted into the storage & transport configuration by setting the platform level (39) and forward outriggers (9) to the appropriate selection. The machine can now be wheeled on its casters (6) through most doorways.

Figure 12.17. Vertical Configuration and Platform with Bearing Blocks (Both with Annotations).
INTRODUCTION
The All-In-Wonder Entertainment System is an all-inclusive recreation/learning center. It was specially designed for a 14-year-old girl with acute dwarfism.

SUMMARY OF IMPACT
The Entertainment System provides the user with a keyboard that is small and easy to use, as well as a gyration mouse for normal computer functions. The gyration mouse allows the individual to use the mouse as a normal desktop optical mouse as well as a desk-free, motion sensing, on-screen cursor controller. It also comes equipped with certain swipe functions that enable the client to perform specified tasks and functions with the flick of a wrist. For game play, the All in Wonder Entertainment Center has been fitted with two wireless arcade control panels for game play up to 10 meters away.

TECHNICAL DESCRIPTION
The cabinet is made primarily of ¾” oak plywood which has the strength to hold just about any item that is proportionally sized to the monitor chosen, and of course less than 100 pounds. The shelves were mounted on the top of 1x3x8 plywood batons and then the batons were glued and nailed to the plywood sides.

The PC built for this project includes the following components.

- AMD Athlon XP 2500+
- Shuttle XPC SK43G
- 256MB OCZ RAM
- 80GB Hitachi SATA Hard Drive w/8mb buffer
- Sony 52x32x52x16 CD-RW/DVD Drive
- ATI 9600 AIW Graphics Card
- Wells Gardner D9200 27” Arcade/VGA monitor
Figure 12.20. Ultra GT Compact Keyboard Suite.

Figure 12.21. Control Panel.

Figure 12.22. Control Panel / PC Draw.

Figure 12.23. Keyboard / Mouse Draw.
INTRODUCTION
The tandem tricycle is designed to provide children who have physical and cognitive disabilities with the physical, emotional and social benefits of being able to ride a bicycle. The design requires that the user have at least limited use of all of his or her extremities in order to make full use of the design features. Accommodations can also be made for children with paraplegia.

SUMMARY OF IMPACT
The tandem tricycle is designed primarily for children with some use of their arms and legs. These children will be able to pedal and steer the vehicle from a position that accommodates limitations of balance and fine motor control.

TECHNICAL DESCRIPTION
The design of the tandem tricycle is based on designs that have been in wide use for more than a century. The drive train and braking components, in particular, are commercial parts that have been adaptively used for this application. The drive train consists of one nine-gear cassette and two pedal cartridge assemblies. The vehicle thus has an adjustable gear ratio, which can compensate for changes in road or track grade or for the diminished capacity of the disabled rider to contribute to the pedaling of the vehicle. Both chains have guides and tensioners to prevent the chain from derailing and potential hazards to the riders. The front pedals are ratcheted. This allows them to be locked in a stationary position for a child who is paraplegic or for one who is simply too tired to pedal. The foot grips for these front pedals incorporate straps that can be used to safely and painlessly bind the child’s feet to the pedals to prevent them from dangling down into the drive train or, worse, dragging on the ground.

The tandem steering is accomplished by means of a dual port rack and pinion. Unlike a standard rack and pinion design, which has only a single port to connect to a single steering axle, the dual design allows two axles to be connected in tandem. This connection provides two key features to the vehicle. First, the child is able to steer the vehicle even though they are seated almost precisely above the drive axle for the front wheels. The steering column can be easily projected forward from the rack and pinion without any compromise in the mechanical viability of the system. Second, and more importantly, the adult caretaker in the rear seating position is able to feel and respond to the child’s steering decisions and, when necessary, to take over the steering of the vehicle without harming the child. This allows the stronger adult to either add power to the child’s steering in order to make sharper turns or to steer away from hazardous obstacles that the child may not be aware of or may not recognize as dangers.

The chassis of the vehicle is constructed of 4130 chromyl steel tubing due to the combination of strength to weight ratios, corrosion resistance and ease of machining that this material displays. Some of the other features of the vehicle include detachable and adjustable components, a padded seating platform for the disabled rider and hand operated cable brakes. Additional safety features such as rider restraints, guards and extra padding are included in the design of the vehicle but are omitted from the prototype for time reasons.

Total costs of the Tandem Tricycle was approximately $1100.
Figure 12.24. Frame Design for the Tandem Tricycle.
INTRODUCTION
The goal of this design group is to design, build and test a safe solution to transport a person from a wheelchair into a general aviation airplane. The device should be able to lift a maximum weight of 250 lbs. It can be assembled, operated, and disassembled in a relatively short time. Set-up and operation should be simple enough to be handled by one person, usually a caretaker or friend. The device is small and collapsible so that it can be stowed inside the airplane; the entire weight of the device was to be less than 100 lbs for proper balance of the airplane. The criteria included safety, portability, user friendliness, aesthetics, ergonomics, weight, and whether or not it is mass producible. The motivation of this project is to help the client, a skydiving instructor who was involved in an aircraft accident. He still enjoys flying but has no movement in his lower body and minimal movement in his upper body. It is the goal of this design team to help the client move in and out of his airplane.

SUMMARY OF IMPACT
The VIP lift can be used not only for transporting pilots who use wheelchairs, but also for other situations that require lifting a person with physical disabilities from his or her wheelchair to another location.

TECHNICAL DESCRIPTION
To make the lift collapsible and easy to store, the final solution was to have the legs slide into the upper part of the A-frame as shown in Fig. 12.25. This is a great space saver, as the collapsed A-frame will not consume any more room than the upper half of the frame. When in operation, the legs will slide out and be held by a pin.

One of the main components in the A-frame design is the cross bar. The three initial choices for the cross bar were an I-beam, a round beam, and a square beam. The square beam was selected due to its stability in resisting twist, and the large bearing area for the carriage. A method of collapsing and storing the beam made it possible to fit within the limited storage space of the aircraft.

One of our main concerns when designing the carriage was to minimize the possibility of getting fingers or other body parts caught in the carriage. The first concept for the carriage was a rectangular shell with a square cross section. Two sets of rollers on the top allowed it to roll across the beam. To provide the necessary vertical motion, either a lifting winch or a pulley (with a remote winch) would be added to the bottom of the carriage. A second concept consisted of a rectangular cross section, which allowed the pulley to be moved inside the carriage. In an effort to improve the appearance and minimize the risk of injury through contact with the sharp corners, the bottom edges on the carriage were trimmed and rounded.

The lifting operation was made easier by utilizing an electrical driven (12 Volt) ATV winch to provide vertical motion. A pulley is used to transfer vertical into horizontal motion. After extensive searching, a winch was found that uses 12 volts, has a .45 hp motor, provides up to 1500 pounds of line pull (well above the demands of the VIP lift), and is well within the budget. A rectangular winch with bearings exposed was used. The carriage slides across the top of the cross beam via bearings mounted on a shaft. The winch is mounted under the carriage to pull the user out of the wheelchair.

The total costs for material and parts are approximately $1260.
Figure 12.25. Aircraft to use Device.

Figure 12.26. VIP Lift.

Figure 12.27. VIP Lift in Disassembled Configuration.
INTRODUCTION
The goal of this project was to create a seat-lifting mechanism that can be installed onto a wheelchair with reclining function, where a caretaker manually operates the elevating and reclining functions. The chair must be cost-effective, efficient, reliable, durable, and aesthetically pleasing. The reclining function is based upon a car seat. Three focused methods for raising the seat are a rack and pinion system, a cylindrical joint arrangement, and a four-bar mechanism.

Because the caretaker will be the primary operator, the device installed on the wheelchair must not increase weight dramatically. If human aid is needed to maneuver the wheelchair, size could make use cumbersome. The unit itself must raise a maximum weight of 220 pounds to a height of one foot.

SUMMARY OF IMPACT
This wheelchair lifting and reclining device will be helpful for daily home use and for use in medical contexts.

TECHNICAL DESCRIPTION
The heart of the system is the scissor jack and hydraulic piston. The scissor jack is composed of sliding joints, scissor cross members and interconnecting bars. A piston is positioned at a slight angle when the scissor jack is collapsed. A caretaker actuates via lever arm the piston connected to interconnecting bars via revolute joint. When pumping begins, these bars are pushed by the piston in turn push the scissor cross members. Because the scissor cross members rotate, sliding joints were made to allow the least amount of friction while limiting rotational motion. The initial angle offset forces a general move upward. The scissor mechanism is sandwiched between two plates, the top plate supporting a seat, the bottom plate mounted on by casters. The designs are shown in Figures 12.29 and 12.30.

The total cost is $540.
Figure 12.30. The design of the chair.  Figure 12.31. The design of the scissor mechanism.
CHAPTER 13
STATE UNIVERSITY OF NEW YORK AT BUFFALO

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PROGRAMMABLE TIME PILL DISPENSER

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INTRODUCTION
The purpose of this project is to create a device that reminds a patient of pill dosing times, while also dispensing the pill or pills needed. The device is easily programmed to dispense pills at any time of day. The programmer (professional) can then simply load the correct pills into the device according to the programmed dispensing times. When the actual time matches the programmed dispensing time, the pills are discharged into a chute for easy access. Pill dispensing is accompanied by an audible alarm, as well as a flashing light built into the LCD.

SUMMARY OF IMPACT
Once the device is programmed and loaded properly, it can dispense pills three at a time, four times daily, for seven days. The use of this device would no longer require an aide to conduct daily visits to the patient to remind him or her to take medications. A device of this type also provides persons who are elderly or cognitively impaired with more independence and privacy. In addition to these benefits, the pill dispenser reduces human error. It is able to compensate for the forgetfulness of the user as well as the nurse aides by providing a reliable reminder of dosing times throughout the week.

TECHNICAL DESCRIPTION
The dispensing of pills is controlled by a rotating disk above a flat plate that has a slot cut into it, and a discharge chute below. Along 30 equally-spaced radial lines on the disk, three holes were drilled to serve as pill slots. On the same radial lines as the pill slots, half circles were machined into the outer diameter of the disk. These half circles or “negative cam lobes” and a roller micro switch are used to index the disk the proper amount so that the holes in the disk line up with the slot cut into the flat plate. When the disk is indexed at the properly
programmed time, the three holes of the disk line up with the slot in the flat plate, and drop their contents through the slot and into the discharge chute.

At the heart of the device is a 68HC11-EVBU microcontroller. The microcontroller controls all of the inputs and outputs of the device. The inputs consist of an up button, down button, enter button, and roller micro switch. The up, down, and enter buttons are used for programming purposes and to shut off alarms after dispensing. The micro switch controls the indexing of the disk used to dispense pills by riding along the edge of the disk on the cam lobes. The outputs of the device are a DC gear head motor, an LCD module with backlight, and an audible beeper. The DC motor controls the rotation of the dispensing disk. The LCD provides a programming interface and is also able to display battery voltage and the current time and date while machine is in run mode. The LCD backlight provides an easy to read display when lighting is dim and also is used as a strobe light in conjunction with the beeper to remind the user that pills have been dispensed. The entire unit receives power from a 9.6 volt NiMH battery pack. This pack can be charged before or during use of the device via a “wall wart” style charger.

A number of safety features have also been included in the device to prevent overdosing, incorrect dosing, and machine damage. If the disk is bumped or manually indexed, the machine will not dispense pills and must be restarted. Also, if the disk becomes jammed, the motor will automatically shut down after a brief interval to prevent damage to the device. After user programming has been completed and the machine is in run mode, the device will not dispense additional pills unless the user provides an input to the machine. This input comes in the form of a button press after pills have been dispensed. Pressing any of the buttons on the machine after it has dispensed pills not only shuts off the strobe light and beeper, but also permits the machine to dispense subsequent pills when the proper time comes. Without the button press after dispensing, the alarms will go off indefinitely and no more pills will be dispensed.

The disk and plate are made from chemically inert, non-static, HD polyethylene. The device disassembles easily for cleaning purposes.

The total cost is approximately $260.
TEMPORARY SUPPORT SLIPPER

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INTRODUCTION
The primary objective of this project is to fabricate a temporary support system for individuals who have sustained ankle injuries. Often, these injuries require the use of an air cast, which can be inconvenient and, frequently, uncomfortable. This device maximizes comfort and significantly increases the ease of use in the healing process of an ankle injury.

The temporary support foot slipper has all of the essential features for a strong cast. It is strong and rigid, and prevents rotation of the ankle in all directions. In addition, the tightness of the cast can be adjusted using the variable compression pump, which is stationed at the upper back part of the boot. Finally, the boot of the slipper is easy to get on and take off, with little stress being applied to the tendons in the ankle. The entire open face of the slipper opens up, so the person using the device simply has to step into it.

This feature is achieved by forming a thin piece of aluminum into the necessary shape of a cast, and welding it to a similar piece of sheet metal, serving as a base plate. Once the ankle of the individual is in place, industrial strength Velcro is utilized to prevent slipping and ensure proper stability of the device.

SUMMARY OF IMPACT
There are two major impacts that the Temporary Support Slipper can provide with regards to ankle injuries. First, it can give the consumer another option for minor ankle injuries. By being easier to use and more comfortable to wear than an air cast, this device has several inherent desirable qualities. Second, the temporary support slipper can be utilized for individuals who may need a device as strong as a cast for their injuries, but do not wish to deal with the complexities that a cast brings to everyday life.

TECHNICAL DESCRIPTION
There are four major components of the Temporary Support Slipper. These are the frame, the pump, the cushions, and the enclosing for the device. Aluminum sheet metal is used in the construction of the frame, due to its rigidity and weight. This sheet metal is 3/16" thick, and is cut and rolled to an appropriate shape. In addition, a base plate is also fabricated, and the two pieces were welded together for maximum strength. Holes were then drilled throughout the frame, in order to lighten the frame, without sacrificing its strength.

The pump for the device is taken from a Spalding Infusion basketball. This small device is easy to use, and stows away conveniently at the back of the boot. Tubing is then utilized to send the air from the pump to the three cushions, stationed inside the aluminum frame.
The cushions are similar to that of an air cast. They are very soft, and each has an airtight hole at its top, where the tubes from the pump enter. Silicon sealant is used throughout these junctions in order to assure an airtight connection. The air level in the cushions increases significantly with only a few pumps. The cushions can be filled to maximum capacity with 25-30 quick pumps.

Finally, synthetic rubber is used to bring it all together. The frame is attached to this material at several locations to ensure stability. A rubber base is also attached to the frame for smooth walking.

The Temporary Support Slipper is truly a unique device, as nothing like it currently exists on the market. It has several advantages to the current technology available to the population. The device is easy to use and very effective. The variable compression is a remarkable feature, and can be used to increase an individual's comfort, or for a more structured and medical purpose.

The total cost was approximately $215.
CLAW GRABBER

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INTRODUCTION
The objective of this project is to design and build a device to allow the use of at least one arm to retrieve objects slightly out of reach of individuals in a wheelchair or bed.

SUMMARY OF IMPACT
Individuals who cannot stand easily, or stand at all, from a seated or laying position need access to everyday items. The Claw Grabber avoids calling another individual into the room to access an item, such as a TV remote control or a magazine. The Claw Grabber will provide independence and, in turn, an improved quality of life for the user.

The operation of the Claw Grabber is simple. There are two buttons: one opens the claws, the other closes them. The user must simply press and hold the black button to open the claws, position the claws around the object to be retrieved, and press the red button to clamp onto the object. While holding the button in, one can bring the object to themselves. The Claw Grabber allows the user to retrieve an object from a distance of approximately 38 inches from their hand reach. This object can be up to 4.25 inches in width.

TECHNICAL DESCRIPTION
The device consists of a pre-existing clutching device made by UNGER, an aluminum handle, a 12-volt DC gear motor, and two switches.

The pre-existing device consists of a 36 inch aluminum pole, through which a thin steel bar runs, and two clutching claws are attached at the end. The claws open and close via a rack and pinion style arrangement. The base of each claw is equipped with a pinion gear. At the end of the steel bar, there is a flat bar with gear teeth on it. This serves as the rack. As the steel bar is pulled, the flat rack running between the pinion gears at the base of the claws causes them to close. A 17 pound compression spring partially returns the claws to their open position.

At the handle end of the arrangement there is a 12-volt DC gear motor. This motor is rigidly attached to a 1.25 inch aluminum handle via a bracket made from 1/8 inch aluminum angle. On the motor shaft there is a one inch aluminum arm through which a 3/16 inch steel cable runs perpendicular. This cable is rigidly fixed to the steel bar. As the user presses the close button, the motor turns in a clockwise direction, pulling the cable, and closing the claws. Due to the high gear ratio of the motor, the return spring cannot open the claws completely. Thus the user must press the other button located on the handle, and hold it until the claws fully open. A limit switch is installed to stop the motion of the motor when the claws reach the fully open position.

The device is powered by a 9-volt power supply. This is done for two reasons: (1) to reduce size, (2) to reduce the motor output to avoid burn out.

The total cost of the project is $311.
Figure 13.6  Motor and Battery assembly.

Figure 13.7  Entire Claw Grabber.
REMOTE CALL AND CONTROL SWITCH PILLOW

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INTRODUCTION
The concept of this project is aimed to fulfill the needs of individuals who are paralyzed below the neck. With this form of paralysis, only a limited range of head movements are possible. Those that have this disability require frequent assistance. To fulfill some of the person’s basic needs, a contoured memory foam pillow is designed with a micro-switch imbedded inside that allows the user to signal for assistance and operate several devices in his or her environment. This device will give the user the ability to sound a call alarm by activating the switch in the pillow. In addition to activating a call alarm, there are various other functions that can be controlled. The switch is connected to a central control module that is used to control remote functions of a TV, VCR or any device that operates by remote control. The control module also uses wireless technology to control small electrical devices or appliances.

SUMMARY OF IMPACT
This project has far-reaching potential in hospital and home care settings where call alarm systems do not sufficiently address the needs of patients with paralysis. This design is intended to improve upon the current call technology in use today that primarily consists of puff switches and bellows. Through increased convenience and comfort, the patient is able to signal for assistance, change the channel on the television, or even turn off a light simply by closing the switch.

TECHNICAL DESCRIPTION
A contoured, visco-elastic memory foam pillow houses the micro-switch that is recessed into the pillow. The activating surface of the switch is comprised of foam similar to that of the pillow and rests even with the surface. The 1/8” mono-plug connector from the switch plugs directly into a multifunctional control unit called the Mini Relax with X:10. This control module is a portable scanning infrared transmitter. The Mini Relax can store five infrared remote codes and has the ability to send one radio frequency transmission to an X:10 radio transceiver. The control module learns codes or signals from any regular infrared remote control that is used for TV’s, VCR’s, etc. It first learns, then transmits five different signals from a variety of regular appliance transmitters.
When the switch is first activated, the control module begins a scan mode and scrolls through the various functions by illuminating LED’s labeled on the face of the module. Once the desired function is illuminated, the switch must be activated again to select the function which is then set in memory. Similar to a computer mouse, the switch must be double-clicked to operate the selected function. The Mini Relax has a timing circuit that sends the module back into scan mode if the switch is not double-clicked within five seconds.

If the X-10 function is selected on the control module, a radio frequency transmission is sent to a radio transceiver that can be located up to fifty feet away. The radio transceiver plugs into a standard wall outlet. There is a relay internal to the transceiver that is energized once the radio signal is received. On the base of the transceiver there is an outlet that a small electric device or appliance may be plugged into. Power is supplied to this outlet once the relay energizes. The X-10 transceiver, once energized, also sends an electrical signal through the existing wiring of the house or building to a universal control module that is also plugged into a wall outlet. The universal control module can control an additional electric device or appliance, but also contains the call alarm. The call alarm may be placed at any distance, as long as it is connected to the wall outlet.

The total cost for the project is $709.
INTRODUCTION
This project addresses the needs of individuals with disabilities, or those who are elderly, to become more mobile by being able to use various forms of transportation. The motorized stool aids individuals in entering a van or sport utility vehicle by lifting them up high enough to simply sit down onto the seat of the vehicle.

SUMMARY OF IMPACT
The device provides safe assistance in rising to vehicle seat height, minimizes caregiver discomfort and strain, and allows individuals to travel on a more frequent basis.

TECHNICAL DESCRIPTION
The device is constructed of a top and bottom frame that were constructed out of ASTM B221 grade aluminum. The top plate of the upper frame is 6061 grade aluminum, which offers extra support due to its rigidity. The scissor arm, which is fixed between the top and bottom frames, is constructed of steel. The implementation of the steel scissor arm is important to providing safety for individuals up to 225 pounds who may use the device. The frame is designed to meet the following criteria described below.

1) Strength and Safety. The frame is strong, being constructed of aluminum and steel. It will support a load up to 225 pounds. The device also features two railings and a non-slip surface. The legs are covered with non-skid rubber pads.

2) Lightweight and Portable. While strong, the aluminum frames are also light. The top frame weighs 15 pounds, while the bottom frame weighs 25 pounds. All in all, the frame is much lighter as compared to similar-sized all steel lifts used for more industrial applications. The device features a set of wheels on the back legs that allow the device to be rolled along, similar to how one would roll a small suitcase.

3) User Friendly. The device makes use of a simple remote control that can be placed on the user’s keychain and is comparable in size to a car alarm remote. The remote features one button for “up” and one button for “down.”

4) Durable and Weatherproof. The metal construction of the device makes it durable. The aluminum frames are rustproof and the steel scissor arm is painted to protect it from the elements.

The total cost for the project is $550.
Figure 13.11 Assembly of Motorized Stool.
PORTABLE SUPPORT RAILS FOR
CHAIRS AND SOFAS

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INTRODUCTION
This device is designed to assist those who are elderly, in standing or sitting down in chairs and sofas. The device is a portable rail system that allows the user to utilize his or her upper body rather than depending solely on their lower body for these activities.

SUMMARY OF IMPACT
The Portable Support Rails are lightweight designs and inexpensive alternatives to hydraulic lifting chairs. The device is easy to use, does not require maintenance, and is adaptable to most chairs and sofas.

TECHNICAL DESCRIPTION
A key objective of both designs of the Portable Support Rail is to be adaptable to most couches. It must be lightweight and able to support the weight of an average person. Both designs of the Portable Support Rail are made of .750” OD X .065” 6061 aluminum.

Design #1 (Figure 13.12 and 13.13) is based on two vertical rails that fit over the seat cushion. The base slides under the sofa or chair and serves as a connection between the two vertical rails, and is separated at a distance of 20”. The two flat aluminum bars that are welded between the rails provide bracing when the rail system is loaded. It has a height of 36.5” at the front of the device, an optimal distance for the placement of one’s hands for support when standing. The rail is horizontal at a distance of 10” from the front and then slants downward to the rear of the device to aid standing or sitting. This does not interfere with a person’s normal sitting practice. A horizontal brace is placed within each vertical rail at a height of 21” above the ground. A vertical brace is welded to each rail at 10” from the front of the device. This provides a “stopping point” so the rail only extends 20” into the sofa. It also provides 10” from the front of the couch to the front of the device. This aids the user in standing within the rail system in front of the couch. All bends were made with a 2” pipe bender. Cushioned gripping is placed around the “handling” surfaces. Self-adhesive felt pads were placed on the underside of the device to prevent scratching of floors.

Design #2 (Figure 13.14) is based on two vertical
rails that are placed over the seat cushion, each with a leg extending to the floor. They are connected in a similar fashion to Design #1, but only one cross support is needed, and is placed between the seat cushion and frame rather than underneath the sofa or chair. The legs have a length of 13”. The total height of Design #2 is 29”. The connecting pipe is welded at 13” from the bottom of each leg. The rails slant downward from the front of the device, extending a total of 20” into the couch. All bends were made with a 2” pipe bender. Rubber feet were placed at the bottom of each leg to prevent scratching and slipping on the floor.

The total cost of the project is $260.

Figure 13.14  Design #2 of Portable Support Rail.
MONOCULAR DEPTH PERCEPTION GLASSES

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INTRODUCTION
People without depth perception cannot drive cars or operate heavy machinery with the same margin of safety as individuals with depth perception. Loss of depth perception may result from losing the use of one of the two eyes. An individual with the use of only one eye can rely on monocular clues for depth perception, but this is not as effective as the depth perception of an individual with both eyes seeing in true stereoscopic vision. The Monocular Depth Perception Glasses were designed to two images to the brain through the same optic nerve, again, simultaneously.

The original design includes a regular pair of glasses with a lens in the frame of the able eye, and a mini-camera in the frame where the unable eye looked through. This turned out to be nearly impossible with the technology currently available; therefore the final design is a prototype to test whether or not the device gives the user artificial depth perception.

SUMMARY OF IMPACT
For a new user this device does provide depth perception displayed on a single screen; however, the two images are seen as two separate images. If a user were to use the device for an extended period of the time, the brain may adapt and merge the two images to more closely approximate that of normal vision. This hypothesis has yet to be tested.

TECHNICAL DESCRIPTION
Two video cameras act as the user’s eyes. The two generated signals are then fed to the TBC-3000, which is a device that essentially synchronizes the two signals. Without this device and its function called gen-lock, the two signals would interfere with one another and the image produced on the monitor would not be helpful at all. After feeding the two signals into the TBC-3000, a simple resistor is used to unify the output signal that went straight to the LCD monitor. The video cameras both operate at 12 volts, while the LCD screen operates at 7.5 volts and the TBC-3000 at 9 volts. There were, however, allowable tolerances in the latter two, which let them operate at 8 volts apiece. The power source is a 12 volt rechargeable battery pack. Power from the battery pack is fed directly to the cameras at 12 volts and also to a 7808 regulator, which drops the potential to 8 volts, before the monitor and TBC-3000.

In order to make this device mobile, an important function for any user, a mount is necessary for the cameras and monitor. The mount is constructed of aluminum and strapped to a backpack, which carries the TBC-3000 as well as the power source.

Testing is done by setting up three LEDs at different depths in an unlit room. Testing concluded that the device does work; however, the disparity between the two images is greater at distances anterior and posterior to the focal point, as would be expected. The device would work better if the two cameras were to focus automatically and change their angles accordingly, which was not feasible, due to time restraints.
Figure 13.16. Monocular Depth Perception Glasses in Use.
EASY-REACH WALKER

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INTRODUCTION
A common thread between users of supportive walking devices is their lack of strength. Due to this lack of strength, most of these persons are dependent on others to get objects that require reaching and arm strength. This device addresses this need by allowing the user to rise to approximately eye level with objects that they wish to reach, thus eliminating the danger of lifting objects above the person’s head.

SUMMARY OF IMPACT
The Easy-Reach Walker (Figure 13.17) gives independence to people that are dependent on others for common tasks such as grocery shopping, preparing food, and house cleaning. Something as simple as getting a glass of water can be frustrating for a person that can’t reach over a counter top to reach a glass from a cupboard. Whether it is due to back problems, height restrictions, or lack of arm strength, every day can be full of frustration. The Easy-Reach Walker can help ease that frustration.

TECHNICAL DESCRIPTION
The project is basically an integration of a walker and a stepladder. The walker height is adjustable from 29-34” (measured from the top of the hand grips). The device can be folded to a thickness of a mere six inches for easy storage or transport. The steps reach a height of approximately 16”. The device weighs about eight pounds.

While the walker is in use, the steps fold up so that they do not interfere with natural walking motions. Velcro straps secure the steps to ensure that they do not unfold unless needed. Since the steps fold to the front of the walker, wheels were added to the front two legs so that it is not necessary to lift weight that is centered far from the body.

The steps can be used by un-strapping the Velcro and pulling the bottom step toward the back of the walker. The aluminum links connecting the steps to the walker support most of the weight. A small leg underneath the bottom step is needed for added safety. If too much weight is shifted to the front of the step, the stairs had a tendency to move. The added leg prevents this motion.
Figure 13.17 Steps in Use.
PEN CASING FOR SHAKY HANDS

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INTRODUCTION
Many people have a loss of fine motor control which can impair their ability to write. Tremors caused by involuntary muscle spasms are present in patients with both cerebral palsy and Parkinson’s disease. With the onset of tremors, a patient may experience a degradation of their quality of life. In particular, the loss of the ability to write can be a constant inconvenience, severely impacting a person’s everyday life. Designing a portable pen that would reduce the effects of tremors on handwriting would allow many people to recover many small inconveniences that writing difficulties impose.

SUMMARY OF IMPACT
Increasing the ease and clarity with which a patient can write provides a significant improvement in his or her life. Initial testing is conducted with patients who had either Parkinson’s or cerebral palsy. Results varied for each patient, showing the best results for Parkinson’s patients who had hand tremors. These patients whose tremors solely affected the hand still had the gross motor skills required to produce a generally smooth writing motion with only small disturbances.

The patients with Cerebral Palsy were generally afflicted with spastic quadriplegia, not only having hand tremors but also muscle spasms of the arm and trunk, making writing extremely difficult. During testing it is not uncommon for the patients hand and arm to spasm causing the pen to lift off the paper completely. This would cause an abrupt interruption in writing by leaving a trail as the pen is forced in an undesired direction.

Patients found that the large size of the casing made the pen easier to hold and control but also suggested adding a soft gel grip. This would provide a valuable addition that would not only add comfort for the user but could also be designed to add additional vibration damping. Another improvement would be to utilize a click pen instead of the capped pen used in the prototype. This would facilitate the preparation of the pen by both removing the need for patients to take off the pen cap and also allowing the internal components of the pen to remain assembled, having no need for adjustment upon the removal of a pen cap.

Throughout testing and the subsequent discussion with a patient who has spastic quadriplegia, it became apparent that pen would benefit being used in conjunction with other assistive devices. The particular example discussed is a wrist brace which the patient used during occupational therapy to decrease the effects of her spasms. Another possible improvement could come from the addition of a stabilizing device to the back of the pen. This would be accomplished by damping the motion of the rear portion of the pen and also adding constraints to exclusively allow rotation and translation in the plane parallel to the paper. However this option would most likely significantly increase the size of the device, severely reducing the portability.

TECHNICAL DESCRIPTION
The prototype is composed of two main parts: the casing and the pen. The separation of the two components allows for the easy replacement of the pen. The prototype is 1” in diameter and 6½” long...
when the pen is in place and 6" long without the pen. The length is consistent with the average pen while the diameter, although larger, does not create difficulties with either holding the pen or its portability.

The casing is designed to counteract vibrations in both the radial and axial directions. Axially the pen is connected to a compression spring in the rear of the casing. This provides travel for the pen, allowing the casing to move towards and away from the paper while the pen retains contact. The connection of the pen to the spring and the spring to the casing does not confine the pen radially and acts as a pivot point. To decrease the radial movement of the spring the diameter of the internal cavity is tapered from the diameter around the pen. The taper provides a smooth transition between the two diameters and allows for the smooth placement of the pen. The prototype is manufactured in two main pieces due to difficulties in obtaining the desired internal geometry when using a single piece of aluminum. The two pieces are connected by a thin tube which is secured by a small screw at each end. Although this configuration has shown no hindering affects on the performance of the prototype it does increase the number of parts needed and can be refined to be made from one piece.

The pen is damped radially by a rubber band web and a foam ring. The rubber band webbing provides the force necessary to center the pen after a disturbance while the foam dampens the initial disturbance, decreasing its magnitude. Four sets of two parallel groves were cut into the front of the casing at 45° angles to provide symmetry for the web. The cuts extend ¾" into the casing and the rubber band is slid into the formed groves to create a web that centers the pen. The foam ring is then slid over the pen and into the casing to dampen the pen's movement as close to the tip as possible.

The total cost of the project is $20.
PORTABLE KNEE THERAPY DEVICE

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INTRODUCTION
For the patients with knee surgery and seniors, exercises with very low impact are recommended such as swimming, walking in the water, and stationary bike with no resistance. This knee therapy device supports exercises that can help users to recover the strength of their knee muscles and prevent stiffness.

SUMMARY OF IMPACT
This knee therapy machine will help patients exercise until they can straighten their knee completely and bend it to at least 90 degrees. The device can potentially improve a patient’s flexibility, which can improve comfort and the mobility.

TECHNICAL DESCRIPTION
This machine is mostly made with aluminum and rubber, so it is very light and comfortable to wear. Three different positions are available for both lower and upper part of the brace, so the length is easily-adjustable. Wing nuts are used for the parts where adjustment is needed, so it does not require the use of any tools. The areas of the device that are in contact with skin (ankle and thigh) are made with rubber. Four Velcro straps are used to hold the leg securely and comfortably. Four bearings are used, one at each leg’s lower and upper part of the brace. These provide smoother movement against high torque and shear stress. The position where the pulley system is placed is carefully calculated, so clients can use their arm as a helper to move their leg to a fully bent and fully extended position. The rope is detachable and also adjustable in length for convenience. The aluminum bridge, which is placed near the knee joint, is used to adjust the width of the brace, so that the client can control the tightness of the knee. The knee pads, made of hard sponge, are inserted in each end of the knee joint for better holding and comfort.

Figure 13.21. The Knee Therapy Machine.
Figure 13.22 Exercise 1 with Knee Therapy Machine.

Figure 13.23 Knee Therapy Device.

Figure 13.24 Exercise 3 with Knee Therapy Machine.
INTRODUCTION
The technology of aiding skiers who are paraplegic with the goal of increased capability on the ski slopes has classically included single ski, static designs. This project surpasses the current technology by creating a multiple-ski, articulating mechanism to duplicate the natural motions that able-disabled skiers create while skiing. This project is not designed specifically for one person; therefore, it is capable of accommodating people of differing statures and of differing ability levels.

The basic idea of the mechanism is the same as the basic idea of classical skiing; when pressure is applied in a certain direction, the angles of the skis change, resulting in a turn. The changing angles of the skis are the most important design aspect of this project, and as such, much development has been done to ensure the correct motion of the parts. The device is comprised mostly of a four-bar mechanism which requires that both skis stay at parallel angles throughout its use. Pressure to one side or the other, created by the user leaning to one direction or the other, results in a change in the ski angles, forming the basis of a turn. Several aspects of consideration were used when designing the mechanism, including weight, balance (in all directions), cost, safety, durability, and size.

SUMMARY OF IMPACT
Skiing is certainly one of the most popular outdoor activities during the winter, and this device will allow people with disabilities the opportunity to get outside and exercise during the winter, while relying very little on friends or family. This device (shown in Figures 13.25 and 13.26) will fit into all current ski and ski binding configurations without modification.
skier’s feet to rest is provided. The actual seat material is canvas, stretched between the seat bars and sewn together.

Future changes that would make the design better include replacing the gas springs with a spring type that would provide proportional force to the distance compressed. The springs installed provide a constant force at all distances, which makes the seat portion unsteady. Also, pins which stabilize the articulating section’s joints would make the system more durable and give more stability to the user.

The final cost of the project is $388.

Figure 13.26. Close-up View of High Performance Sit Ski.
LETTER-OPENER

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INTRODUCTION
For people who have limited use of their hands, trying to open letters can be a struggle. A person who has only one arm or just one hand can have great difficulty opening ordinary mail. The objective of this project was to enable a person to quickly and easily open envelopes with just one hand. With just a few minutes of practice, almost anyone can learn how to use this invention to neatly open an envelope in less than five seconds. One unique design feature is that the width of the cut is limited, which eliminates the chance that the important documents inside will be destroyed.

SUMMARY OF IMPACT
This device is compact in size, and weighs only four and a half pounds because most of the components are aluminum. This makes it highly portable and easy to maneuver. This letter opener uses a very simple motion to cut the envelope. The user grasps the handle and then applies a small amount of downward pressure to turn the rotary blade against the fixed square blade.

After the clamping bar contacts the envelope, it applies pressure which prevents any movement of the letter while the two blades shear off the end. Continued downward motion of the handle turns the rotary blade which then cuts off the end of the envelope. It takes little effort on the handle to cut the end of the envelope off. The rotary blade has a stop machined into it which will limit the amount of paper cut off to 0.040”. This design ensures that the papers inside the envelope will not be damaged while the envelope is being opened.

Before the cut can take place, the envelope must be aligned properly inside the mechanism. This job is made simple by using the guide rail that runs perpendicular to the cutting blades. The envelope is placed lengthwise against this rail, and then slid under the clamping bar until it hits the stop.

There are several other components which are necessary to make this letter opener function. The two side braces are essential to hold the rotary blade in position as well as keep the entire mechanism together. These parts had to be machined very precisely to keep the clearance set properly between the blades.

TECHNICAL DESCRIPTION
There are two main components, the handle and the base. There are two blades; the first is a rotary blade and the second is a square blade. The shearing action between these two blades is what makes this letter opener operate so smoothly. There is also a spring-operated clamping bar which is critical to holding the envelope in place while the user operates the handle. The spring mechanism is calibrated to operate with the first downward movement of the handle.

Clamping bar side braces are used to keep the clamping bar pivoting on the same axis as the rotary blade. The spring mechanism mechanically links the handle to the clamping bar. This acts as a limiting device to keep the handle from rising too far upwards and also applies pressure to the clamping bar. There are spring pins positioned between the clamping bar side braces and the side braces themselves which limit the travel of the handle.

Materials were chosen for this assistive device based on their strength and durability. Every part is made of aluminum, except for the two blades which are steel. Aluminum is strong, lightweight, and looks nice with a brushed finish. Steel is used for the blades since paper can be very abrasive to the cutting blades. The hardware used to bolt the components together is all stainless steel. This was chosen to be more esthetically pleasing as well as durability.
The total cost is around $220 for this one-of-a-kind prototype. This device does have the potential to be mass-produced at a much lower cost.

Figure 13.27. Letter Opener.

Figure 13.28. Letter Opener in Use.
INTRODUCTION
For some individuals, the process of placing on or removing eyeglasses is difficult to impossible to perform independently. The objective is to design and build a foot-activated device to allow the user to complete this action without using his or her hands. This device (Figure 13.29 and 13.30) will be useful for those whose hand functions are limited. This addresses a problem which affects people with hand injuries, severe arthritis, or who generally have a lack of hand strength or control. The overall design is meant to create an appealing and safe product to help users with these disabilities become more self-sufficient.

SUMMARY OF IMPACT
As a result of this product, a person having the aforementioned disabilities will now be able to put on and remove eyeglasses without needing aid.

TECHNICAL DESCRIPTION
This device is designed to be set up by opening the tripod legs, adjusting the height, and adjusting the clamps to match the width of the eyeglasses intended for use. The design incorporates two spring loaded clamps connected to a foot pedal by a stainless steel cable. The clamps are mounted on an aluminum plate which can be adjusted to place the clamps at the angle desired for ease of use. The stainless steel cable is attached to the clamps by a T-shaped plate which opens the clamps at the same time when the cable is pulled down. The user opens the clamps by pressing their foot on the foot pedal. The user can then place their eyeglasses into the clamps. The clamps are width adjustable to be able to fit any sized pair of eyeglasses. The clamps are adjusted by loosening the wing nuts on both sides and sliding them either way through the slots in the plates. When they are positioned to fit the eyeglasses used, the wing nuts can be tightened again.

The clamps are intended to pinch the sides of the eyeglasses in the same location and same way as a person with fully functioning hands would grip in order to put on or remove eyeglasses. When the eyeglasses are placed within, the user would then release the foot pedal and the springs inside the clamps will cause them to close. The eyeglasses will then be held in place by the Eyeglasses Holder, and the user can step away from the device without their eyeglasses. The eyeglasses will then be held until it is necessary for them to be placed on again. In order
to put the eyeglasses back on, the user would simply step back into their eyeglasses and press the pedal to open the clamps. The eyeglasses are then released and the user can step away, wearing their eyeglasses. There is a mirror mounted behind the clamps in order to assist the user in positioning their eyeglasses.

The total cost of this project is $70.
INTRODUCTION
The objective of this project is to build an assistive device to aid users of nursing home and hospital restroom facilities in the dispensing of commercial toilet tissue. Commercial rolls are often unperforated, and difficult to pull and tear, even with two functioning hands. The user places a hand under this wall-mounted device, triggering a photo sensor that engages a drive motor to unroll material. The user then tears the material by pulling it against concealed blades.

SUMMARY OF IMPACT
This assistive device (Figure 13.32) is designed to relieve frustration in institutional restrooms. Currently automated hand dryers, faucets, and hand towel dispensers are available for commercial and institutional installations, offering ease to both persons with and without disabilities. This design permits one-handed operation to the user and relieves the user from frustrating pulling and tearing motions, which often result in an uncomfortable and unsuccessful feeling. The design is safe, with concealed wiring, low voltage components, and hidden blades, all while neatly blending into an institution.

TECHNICAL DESCRIPTION
Based on a market search, a comparable device is not found to offer equivalent specifications or value to the end user. The cabinet in which the internal components sit is constructed of 16 gauge cold rolled steel finished in a black textured powder coat for durability and attractiveness. An easy-release door is designed for quick change of the commercial tissue roll. The unit is powered from standard 110-120VAC power, and features a cord and plug.

Drive Spool
Inside the unit, a drive spool is readily accessible. The drive shaft is machined from 2024 aluminum and has nylon drive wheels. The assembly has a drive pulley, mounted between two flange-mounted bearings. All components are attached to a 14 gauge cold rolled steel bracket that is finished to match the cabinet.

Motor Assembly
The motor is a 24VDC gear motor with a small drive pulley. The motor and the drive spool are joined by a toothed drive belt. Both components mate to the cabinet through formed indentations to conceal the Allen bolt heads on the back side of the cabinet.

Electrical System
Through standard 120VAC power, a transformer mounted within the plug box converts the 120VAC to 24VDC for use with the gear motor. A DC powered photoelectric switch is mounted on the underside of the cabinet, and is wired so that when a user’s hand is within 9” of the switch, it will power the motor, driving the tissue roll to unroll through an opening beneath the cabinet. A relay is mounted within the circuit to power the motor once the photoelectric switch is tripped.

The device offers several benefits for users, as described below.
Ease of use. The user simply places a hand beneath AAD and tissue will unroll for quick and easy dispensing.

_Safety and Integrity._
The internal components run on low voltage components to offer maximum safety. The cabinet is constructed of heavy gauge steel, die-formed to allow the most rigid structural integrity.

_Aesthetically Pleasing_
With a baked-on textured powder coating, the AAD neatly blends into commercial and institutional installations.

_Easy Installation_
To install, a standard 110-120VAC is simply connected and mounted to a wall through punched holes in the rear of the cabinet. The AAD mounts flush to the wall.

Users are delighted by the ease of dispensing commercial toilet tissue and would be happy to find such a unit within an installation more frequently.

The total cost is about $160.
VERSATILE HOSPITAL STROLLER

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INTRODUCTION
When children are hospitalized for whatever reason, they are often required to use several pieces of equipment. The objective was to design a versatile stroller for use in such a setting. This will benefit the nurses, patients, and the families of the children residing in the hospital by allowing one place for the equipment to gather. This will enable a parent to leave the room with his or her child and still hold the equipment he or she is using.

SUMMARY OF IMPACT
A stroller has been built that has the capabilities of a store-bought stroller and allows for an IV bag to attach at the back of the seat. A shelf is designed to fit below the seat to hold a heart monitor or for extra storage. The stroller folds for storage when not in use. The common stroller is generally lightweight; this is heavier and allows for stability. The device allows patients and their families the freedom of walking around the hospital while still maintaining their safety because they can bring the necessary equipment with them.

TECHNICAL DESCRIPTION
The stroller has two side supports to which the front legs are welded. The side supports are made from 1” thick 6061 aluminum and cut with a 3” radius and a length of 7.” The four legs are made from 7/8” 6061 aluminum tubing. The back legs are welded to a 6” 6061 aluminum disk. The front legs move on double castor wheels, and the back legs move with stationary wheels. This allows for easier mobility of the design. There is a lock mechanism that holds a disc to the side of the stroller and allows the legs to rotate and fold. A mold is made which holds the locking mechanism for the back legs. This prevents the legs from swinging, and additionally stabilizes the stroller. A handle has been mounted at the top of the seat so that the stroller will pushed with ease. The seat is reclined for comfort. The seat is plastic and allows for a quick cleaning. There is comfortable padding for the child to sit on, which can be removed for cleaning. There are several safety components to the design: a seat belt and bolts covered in padding. Also, the mold which holds the locking mechanism also covers a space between the side supports and the disk to prevent pinching of the child’s fingers.

The total cost of this design is $455.
Figure 13.35. Folded Hospital Stroller.

Figure 13.36. Locking Mechanism.
INTRODUCTION
This project is designed for people who have difficulty reaching into certain places. People who use wheelchairs cannot reach up to grab something off a high shelf, nor can they reach something that fell down a ventilation shaft. Even those without disabilities have this difficulty at times. The Grapple Extension Claw is an innovative solution for this problem.

SUMMARY OF IMPACT
The main features of this device are a telescoping pair of shafts with an internal claw control setup. This setup is connected to a slider mechanism in the base of the larger shaft. The telescoping aspect allows the Grapple Extension Claw to be adjusted to the desired length to a certain degree. The slider mechanism consists of a metal ring on the outside of the shaft attached to the internal setup. This allows people to use the device from any angle. It also simplifies the movement needed to operate the claw.

All these attributes allow the user to grab most lightweight objects off surfaces, shelves, and most out-of-the-way places. Most people with disabilities will be able to reach beyond their constraints and have a sense of freedom they may have felt they lacked.

TECHNICAL DESCRIPTION
The base of this project is a telescoping boat hook. The hook at the far end is removed and an opening made at the rear end. A hole is drilled into the inside end of the smaller shaft to allow the internal mechanisms to operate. Two slots are milled into the base of the larger shaft for the sliding mechanism, while one exists in the smaller end for the link system.

The internal setup consists of a pneumatic piston cylinder setup. Two piston cylinders are connected opening to opening by coiled rubber tubing. One piston is spring-loaded to normally remain closed while the other has no springs. Within the tubing is a degree of injected air pressure. The spring-loaded piston cylinder is secured near the end of the smaller shaft by a set of screws drilled through the outside, in the pushed-in position. The non-spring-loaded piston cylinder is similarly secured in the base of the larger shaft, with the piston fully extended. The coiled tubing runs through the hole drilled in the inside of the smaller shaft.
Connected to the spring-piston in a link setup consisting of an aluminum rod attached through pivot points to a bolt connected to another pivot in the end of the smaller shaft. The lower claw mechanism rotates off this point, while the upper claw is fixed to a metal ring on the end of the shaft. Anti-slip tape pieces are attached to each claw to facilitate gripping.

The slider mechanism in the base of the device is a metal ring on the outside of the shaft, secured to the piston through a set of screws and other fasteners. These screws go through the slits in the shaft made for that purpose. A bolt is drilled in the side of the slider ring in the event the user wishes to attach a handle in order operate the device in this manner.

The operation of this device is quite simple. The user simply applies pressure to the slide to push it forward, forcing the air pressure into the other end of the setup. This pressure pushes against the other piston, moving it outward and operating the pivot points. Pushing the system forward moves the pivot points and moves the lower claw from the opened to closed position. The spring load in the linkage piston cylinder causes the mechanism to open back up when the slider is released.

Due to the modifications made to both the exterior and interior of the boathook, the length of the Grapple Extension Claw is 64.5 inches when retracted, and 92.5 inches when fully extended.

Total cost for this project was $123.

Figure 13.39. Grapple Extension Claw.
INTRODUCTION
A problem with using a wheelchair is the difficulty in participating in many outdoor activities. The focus of this design project was on making it possible for a standard wheelchair to travel on sand.

SUMMARY OF IMPACT
Beach wheelchairs are expensive and usually fairly bulky. Also, a lot of them are hard to transport, due to their size and inability to be easily taken apart. The beach wheelchairs, if available at a resort or other beach facility, are limited. This is a less expensive option consisting of an assembly that can be easily attached to a standard wheelchair for a day at the beach.

TECHNICAL DESCRIPTION
The wheelchair design for the beach has two main parts, the front and the rear assemblies. We wanted the standard wheelchair to function as normal, but with the addition of larger, sand-capable wheels.

Our first goal is to find a rear wheel assembly to make it possible to attach an assembly of plates to the axle of each rear wheel. A one-time assembly consists of an 8” diameter plate on the inside of the original wheel as well as an 8” diameter plate on the outside. These two plates are fastened by 4-3/8” x 5” countersunk bolts together squeezing the wheel. Next, an assembly consisting of two 8” diameter plates connected in the middle by a 2” wide hollow steel pipe is attached to a 23” ATV tire. Now, the ATV tires can be mounted onto the wheelchair. This assembly allows room for the person to still use the handrails in the event that they want to control the wheelchair themselves.

Our second goal is to design a front wheel assembly to keep the front wheels up off the sand. We decided to run an axle through the spokes of the wheelchair. A ½” steel rod is run through a hollow tube to form the axle. Two U-bolts are then used to hold the axle in both the vertical and lateral directions so that it will not slide as the wheelchair maneuvers. Next, 12” Roleez sand tires are slid on the ends of the rod and locked in place using pins.

The advantages of this design coincide with the design goals. Compared to the marketed beach wheelchairs, this is the less expensive option. The assembly eliminates the hassle of handling two completely different wheelchairs. Also, most beach wheelchairs are only pushed from behind while this assembly allows for the person to propel it himself or herself.

There are a few issues that may have to be addressed on a broader scope. Compatibility is one such issue. Although, the wheelchairs we used accommodated the assembly, different wheel materials and spoke structures could present a problem. We did have equal success using only two of the four bolts, which would make this assembly much more adaptable to other types of wheelchairs. Another hindrance could occur with wheelchairs that have wheels that are slightly tilted, not perpendicular to the ground. With a straight extension, this would cause the beach wheels to ride much higher and therefore ineffectively. One other issue is the steering. The wheelchair operates well...
back and forth, but because of the elimination of the swivel effect on the front wheels, the wheels have difficulty turning.

Figure 13.41 Components of the Beach Wheel Chair.
INTRODUCTION
This project addresses the problems encountered by people who have difficulty moving large or heavy objects around the home. These people range from those who are elderly who cannot lift that much, people who use crutches, wheelchairs, or walkers, and people with disabilities that limit their strength or mobility. In order to overcome the problem of moving heavy objects, a remote-controlled vehicle is designed that is small enough to be used in a house, but could support large and/or heavy loads easily.

SUMMARY OF IMPACT
The goal of this project is to design a remote-controlled vehicle capable of handling a 300 lb load, which is also capable of maneuvering around a household setting. The design needed to be compact and maneuverable, as well as easy to use. When these requirements are met, the device will be able to aid many people who would otherwise have to rely on other people or risk injuring themselves in moving large or heavy objects. The versatility of this project allows for its use for many types of loads, both in and outside the house.

TECHNICAL DESCRIPTION
There were several different ideas for the design early in development. While the overall appearance remained the same, the different parts of the vehicle – drive system, steering system – had many different ways in which they could have met the design requirements. In the end, the simple and easy to use ideas were used. This makes the vehicle easy to use and easy to repair.

Frame. The frame for the vehicle is made from a combination of round steel tubing and angled steel. The bed of the vehicle is made as a flat area roughly 27 inches in width and 32 inches in length. The tubing is bent to form the outside perimeter of the load bed with crosspieces for support. The angled steel is used to create supports for the front and rear axles. A tray is also made from the angled steel to securely hold the battery in its place. In order to keep the design as safe as possible, the frame is made by welding the pieces of tubing and angled steel together, leaving no sharp corners or rough edges sticking out from the vehicle. A wooden deck is constructed to fit on top of the frame to act as the bed of the load area. Since all the other components of the vehicle are housed underneath this bed, the maximum amount of area for carrying the load is obtained.
Drive System and Rear Axle. The drive system for the vehicle is a gear head motor found in many scooters used by the elderly or handicapped to move around. This motor is ideal for this design since it incorporated everything needed for the drive system in one compact unit that could also serve as the rear axle for the vehicle. The motor uses a DC voltage power supply, is already geared down to the proper speed and power required, had keyed shafts on either side for mounting the tires of the vehicle, and included differential gearing. Additional aspects of the motor are that it includes a manual hand brake that can be used as a parking brake as well as the ability for dynamic breaking through the motor. Dynamic braking occurs when an electric motor is forced to spin - thus acting like an electric generator - while the two terminals of the motor are kept in contact. This allows for the motor to convert the motion of the vehicle from mechanical energy to electric energy and slow the vehicle down.

Steering System and Front Axle. The steering system for the vehicle consists of the front axle from a lawn mower. It uses a simple four bar mechanism to control the orientation of the front wheels. The position of the wheels is adjusted by using a linear actuation motor to move the connecting link of the steering assemble to the right or left. The only disadvantage found for the front axle is that it is not set up for Ackerman steering. This means that when the front tires are turned sharply, the two tires don’t roll easily around the turn, but slide sideways a little bit. Adjustments to the connecting link may eliminate this problem.

Radio Control Systems. The radio controls used for this vehicle are relatively simple to use. The handheld transmitter and the receiver on the vehicle were both bought over the counter at a hobby store. They are the same type of equipment that is used in radio controlled (RC) cars. The major difference in the control systems is in the connections between the receiver and the motors. In RC cars, simple electronic servos are used to regulate the current going to the motors. However, the motors used in this vehicle used far too much current for these types of servos to handle. The problem is solved by using two H-bridge motor drives that could handle the current. These motor drives not only adjusted the signals from the receiver running on 6 volts to the motors running at 12 volts, but they also acted as the electronic servos to control the motors. This is accomplished by using the RC setting on the motor drives and connecting the RC receiver directly to the motor drives. This allowed for a much simpler electronic setup, and was more cost-effective.

Tires. The tires purchased for the vehicle are similar to those used on yard equipment. They consist of the rubber tire portion with a tube, the rim, and bearings mounted in a housing connected to the rims. These tires were able to be used directly for the front tires. The rear tires’ bearings and housing had to be removed from the rims and hubs and had to be made to fit both the rims of the tire and the drive shaft of the drive motor. The tires are 10 inches in diameter, which allows the vehicle to overcome objects in its path such as rocks, door jams, etc. cost

At the time the photos of this project were taken, the remote control systems were being worked on and do not appear in the pictures. They are mounted to a thin of aluminum which is clamped to the tubing of the frame. It is mounted on the opposite side of the centerline bed support from the battery.

The total of the project is $785.
CHAPTER 14
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TOOTHPASTE DISPENSING AND MOUTH-RINSING TOOTHBRUSH

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INTRODUCTION
The toothpaste-dispensing and mouth-rinsing toothbrush was developed to allow people with the use of only one hand to brush their teeth in a fast and sanitary manner. This toothbrush was designed so that the entire process of teeth cleaning can be performed using one hand.

The objectives for the function of this product were to allow a one-handed person easily to: 1) apply toothpaste to their toothbrush, 2) brush their teeth effectively, and 3) rinse their teeth and the toothbrush. The objectives for the physical product were that it be: 1) low cost, 2) sanitary, 3) reusable, 4) easy to clean, and 5) simple and quick to use.

Existing toothbrushes are very difficult to use for people with the use of one hand. It is difficult to apply toothpaste from a standard toothpaste tube to a standard toothbrush using only one hand. Also, turning the faucet on and off for rinsing is also difficult while holding the toothbrush. Existing products that apply toothpaste easily to the brush head do not address this problem of rinsing the teeth and brush.

This toothbrush was developed through a design process that began with identifying the problem and understanding the clients’ needs and led to extensive market research and the establishment of engineering specifications. Finally, a design was modeled into a working prototype.

SUMMARY OF IMPACT
The toothpaste-dispensing and mouth-rinsing toothbrush (Figure 14.1 and 14.3) allows users to apply toothpaste to the brush bristles and also run water through the brush head with the turn of two gears on the handle that are easy to use with the thumb and pointer finger. This toothbrush is easy to operate for almost all people with a hand disability.
The toothpaste is pushed from the toothpaste chamber with the turning of a gear on the handle as well. The gear turns a pulley, which pulls the base of the chamber up and forces the toothpaste up the neck. By forcing toothpaste back down the neck, the chamber can be refilled.

The toothpaste comes out of a hole in the head of the toothbrush between the bristles. The water flows from the head out of 14 holes between the bristles. The user can set the toothbrush on its flat base and turn the faucet on. The gear screw will pinch the tube and keep the water from flowing through the head. The user twists the gear that forces toothpaste up through the brush head and brushes his or her teeth. When finished, the user releases the water flow up through the head by turning the gear screw that opens the tube up. The flowing water rinses the teeth and mouth, and also rinses the bristles of the brush clean of toothpaste.

The cost of the parts of this toothbrush was $11.
INTRODUCTION
In order to assist people with arthritis, a toothbrush having toothpaste integrated in it has been designed. Frequent travelers may have interest in such compact product, which will prevent leaks in luggage.

SUMMARY OF IMPACT
Without having to use an extra hand to apply toothpaste on the brush, a single hand can be used throughout the oral treatment. The user is able to hold the large handle with good grip in one hand. He or she can next push a single button with this same hand to apply toothpaste on the brush.

TECHNICAL DESCRIPTION
The Toothbrush Combo is a cylindrical apparatus measuring 3 inches in diameter and 19 inches long. It is composed of two main components: 1) the bottom part, containing the mechanical system to push the toothpaste, and 2) the top part divided into: a) the toothpaste compartment, and b) the brush, conducting canal and tube. Those components are held together by two fasteners.

The material used is a type of plastic, UHMV (ultra high molecular weight polyethylene). The bottom part of the device is 8.5 inches long. It contains the mechanical system and six screws holding the system in place. The mechanical system is comprised of different components: batteries, switch, motor, treated rod. Power is generated by two 3CR batteries which are combined and connected to a switch by wires. The switch is a complex part which is then attached to the motor. Between the switch and the motor, contact is made by two parallel aluminum thin plates. The aluminum plates are used to better conduct electricity and also to make the whole system lighter. These aluminum plates are guided by the tip of an L shape rod, which is then attached to a button. The button is situated on the outer surface of the bottom part. It sticks out in order for the users to be able to easily press on it. The rod is controlled by pressing the button to the left or to the right. By doing so, the rod turns and pushes the plates. The plates are pushed towards the motor’s pole. When they get in contact, the motor is turned on. Depending on which side the button is pushed on, the motor can rotate clockwise or counterclockwise. The motor turned on, it spins a treaded rod connected to it. A cap is attached to the treaded rod which can then move up or down depending on the direction of rotation of the rod. While the cap moves towards the top of the toothbrush, it pushes the toothpaste.

The toothpaste is contained in the top part which is 10.5 inches long. The top part is divided in half. The first half is a storage compartment. The second half allows toothpaste flow to the brush. The storage compartment contains the toothpaste. Its capacity is 25 inches cubed. From the outside, the storage compartment has a cylindrical shape. From the inside, it has a square shape. In this compartment, the cap squeezes the toothpaste into the conducting canal. The conducting canal is perforated along the other half of the top component. It allows the squeezed toothpaste to
flow inside the top part of the whole toothbrush. Before the canal ends, there is another perforation where a plastic tube penetrates the conducting canal perpendicularly. This plastic tube comes out of the brush situated at the top end of the toothbrush. The transparent plastic tube connects the conducting canal to the brush. From the conducting canal, passing through the transparent tube, the toothpaste comes out of the tube while spreading on top of the brush.

This device is easy to operate. While holding the bottom part with one hand, use your thumb to push on the button. This activates a motor that turns a treated rod. A cap is screwed on that rod and, while the rod rotates in the counterclockwise direction, the cap moves up towards the brush. The displacement of the cap pushes the toothpaste contained in the toothpaste compartment, which in turn is squeezed into the conducting canal. Right before the end of the canal, a plastic tube is inserted perpendicularly to the canal. It allows the toothpaste to flow out of the system. The toothpaste then spreads out on the brush.

The overall cost of this prototype is: $84.

Figure 14.5. Sectional View.
ONE-HANDED JAR OPENER I

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INTRODUCTION
The easy jar opener was developed to address the needs of persons with disabilities who have limited strengths and dexterity. This design was intended for complete operation with only one hand while most jar openers require the use of both hands.

The objectives of this product were to develop a method of opening a jar that: 1) is usable with one hand, 2) requires little strength to operate, 3) is convenient to use, 4) will accept various size containers, 5) is marketable and cost-effective to produce, and 6) has a pleasing appearance.

The one-handed jar opener 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 used.

Most current jar openers, as researched, are opened through a method of using two hands. This two-handed method is either mounting and holding the jar on a base, while pressing a button or turning a lever. The few single handed jar openers found out there are expensive and not easily marketable.

SUMMARY OF IMPACT
Limited dexterity is a broad term that covers arthritis, tendonitis, and an amputated or paralyzed arm that limits the ability for persons to operate many common devices that are usually taken for granted. A jar opener is among the more complicated and challenging devices to operate with a single hand.

When operating the one-handed jar opener, the user is required to raise the top cone with the vertical lever arm. The top lever stays in this upright position to then place a jar on the bright yellow platform under the inverted cone. The vertical lever is then lowered over the jar and fits on snug. The horizontal lever with the black rubber handle is then used to twist the top off, turning to the right. The vertical lever is then raised, again, locks in place, and the jar is removed. The design has a four step easy process.

TECHNICAL DESCRIPTION
The one-handed jar opener consists of two levers, one vertical and the other horizontal. Each lever has a specific motion and task to execute. The vertical lever raises up, and locks in place, and then is easily lowered, pulled by the springs that are attached to the base. The upward motion of the lever requires about 5 pounds of strength. Coming down, the lever needs about 3 pounds to keep it steady and not come down harshly onto the top of the jar with the force of the springs. This covers the jar. Then the horizontal lever twists the top off.

The jar opener accommodates jar of approximate diameters of 4 to 6 inches.

The cost of the parts for the prototype was $76. The estimated cost for market sales is about $40.00.
Figure 14.6. One-handed Jar Opener.

Figure 14.7 One-Handed Jar Opener with Jar.
INTRODUCTION
The one-handed jar opener was designed and created to minimize the effort required to open the common household jar and to make opening the jar possible for those with only one arm or hand. Existing jar opening devices fall under three categories, those that: 1) require the use of two, full-strength hands, 2) require the jar to be held in place by the user with at least one strong hand, and 3) are completely automatic. The problem with the first two categories is that neither product is designed so that someone with one arm or hand can operate them fully, and the third category is often extremely expensive.

In response to this, the one-handed jar opener was designed to be fully functional with the use of only one hand, while remaining low in cost. In addition to these parameters, it was also designed to remain as small and lightweight as possible.

SUMMARY OF IMPACT
Lack of hand strength and the inability to manipulate everyday objects can be detrimental to a person’s ability to function. The one-handed jar opener accomplishes the goal of allowing those with severe hand disabilities to painlessly and effortlessly open jar lids with the use of only one hand.

With the advent of a low cost, one-handed jar opener, the lives of those with limited hand strength will be much less frustrating. With the absence of difficult, painful, and sometimes impossible tasks such as opening jars, the quality of life for those with hand disabilities will therefore be increased.

TECHNICAL DESCRIPTION
The one-handed jar opener is a wooden frame that will be permanently attached to a household countertop via bolts or adhesives. The frame itself is made out of a 10” x 6.5” x 3/8” particleboard base, with two 3” x 14” x 3/8” particleboard legs. These are held together by four 1 ¼” wood screws. The cross beam at the top is ¼” thick steel, with a 5/16” counter-threaded hole in the middle. A 5/16” counter-threaded bolt is fed through this hole, and brazed to the slotted adaptor and gear mechanism. Inside the slotted adaptor, a 1” spring is inserted in order to maintain downward force while in use. The gear mechanism is an existing product on the market, modified by taking off the existing handle, and using a metal pin to hold it into place. The base consists of a PVC cone with slots in the bottom to lock down to the pegs sticking out of the base plate. This cone is coated with a rubber material in order to provide adequate friction.

When the crank handle is inserted into the eyehole of the bolt, it is then rotated counter-clockwise. This advances the thread until the gear mechanism touches the top of the jar, which has been centered on the base cone. Once it reaches this point, the sides of the gear mechanism close onto the lid and then lock down. At this point, all rotational motion is then used to unscrew the lid. Because the threads are still advancing, the gear mechanism is allowed to travel upwards with some resistance (from the spring), but does not have any rotational freedom of motion.

The total cost of parts for the jar opener was $40.
Figure 14.9. One-handed Jar Opened Exploded Assembly View.
QUICK RELEASE THROTTLE AND BRAKE AID

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INTRODUCTION
Safely operating a motor vehicle with a back or lower extremity handicap can be difficult. Current available solutions focus on either permanent modifications to a vehicle, or devices that are laborious to install and remove on a temporary basis. Research shows that there is no current solution for the situation where one person using a vehicle has a handicap that requires modified controls, and another person who shares the same vehicle does not. The design shown in Fig. 14.10 was developed using multiple concepts for each function, selecting their positive aspects, and combining them into one design.

SUMMARY OF IMPACT
The Quick Release Throttle and Brake Aid is designed for the person who shares a vehicle with someone. This product allows the vehicle to be converted from hand controls to normal feet controls in less than ten seconds without requiring extraordinary strength or flexibility. This device allows both people to operate the vehicle safely in the method that is most convenient for them. The design consists of a lever that is permanently installed, and a removable connecting lever, both made from 6061-T6 Aluminum. It is simple, lightweight, and very safe and easy to operate.

TECHNICAL DESCRIPTION
The assembled device is shown in Fig. 14.10 as it would be fully installed in the vehicle with the connecting rod in place.

The Connecting Rod (Fig. 14.11) consists of two hollow tubes, the Insert and the Adapter. The Insert slides into the Adapter, and has multiple holes to allow for length adjustment. These holes allow the device to fit into most small cars and station wagons without vehicle specific Connecting Rods. The Insert has a slot that connects to the permanently installed Lever, and the Adapter has a similar slot that slides over the brake shaft.

The throttle is controlled by a cable connected on one end to a device similar to a brake from a bicycle and on the other end to the top of the accelerator pedal. The car is accelerated simply by squeezing the Accelerator which is mounted on the handle of the Lever. The brake is controlled by simply pushing on the Lever, which causes rotation about
the mount bolt, forcing the connecting rod to depress the brake pedal. When the lever is released, the force of the brake pedal returns the lever back into its starting position.

This prototype was installed on a 1994 Ford Taurus in order to evaluate the design. It was backed up for ten feet, turned a corner, and then was accelerated to thirty miles per hour using the hand controlled accelerator. The vehicle was then stopped using the hand controlled lever in less than the target of five feet.

A prototype costs were approximately $50.00.
INTRODUCTION
While there is a broad market for devices that aid in the opening of jars, only a select few existing products permit the removal of jar lids with the use of only one hand. This design project resulted in the final rendition of Jar-Beast™, a durable product that works efficiently and dependably, and is easily usable with one hand.

SUMMARY OF IMPACT
The Jar-Beast™ quickly and reliably opens jars. With a few turns of its handles, it can open almost any jar while requiring the user to use only one hand. The Jar-Beast™’s attractive and modern design will look great in any kitchen.

TECHNICAL DESCRIPTION
The base of the Jar-Beast is constructed of a combination of masonite (a plastic-coated fiber board) and billet aluminum, and measures 16.4” long, 12” wide, and 0.9” thick. The base’s sheer size and weight allows for excellent stability when removing jar lids.

The jaws that grip the jar and hold it in place are self-centering in design. This was achieved by mounting the jars on an inverted turnbuckle whose opposing-thread screws are brazed together in the center. The resulting assembly is one whose jaws move at the same rate to and from a central point when the user turns a single handle, as shown in Fig. 14.14.

To compensate for slack in the threads of the turnbuckle, as well as provide extra support for taller jars, the jaws are constructed of 2” high by 3” wide aluminum blocks that are welded to the turnbuckle. Each of the jaws has a V-shaped groove for gripping jars of various sizes. To further enhance gripping power, the V-faces on the jaws are coated with a non-stick rubber surface. With all the design features implemented, the resulting jaw assembly allows jars to be efficiently and dependably secured into place, all while requiring little physical input from the user.

The 6”-diameter lid-removing funnel is made of 24-gauge (0.024” thick) stainless steel. The funnel’s thick metal construction ensures that the funnel will not buckle, deform, or crack if the user tightens the funnel onto a jar lid excessively. The inside of the funnel is coated with the same non-slip rubber
material that coats the V-surfaces of the jaws. The funnel allows for the opening of a wide variety of popular jar sizes, and the rubberized coating provides adequate friction for the efficient removal of the jar lid when the funnel is rotated.

The funnel is attached to a threaded rod via a bearing assembly which, when turned, allows the user to adjust the funnel to an appropriate height according to the jar they want to open. The bearing assembly permits the funnel to rotate independently of the rod.

Once the jar is fitted into the jaws and secured in place, the funnel is lowered onto the lid, simulating the downward gripping force a hand would normally exert on a jar lid when opening a jar manually.

The jar lid is then removed by rotating the funnel using the attached handle. Finally, the funnel is retracted, revealing the jar with the fully loosened lid sitting on the top of the jar.

Total cost to construct the prototype Jar Beast™ was $78. However, it has been estimated that, with more cost-effective selection of materials and fine-tuning of design for ease of manufacturing, the production Jar-Beast™ could be made to sell for roughly $40.
JAR AND CAN OPENER

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INTRODUCTION
The purpose of our device is to loosen jar or can lids for easy removal. Other devices encountered are either expensive, ineffective, or too complex and prone to breakage.

SUMMARY OF IMPACT
In prototype form, this project works rather well by loosening various sized jars to the point where they are easily opened by the slightest twist.

During a redesign the movement of the twisting arm should be made smoother, as this was one of the aspects with room for improvement. Perhaps by adding tracks with wheels to allow for smoother up and down motion one can accomplish this without compromising the basic design.

TECHNICAL DESCRIPTION
Currently, this design is 18 inches high, 10 inches long at the base, and 11.25 inches wide. The cone slides up and down the center of the base while the lever arm extends eight inches. The redesign of incorporating tracks would allow for a much straighter and uniform movement of the cone. Such modifications would not affect the function, but would improve the effectiveness of the device in removing jar lids.

A few special parts were used including:

1) The rubber lined cone
2) The brass connecting joint
3) The back of the base containing the vertical track

These three parts are the main working components of our device and though they could be modified, they serve an important function and must be incorporated.

The cost of production was kept as low as possible. Figures 14.18 and 14.19 show a CAD view of our device. The cone assembly slides vertically over the
jar and the handle shown is used to pivot the cone while it grips the jar lid, loosening it for removal. Excluding screws and brackets, a total of eight parts make up our design. These CAD drawings were created in Pro-Engineer Wildfire.

Shown in Figure 14.20 is the operation of our device. The jar is in place and mild pressure is exerted downward as the lever arm is turned, taking the lid off the jar.

Parts costs come to about $20 dollars per jar opener, excluding assembly costs.
EASILY ADJUSTED BIKE SEAT

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INTRODUCTION
A trend often noticed in biking is the improper pedaling position of recreational riders. This problem is prevalent in seniors and other disabled riders. Many of them have difficulty adjusting their bike seats to proper riding position. Using a bike at the improper position often causes lower back pain and cramping, defeating the purpose of bike riding as a low-impact cardiovascular workout.

The only current solution on the market was a product called the Gravity Dropper™. This product is geared for competitive mountain bikers. The seat drops three inches with a pull of a trigger in order to give the rider an advantage going downhill. Their product does an excellent job at this, but their concept does not allow for variable adjustments. This project’s objective was to find a way that a bike seat could be easily adjusted to any height that the rider chooses.

SUMMARY OF IMPACT
The adjustment can be attached to any bike with a few easy connections. Getting on and off the bike will be easier, because the seat can be lowered before one gets on and then raised when the rider is in position. The rider can adjust the bike, while riding, to a position where they feel most comfortable, making the ride more enjoyable. This product helps to eliminate some of the annoyances that keep some people from riding bikes.

TECHNICAL DESCRIPTION
The unit was designed with two aluminum clamps at either end of the device. The top clamp connected the gas piston to the seat post. The bottom clamp connected the piston to the bike frame. This was in order to keep the piston in the proper position so the maximum force is applied to the seat. The device is activated by a lever arm, which depresses a button located on top of the piston. The lever is pulled down by a wire, which is connected to a button at the handlebars, similar to that of bike brakes.
The design was made to be universal for all bikes with similar post diameters. The piston is aligned parallel to the post so that the seat can move as smoothly as possible. The whole product is made out of aluminum, but is a little bulky. In future designs less material could be used, thus bringing down the total cost as well as making the product lighter.

The product came to a total cost of approximately $60.
EASILY-ACCESSIBLE CABINETRY

Designers: Lindsey Bellini, Daniel Flahive, and Mary Patricia O’Brien
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INTRODUCTION
The cross-link system was developed to address the inconvenience experienced by many when accessing items located in lower cabinets. The intent of this device is to bring the shelf out of the casing and raise the shelf up for any person to be able to reach the items stored on top of the shelf. Also incorporated into the universal design are objectives not to affect the aesthetics of the exterior cabinet.

Multiple ideas and concepts culminated to form the final prototype. For simplicity of design a motor was not used, nor were any other parts that require a power source; this product is based purely on a mechanical design.

Currently on the market are cabinets that have shelves that slide out of the cabinet casing, but these products have limitations. These products still make the user bend to retrieve items. Also on the market are hydraulically-lifted shelves for heavy kitchen appliances, but these are expensive and unnecessary for average kitchen use.

SUMMARY OF IMPACT
It can be difficult for an elderly person or a person with back problems to access items stored in the lower cabinets of their home. This cabinet was developed so that individuals who are elderly or who have disabilities can maintain independence. This design is easy to operate for all persons of society, regardless of ability.

TECHNICAL DESCRIPTION
The cross-link system mounts to a shelf on sliding tracks attached to the bottom of a cabinet. Each of two cross-links components are made of two 12.5” by 1” aluminum flat-stock with three 3/8” diameter holes in them. One hole is located at each end and the third is in the center of the piece of flat stock. The links are connected to each other by a pin-joint with a bolt through the middle hole of the links. The links are then connected to the upper track by two additional bolts through a hole on each link. The track is made of 2” aluminum bent stock that is 13” long. There is a 3/8” hole 7/8” from one end that is used to connect the link to the track. There is also a sliding slot even with the hole that is 5.25” long slot that connects to the other link by a bolt. The other side of the bent stock has two 1/8” holes which are used to mount the track to the sliding shelf on the bottom of the cabinet. The link attached to the slot on the upper track is connected to the lower track at the 3/8” hole by a pin-joint. The link that is connected to the 3/8” hole on the upper track is connected to the slot on the lower track by a long...
bolt that then connects to a mirror image of the cross-link system.

Two chains that are connected to the long bolt by S-hooks are anchored to the back of the cabinet by eye-bolts. As the user pulls the door open, the chain becomes taut and the long bolt in the lower tracks’ slots move along the tracks causing the links to come together and the shelf to lift (Fig. 14.25 and 14.26). A spring is used to decrease the amount of force needed to move the cross-links. When the cabinet is completely opened, a 20” piece of aluminum slides into place between the casing and the shelf. This locking system keeps the chain taut and the shelf at its full height. To close the cabinet, the locking device has to be disengaged. As the cabinet is pushed back into the casing, a spring helps the process be smoother. As the chains become loose, the links move back into their original place and the shelf lowers. Cables attached to the back of the cabinet keep the chains away from the sliding tracks.

This product enables usage on most current cabinetry. The length of the cross-links and tracks can be machined to fit any cabinet.

The materials that were chosen are capable of sustaining a 15 pound load. Aluminum was found to be the optimum material for the cross-links due to its light weight and strength needed for the load. Since the cross-links needed to be attached to the bent metal stock, it was decided that these tracks also be made of aluminum. This allowed for the two pieces to be easily attached using bolts.

The prototype (Figure 14.28) constructed is a down-size of the actual product. The cost of the parts for the prototype was $50.11. The estimated cost for the full size product in mass production to be $48.00.
AUTOMATIC MOTORCYCLE CENTER STAND

Fitsum Berhe
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INTRODUCTION
A motorcycle center stand was designed to assist riders as they stop and go on their motorcycles. Many motorcyclists with lower limb disabilities are unable to ride because they have difficulty stabilizing the motorcycle. Also, people of smaller stature may not be able to make ground contact with their feet. A motorized center stand stabilizes the motorcycle when necessary with minimal effort to the rider. Patents for similar devices exist in the market today but require alterations to be made to the motorcycle. This design is unique in that it mounts onto the frame using existing fasteners.

SUMMARY OF IMPACT
Motorcycle riding can be for leisure or out of necessity. Many people have either no use or limited use of their legs and so they may not be able to participate. Motorcycles can weigh up to 800 pounds without the rider. When riders start and stop their motorcycles, they need to use their legs to prevent the motorcycle from falling to one side or the other. This motorcycle support could make motorcycles more accessible to those with disabilities ranging from loss of legs to arthritis. Using this system, they could enjoy the opportunity to ride a motorcycle. In addition, riders without disabilities can use the system for added convenience.

TECHNICAL DESCRIPTION
The automatic center stand consists of a steel crosspiece that mounts underneath the motorcycles exhaust. It is welded to two brackets on each side of the motorcycle. One of the brackets is attached to the frame using two motor mount bolts. In order to accommodate the thickness of the bracket, the original bolts were replaced with slightly longer ones. The bracket on the other side is affixed using the original kickstand position switch bolts and a U-bolt around the frame. A section of steel square tubing is welded perpendicular in the center of the crosspiece in order to mount one end of a linear actuator.

The linear actuator is the device used to automate the stand. The other end of the actuator is mounted to another section of steel square tube that is welded to the motorcycles center stand. Both ends of the actuator are mounted on clevises that allow it the freedom to rotate as it extends and retracts. The
motorcycle’s original center stand needed to be modified in order for it to serve its new function. Standard center stands lift the motorcycle’s rear tire off the ground. Therefore, the legs of the stand were shortened to an appropriate length such that it just makes contact with the ground. Wheels were attached to the stand so that during rolling starts and stops the bike’s support could slide relative to the ground. Two inch diameter rubber wheels were mounted on the outside of the stand. Finally, a switch was wired from the actuator and mounted between the handle bars so that it could be easily activated by the rider. In experimental trials, the design proved successful. After installing the automatic center stand, it was tested for a week under varying road and weather conditions. It completely eliminated the need for the motorcyclist to use his feet during starting and stopping.

The total cost of parts and supplies was $81.
ADAPTED BRAKE AND THROTTLE

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INTRODUCTION

The Adapted Brake and Throttle (ABAT) is a design that enables a person without function of either leg to drive an automatic transmission car. Existing solutions are expensive permanent fixtures, or are not simple enough to operate. In order to meet the goal of a portable and cheap system, easily-manufactured and pre-existing parts are utilized. Broken or worn parts are, therefore, replaceable without hassle.

What sets ABAT apart from similar portable devices is its squeeze throttle action. Both braking and throttling are accomplished by low effort force. The device fits most compact and mid-sized cars, allowing a comfortable driving position.

SUMMARY OF IMPACT

With the ABAT, a person with disabilities is able to drive any number of cars, because the non-permanent assembly can be installed in five minutes, and removed in two minutes. The straps only need to be special-fit to the brake pedal beforehand. A second car or complex electro-mechanical system for the disabled person is not necessary.

TECHNICAL DESCRIPTION

The ABAT boasts a squeeze throttle action, a bar that engages the throttle when pulled up through a direct link cable. The base is a hinged steel plate, which straps to the brake pedal. Bolted to the base is a steel rod, which the cable passes through. A steel base cap tops off the rod and is removable when fastened with wing nuts. Two steel rail guides are bolted to the base cap and allow the squeeze throttle to slide. A wooden dowel is screwed in between the top of the two rails, where the force to operate the brake is applied.

Total cost of the concept is $22, cut from a steel rail, a rod, and steel stock. An all aluminum production version would weigh much less, and would cost about $30 for a concept. The projected cost of
materials for production is $10 per aluminum ABAT.

Figure 14.34. Client using Adapted Brake and Throttle.
ALARM CLOCK FOR INDIVIDUALS WITH HEARING IMPAIRMENT

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INTRODUCTION
Waking up at a particular time to a standard alarm clock is difficult for people who are hearing impaired. Alarm clocks for people who are deaf exist, but they primarily consist of a pad that vibrates, which is placed under a pillow. The problem with this is that, if the pad is moved during the night, then the clock may fail to wake the person. An alarm clock with a vibrator that goes directly into the pillow ensures waking up on time.

SUMMARY OF IMPACT
This design is the same size as a standard alarm clock. It was created with younger children in mind. The alarm clock is encased in a pillow shaped like a ladybug. The vibrating unit is attached by wires to the primary pillow, which encases a vibrating device. The vibrations begin lightly when the alarm goes off, and eventually become more intense. It is easy to use and effective in waking people from their sleep.

TECHNICAL DESCRIPTION
The alarm clock consists of two units. The first unit is the base unit. The base unit consists of a modified standard alarm clock. It has a digital display and the typical functions of standard alarm clock. The alarm sound function has been rewired to a resistor which amplifies the voltage being sent to the vibrator. The second unit is the vibrating pillow. This is located directly inside the pillow.

Because the vibrations become intense, this alarm clock could also be used by heavy sleepers, who have trouble waking up to sound. The parts used in this design are easily manufactured. Production is simple, and could be produced in mass.

The cost of this design is approximately $35.
Figure 14.37. Pro-Engineer drawing of Clock Prototype.

Figure 14.38. Circuit Diagram of Alarm Clock.
ASSISTIVE AUTOMOBILE BRAKING AND ACCELERATION SYSTEM

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INTRODUCTION
Drivers with lower limb injuries face difficulty in operating automobile pedals. Hand-operated pedal control systems are a typical solution to this problem. Existing products employ rigid bars that attach directly to the brake and gas pedals which the driver must push or pull while steering the vehicle. This can be cumbersome and have a negative impact on the overall driving experience. There is currently nothing on the market that resembles this product.

SUMMARY OF IMPACT
The system is universal and can be adjusted to fit on any automobile steering column. Only the driver’s arm strength is needed to work the levers that operate the hydraulic cylinders on which the system is based; no external pumps or power sources are needed. By allowing the driver the use of hand controls to operate the pedals, the driving experience can be both comfortable and enjoyable. Aluminum and steel are the primary construction materials, while PVC reinforced hose is used to transmit the hydraulic fluid between cylinders. These robust materials ensure product longevity and reliability. Drivers who have trouble operating standard braking and accelerating systems will be able to drive independently.

TECHNICAL DESCRIPTION
The Assistive Braking and Acceleration System consists of several key components, such as a control module clamped around the steering column and an actuator module that lies in the foot-well of the car. Figure 14.39 displays the system in its entirety.

The driver operates the device by pulling (or pushing) either one of two handlebars that push on master hydraulic cylinders. From a neutral position, pulling the handle activates the brake master cylinder, while pushing the handle activates the gas master cylinder. Hydraulic fluid is then pushed through individual PVC-reinforced hoses to the appropriate slave cylinder down on the actuator module. The actuator module consists of a wood frame attached to a quarter inch thick, rubber foot-mat that sits in the foot-well. The two slave cylinders rest on top of the wood frame, one for the brake and gas pedals respectively. These are placed such that the pistons in the cylinders will push directly against the pedals. The foot-mat which holds the frame and cylinders in place, sits against the rear of the foot-well to keep the cylinders from moving backwards when activated.

The control module is fastened to the steering column by an octagonal shaped clamp, comprised of two steel sheets, that fastens together using 4 bolts in the horizontal direction. Each half of the clamp is made from a 1/8" thick, 2"x12.5" sheet of steel, bent into the appropriate shape. Two steel tabs are welded to the bottom of these with coaxial holes drilled through them to support the axial torsion bar. Two handlebars are attached to the ends of the torsion bar, and are perpendicular to its long axis; both are approximately 12” long. Also attached to the bar are plungers that push on the master cylinder pistons as the bar is rotated. The left clamp half has the master cylinders mounted to it. This
leaves the bulkier side of the clamp closest to the door opening for easier installation.

The two master cylinders are both made from 2” diameter, machined aluminum; both have 1” diameter aluminum pistons. Each cylinder is welded to its own 3/8” thick aluminum plate. Another 1/8” sheet of steel is welded on the side of the left clamp half, and each aluminum plate (with its cylinder) is bolted to this steel plate.

Two heavy-duty, reinforced PVC plastic hoses, one for each cylinder, connect the master cylinders on the control module with the slave cylinders on the actuator module and are rated to withstand more than 300 psi; both hoses are 0.5” outer diameter, 0.25” inner diameter. Fig. 14.40 shows the control module and the connecting hoses.

The actuator module starts with a commercial grade foot-mat as a mounting surface for the wood frame. It also serves to keep the frame stable and stationary. The simple wood frame is constructed of 2x4 spruce wood timbers. On top of these are the two slave cylinders. The brake cylinder is 1.5” diameter machined aluminum with a 0.5” diameter aluminum piston. The gas cylinder is 1.5” diameter machined aluminum with a 3/8” diameter aluminum piston. These are fastened to the wood frame with metal U-brackets and positioned so that the pistons are in line to make contact with the pedals.

A 20 lb maximum operating force is required to operate either of the two handles; both have a 60 degree range of motion from the neutral position. There is a 9:1 mechanical advantage when pulling either of the handles, resulting in a 50 lb force exerted on the pedals by the master cylinder pistons; both pistons are allowed a 6” stroke length during operation. Regarding the PVC hose and all cylinders combined, an approximate total of 1.77 cubic inches of hydraulic fluid is needed for optimum performance. As with any hydraulic system, the absence of air pockets within the cylinders and hose is critical; only then, through fluid suction, will all pistons return to their initial positions.

The total cost of the materials used is approximately $62; the aluminum stock used for the cylinders constitutes the bulk of this figure.
AUTOMATED WHEELCHAIR STORAGE SYSTEM

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Sascha Ruemenap, and Dan Santos
Collaborators:
John Deere, PTC, Georgia Tech, Univ. of Illinois, Univ. of Maryland, Bentley College
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INTRODUCTION

The objective of this engineering project is to modify the existing John Deere Gator (Figure 14.42), a small utility vehicle used for hunting, fishing, and on golf courses etc. The location to store the wheelchair was first determined through a selection decision matrix. With the chosen location, the device to move the wheelchair from the point at which the user leaves the wheelchair, to the storage location, needed to be designed. Research was done on different ways to complete the required tasks: pick and place (e.g. lifting, rotation, and translation), attachment, and folding of the wheelchair. Concepts were then generated, evaluated, revised, and finally a concept was selected for the design. The final design is a pole located behind the driver with a rodless linear actuator that sits atop a gear, which is attached to an electric motor, and acts as a turntable. Attached to the actuator is an arm perpendicular to the pole. At the end of the arm, away from the pole, the attachment device for the wheelchair is located. The attachment device is one track, in which one of the wheelchair wheels is rolled into and then locked into place.

SUMMARY OF IMPACT

This design is a major component in making the Gator accessible to wheelchair users. The design allows for the storage and unloading of the wheelchair and interfaces with another design project, that of a seat transporter so that the person using the Gator does not need any help getting into, getting out of the gator, and storing and retrieving the wheelchair. With this design, in conjunction with the seat transporter, a new market has been opened for the John Deere Gator while also expanding the choices and freedoms for those with disabilities.

TECHNICAL DESCRIPTION

The design of the pick and place mechanism was designed in three steps: determining the location, designing the way to attach the wheelchair to the mechanism, and the how to pick and place the wheelchair. The best location for storing the wheelchair was determined to behind the passenger seat of the Gator with the wheelchair folded and...
standing on its wheels and parallel to the side of the Gator.

The best way to transport a wheelchair to the selected storage location from outside the Gator is using a linear actuator to lift the chair. The linear actuator sits on top of two bearings and a turntable, which is directly connected to a pneumatic rotary actuator that turns the whole assembly.

There is an arm which extends from the linear actuator and connects the pick and place part of the design to where the wheelchair attaches to the device.

The wheelchair attaches to the device via a track which one of the wheels is rolled into. Then a locking mechanism slides down the post and locks the wheelchair into place. This locking device makes it safe for the user to move out of the chair, folds the chair, and latch the chair so it stays folded.

With the wheelchair in place, the pick and place device can be activated.
ASSISTIVE TOOTHPASTE DISPENSER

Designers: Robert Leidel, Chris Rochon, and Jon Ciccarelli
Supervising Professor: Janis Terpenny, Ph.D.
Department of Mechanical and Industrial Engineering
University of Massachusetts
Amherst, MA 01003-2210

INTRODUCTION
A project was developed to aid a person with a hand disability aid in brushing his or her teeth. Two of the major product types researched (using the Thomas Register and the USPTO Patent Database) are disposable toothbrushes with the toothpaste in the handle and toothpaste dispensers with motorized pumps. Using design practices such as the 6-3-5 method, a House of Quality (QFD) matrix, a customer questionnaire, and the TRIZ method, a new option, a mechanical toothpaste dispenser was developed with the aim of balancing cost efficiency with functionality.

SUMMARY OF IMPACT
The assistive toothpaste dispenser allows a person with only one hand or limited manual dexterity to easily put toothpaste on his or her toothbrush, without requiring use of a specialized toothpaste or toothbrush. Furthermore, the product may be useful to persons without disabilities. It provides a sanitary, semi-permanent stand for toothpaste and a temporary stand for a toothbrush during use.

TECHNICAL DESCRIPTION
The entire housing of the dispenser prototype was created from aluminum and the components were subsequently welded together. The roller assembly was also manufactured from aluminum with the exception of the large wheels, which were cut out of fiberglass. When the wheels are turned, the rollers turn in opposing directions, squeezing out toothpaste while advancing down the tube. Tracks along the walls guide the rollers. The rollers themselves are covered in a rubber shrink wrap to promote this action. The result is a controlled amount of toothpaste leaving the tube to be used on the toothbrush below it.

At a reasonable cost to the user, this design is reusable, in contrast to disposable toothbrushes.

Additionally, because our dispenser is a purely mechanical system, it is simple enough that it requires no complex set up or special care due to electronic parts.

These characteristics make the dispenser easy to use, easy to assemble, and affordable.

While the prototype works, it is only a proof-of-concept. Injection molded plastic would be the ideal material to create the marketable product. This is partially due to the high tooling costs of aluminum. Not only would it be less expensive and faster to injection-mold all parts out of plastic, but a large metal structure would surely drive away many potential customers. An additional benefit of using plastic would be reduced friction and, therefore, less required force. Using an injection-molding estimator (Professor Kazmer, Univ. of Massachusetts-Amherst), the estimated cost is $7.04/part, including processing, materials, and tooling. This is based on an analysis of potential customers and a conservative estimate of a production volume of 20,000 in the first year. The price to consumer would be less than $15.00.
Figure 14.49. Roller Assembly.
**IMPROVED TOOTHPASTE DISPENSER**

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*Supervising Professor: Janis Terpenny, Ph.D.*

*Department of Mechanical and Industrial Engineering*

*University of Massachusetts*

*Amherst, MA 01003-9265*

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**INTRODUCTION**

A toothpaste dispenser was designed to assist those with hand disabilities. For the most part, the designs for combination toothpaste/toothpaste dispensers are designed for people who travel and not for an individual with disabilities.

**SUMMARY OF IMPACT**

The main goal of the Improved Dispenser was to design a dispenser that can be used with, and maintained with, one hand. Additionally, the design is easy to operate for people who have trouble with coordination. The Improved Dispenser will make the task of brushing one’s teeth easier and less frustrating. In addition, people who have suffered a temporary ailment, such as a broken hand or finger, will also benefit from an easier application of toothpaste.

By designing a toothpaste dispenser that works with the tube style toothpaste container, customers will not be forced to buy a single brand of toothpaste. The Improved Dispenser is also made from components that are reliable and easy to replace, making it a long-lasting solution.

The Improved Dispenser was designed so that it could be practical for everyday bathroom use. To do this is electric solutions were not used for safety purposes. In addition, batteries were not used to save users from constantly having to spend money to replace them. The most practical solution was a manual device.

**TECHNICAL DESCRIPTION**

The Improved Dispenser is made of five main components: 1) the base, 2) the roller, 3) the gear, 4) the rack, and 5) the ratchet. The base in the prototype was made of three separate machined aluminum pieces out of convenience. In reality, the base would be a single plastic piece. The base itself is nine inches long, three inches wide, and the three inches in height. The base floor holds the toothpaste tube and also secures the rack. The side walls are a quarter of an inch thick and slotted. The slots serve the function of holding the roller and setting the roller height so that it is offset from the base floor that the toothpaste tube rests on. The offset is equal to the thickness of an empty toothpaste tube. This allows the roller to be able to roll out all the toothpaste. The front side of the base has a piece that serves the function of holding the toothpaste tube in place, and preventing it from moving forward or being bent upward. The bottom of the base is made of a material with a high coefficient of friction. This allows the base not to slide on the bathroom counter when force is applied the ratchet.

The roller is made of one shaft that consists of two different diameters. The first diameter is equal to the diameter of the gear hub (1/4 inch). The gear fits onto this portion of the shaft. This diameter also allows the roller to slide in the slotted side of the base walls. The ratchet is attached to the roller and allows for the user to turn the roller and gear with a high ration of mechanical advantage. As the roller turns, the gear being set on the rack allows the roller to move in the horizontal direction, and as a result, the roller larger diameter (1 inch), applies force to the toothpaste tube. When all the toothpaste is dispensed, the ratcheting direction can be switched so that the tube can be taken out and a new tube can easily be placed underneath the roller.
For the prototype, the roller, gear, and rack were all comprised from aluminum, but for the final design would be made from plastic. By making these pieces plastic one will be able to cut down on cost while maintaining functionality. Plastic gears and rack are commercially available, and when bought in bulk, very inexpensive. In addition, the final design would also include a manufactured ratchet opposed to a commercially available ratchet. The projected final cost and prototype cost were:

<table>
<thead>
<tr>
<th>Component</th>
<th>Prototype Cost</th>
<th>Projected Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass Gear</td>
<td>$12.15</td>
<td>$0.98</td>
</tr>
<tr>
<td>Brass Rack</td>
<td>$27.48</td>
<td>$1.90</td>
</tr>
<tr>
<td>Ratchet</td>
<td>$10.30</td>
<td>$3</td>
</tr>
<tr>
<td>Aluminum</td>
<td>$10</td>
<td>$2</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$59.63</td>
<td>$7.88</td>
</tr>
</tbody>
</table>

From the projected material cost of $7.88 and manufacturing cost the estimate of the overall price for Improved Dispenser would be $24.40. This figure is already $3 less than the major competitor. Going into production and possibly making minor modifications would allow the Improved Toothpaste Dispenser to be more affordable than the current solution.
**INTRODUCTION**

The PG Propulsion Wheel allows wheelchair users to more easily navigate up inclines or over obstacles that they encounter in their homes and in their everyday lives. The wheel is equipped with a gearing system, so the users can exert less force to propel themselves.

The objectives during production were to make the system modular. The user should be able to switch back to their existing wheel, if needed. The method of propulsion was kept the same, to maintain consistency in the users’ lives. Another objective was to maintain the relative width of the wheelchair. It is already difficult for people in wheelchairs to navigate through doorways and other small passages. The last objectives were to allow the wheelchair to be easily transported and keep the product relatively inexpensive.

There is no existing system that is directly comparable to the PG Propulsion Wheel. Current proposed designs have the gearing system on the backside of the wheel. These products are not modular and the wheelchair cannot be folded up for easy transportation.

Electric wheelchairs are another option for people with limited arm strength. Electric wheelchairs can cost anywhere from $2,000 to $10,000. They are also bulky and hard to transport. Other people opt to buy threshold ramps that help them get over thresholds from room to room. These can cost $50 to $60 a piece, which can add up and become costly.

**SUMMARY OF IMPACT**

For wheelchair users with weaker arms it is difficult to navigate on inclines or over obstacles, such as bumps in pavements or thresholds between rooms in homes. The PG Propulsion Wheel gives wheelchair users an option that allows them to exert less force to mobilize their wheelchair. The wheel does not add width or change the method of propulsion of the existing wheelchair.

**TECHNICAL DESCRIPTION**

The PG Propulsion Wheelchair works by using a planetary gearing system. The planetary gearing system consists of a central gear, the sun, attached to the central axle and made out of mild steel. The sun is surrounded by three larger fiberglass circular gears, referred to as the planets. The three planets and the sun are enclosed by an outer ring of fiberglass. Attached to the back and front of the outer ring are circular aluminum flanges that restrict the planets from slipping out of place.

The rim is connected by a set of six 3/8” diameter stainless steel rods that are welded to the sun. The rods act a set of secondary spokes, which allow the sun to rotate as the rim is propelled. The attachment of the rim to the sun also allowed the user to keep the same method of propulsion.

The outer ring is connected by a galvanized steel bracket to a stationary section of the wheelchair.
behind the wheel. By allowing the sun to rotate with the propulsion of the wheelchair and keeping the outer ring stationary, the planetary gearing system works properly.

The bracket is attached to the wheelchair by a quick-release attachment. The assembly is designed to be attached using the quick release axle of the user’s existing wheelchair. The central axle may be the only universal feature on manual wheelchairs. The PG Propulsion Wheel is designed to be mounted by inserting the axle through the center of the sun. The mounting of the wheel is also designed so that it is able to be taken off whenever the user needs to use an ordinary wheel.

The planetary gearing system used can provide a mechanical advantage ranging from 2:1 to 10:1. The mechanical advantage can be decreased by increasing the size of the sun and decreasing the size of the planets. For the prototype, a mechanical advantage of 7:1 was fabricated, in order to demonstrate the concept visually.

The design has shown that the design idea is practical. The force needed to move the rim is substantially less. The decrease in force needed is gained at the cost of speed. Tests on inclines demonstrate the minimal force needed to ascend the incline.

Plans for an actual model of the PG Propulsion wheel include nylon gears. These would keep the weight of the existing wheelchair relatively similar. Nylon gears would also minimize any noise that the gears would make.

The total cost of materials to produce the prototype of the PG Propulsion Wheel was $211. The material cost does not include the cost of the wheel or the rim.
INTRODUCTION
The long-cane is a widely used and accepted travel aid of people with visual impairments. An enhanced long-cane travel aid with an embedded electronic collision warning system was developed to reduce risk of injury from walking into suspended or overhanging objects.

SUMMARY OF IMPACT
A user of the traditional long-cane can feel the nature of a path and can detect holes, bumps, curbs, steps and obstacles on the ground. However, suspended or protruding obstacles above waist height cannot be detected with a traditional long-cane. Embedding a microprocessor controlled ultrasonic sensor system into a long-cane will make travel safer for the user and advance the state-of-the-art of mobility aids research.

TECHNICAL DESCRIPTION
A miniature ultrasonic obstacle detector using an embedded DSP capable microcontroller and piezoelectric transducers is embedded into the body of a long-cane. A coded ultrasonic pulse is sent out to bounce off all obstacles up to four meters ahead of the user. Two receiver transducers capture the reflected signals which are decoded using correlation techniques. The two receivers form a synthetic aperture that discriminates obstacles that pose a collision hazard. The range and elevation of obstacles detected in the danger zone are calculated from the geometry of the sensor array, the time of flight information, and the angle of tilt of the cane. The information is transmitted at 900 MHz to a wireless receiver and microcontroller which indicate the range of the obstacle to the user in a voice message.

To achieve pulse compression, a binary code sequence, a 13 bit Barker code, was embedded into a carrier signal by shifting the phase of the signal 180° between ones and zeroes. As shown in the figure, a transmitted pulse with an embedded binary code sequence can be detected even if the energy content of the reflected signal is low and the signal is buried in the noise. The technique can also differentiate between obstacles spaced closer than the length of the pulse. The ultrasonic transmitter and receivers used were 40 kHz piezoelectric transducers.

A representative echo was sampled and used for the reference vector in correlation to compensate for the system response. This reference vector is cross-correlated with 53 ms of received signal to identify the echoes from obstacles up to 3 meters away and determine the TOF. A cross correlation between the signal vector and the reference vector associated with the coded transmit pulse is then performed as in Eq. 14.1.

$$c(l) = \sum_{i=0}^{N-1} e_i \cdot x_{i+l} \quad l = 0, 1, \ldots N$$  (14.1)

where:
- $c(l)$ is an element of the result of the cross correlation vector,
- $N$ is the number of samples in the signal,
- $e_i$ is an element of the zero-padded correlation vector,
$x_{t+1}$ is an element of the compensated signal vector, and

$l$ is the lag.

The vector resulting from the cross correlation shows a peak or local maximum for each received echo. The timing of a peak is proportional to the distance to an obstacle. The peaks in the vector from one receiver are matched to corresponding peaks in the vector from the second receiver. The fixed spacing between the receivers determines the maximum arrival time difference that an echo returning from a particular obstacle can have.

Fig. 14.58 shows the geometry of the two receivers. The simpler, vertical arrangement of the receivers is shown in black. The blue shows the receivers at an angle of 34° as they would be in the long-cane.

There will be no difference in arrival times when the obstacle is centered in front of the receivers. The difference in arrival times at the two receivers can be calculated for the vertically oriented receivers as:

$$\Delta t = \frac{d}{c} \cdot \sin(\theta)$$

where:

$\Delta t$ is the difference in arrival times,

d is the distance between the receivers,

c is the speed of sound in air, and

$\theta$ is the angle between the line perpendicular to, and bisecting, the line connecting two receivers and the line from the bisect point to the target.

There is a finite range of $\theta$ for the censor embedded long cane to respond only to obstacles that pose a collision threat not detectable by traditional use of the long cane. The first set of peaks that collaborate within that range trigger a warning.
INTRODUCTION
The Single Hand Jar Opener is intended to allow the user to loosen jar lids with one hand while remaining relatively light, simple and portable. Considerations of the target audience, composed primarily of those who are elderly and those with limited use of one hand, dictate a specific set of engineering requirements. First, the device must be entirely operable with only one hand. The device must operate with little or no grip strength. The operation must be simple and the device must be portable.

SUMMARY OF IMPACT
The Single hand Jar Opener widens the group of people who can open jars. It allows anyone with the use of one hand to successfully remove jar lids. People with limited use of both hands (including limiting grip strength/ability) can effectively use the device. It is also useful for those who have only occasional difficulty with jars and others who seek an efficient lid-removal tool.

The prototype shown here represents the early development of the design. It demonstrates the overall effectiveness of the concept at meeting the design requirements and highlights some of its primary advantages over alternative concepts. The opener is simple to use, is self-adjusting and requires only one handle and one motion for all aspects of its operation. It lays flat for convenient storage and requires no electricity for operation. As a prototype, it does not represent a mass producible design; additional modifications will be necessary prior to the introduction to market. An anti-roll device should be fitted to the opener to maintain a parallel orientation between the opener rails and the surface on which the jar rests. It would be composed of a rectangular base frame and telescoping uprights running through the side rails.

TECHNICAL DESCRIPTION
The Single Hand Jar Opener device is intended to coverts linear motion from the user into rotational motion on the lid. The prototype is shown in Fig. 14.60. It is composed of two sliders, a lower jaw and an upper opener track. A fixed back stop forms the other half of jaw. The sliders run in the side rails which form the frame of the device. A scissor mechanism transfers the user’s force from the handle to the sliders. See Fig. 14.63 for part arrangement.
To use, the device may be removed from convenient storage via the handle; which extends the scissor mechanism, pulling the sliders together, preparing them to accept jars. The device is then placed on the jar, centering its lid the on the transparent top piece. As the handle is depressed, force is transmitted through the scissor linkages to the sliding plates. The bottom jaw slider moves against the jar, forcing it against the fixed backstop. The top slider moves in the opposite direction of the bottom slider contacting the jar lid. As the force is increased, the spring is compressed until the normal force generated on the lid is sufficient to stop slippage, at which point lid rotation is initiated. When sufficiently loosened, the device is lifted by the same handle causing the sliders to retract, which frees the jar. The lid may then be removed. The handle is depressed with the device off of the jar to return it to the storage position.

As produced the prototype has dimensions of: 21 ½” x 7 ½” x 4” in the compressed position and weighs 9 3/4 lbs. It can be produced from commercially available aluminum at an approximate $46.00. Design changes for mass production could approximately cut the costs in half.
INTRODUCTION
The Conehead Jar Opener is designed to aid in the opening of tight jar lids. This device is applicable to a wide variety of people of different ages and abilities. The Conehead is designed to adjust to the many different shapes and sizes of jars. The opener can help anyone with a missing arm, hand, and/or fingers, anyone with a disease such as arthritis or tendonitis, or anyone who does not have the strength to open a tight jar lid.

SUMMARY OF IMPACT
The design is lightweight and mechanical. The proof of concept had some materials-related problems that could be solved with tighter manufacturing tolerances and improved selection of materials. Those problems aside, this design provides a sufficient mechanical advantage to tackle the design challenge.

TECHNICAL DESCRIPTION
The Conehead Jar Opener has five main parts which work together to perform the final objective of opening a jar: 1) the base plate, 2) the vertical column, 3) the lockdown lever arm, 4) the cone; and 5) the rotating base.

The base plate, which stabilizes the entire device, is equipped with four rubber pads on the bottom which prevents the jar opener from slipping. The base plate is 12” long, 12” wide, and is 3/8” thick. It is machined from 60-61 aluminum.

The vertical column connects the base plate to the lockdown lever arm. This column in 12” tall, which allows larger jars to be opened. It is also 1” thick enabling it to withstand the torque needed to open a jar.

The lockdown lever arm is a unique part to the Conehead Jar Opener. The lever arm can move up and down, enabling any size jar to be opened. As the lever is pulled down, it locks down on the jar, creating a strong normal force on the jar. The lever is an 8” long, cylindrical shaft made of stainless steel.

The cone (4) is responsible for gripping the lid of the jar. Once the lever has been locked on the jar, the cone grabs the lid with its internal rubber lining. The cone shape allows the device to adapt to the many different shapes and sizes of jars. The internal rubber lining creates a strong friction force enabling the jar lid to be stationary as the rest of the jar is rotated. The cone is made of thick plastic. The length of the cone is 8”, while is has a 6” handle on top allowing the user to get a good grip on the device.

The rotating base is where the jar is placed. It has a connected lever arm which, when turned, creates a mechanical advantage for the user. The rotating base has a rubber surface which creates a friction force on the bottom of the jar. The rotating plate is made of 60-61 aluminum.

A “directions” section would be available with the packaged device stating the following: Place the jar on the rotating base. Pull the cone over the jar pressing down on the lid, thus locking the cone on the jar. Then rotate by pulling the lever on the
rotating base plate in a clockwise direction. Lift the cone off and the jar will be open. An approximate cost is $23.

Figure 14.65. Designers and Conehead Jar Opener.
INTRODUCTION
Tooth decay is one of the most prevalent diseases in the United States today coming in second only to the common cold. In their efforts to avoid this disease, Americans spend $2 billion a year on dental products such as toothpaste, toothbrushes, and mouthwash. Such products are essential to keeping our teeth clean. However, people with limited manual dexterity may find the simple task of applying toothpaste onto the brush to be quite challenging. Examples of those affected may be those who have carpal tunnel, arthritis, or a broken arm or hand.

SUMMARY OF IMPACT
Temporary or permanent disabilities in the hands or arms affect millions of Americans. By combining the paste and brush into one easy-to-operate device, the Pastebrush makes brushing teeth a simple one-handed task. Simply grasp the brush and give the dial a quarter turn and paste is applied to the bristles. With its ergonomic grip and smooth operability, the Pastebrush is easy to use for anyone with a disability in a hand or arm.

Looking for the perfect travel companion? With its compact size and all-in-one capability the Pastebrush eliminates the need to pack a toothbrush and toothpaste when traveling. Also, the twist n' lock cap allows the user to insert any type of paste. Snap-on, replaceable brush heads allow for easy replacement of the bristles when they become worn.

TECHNICAL DESCRIPTION
The overall design of the Pastebrush is shown in Fig. 14.67. It is comprised of six parts, the most complicated of which is the ball valve that is used to start and stop the flow of paste through the brush head. The spring, with the stopper mounted on top if it, serves as the driving force that moves the paste. The stopper has a conical shaped depression on the top with a slope of five degrees below the horizontal. This angle allows the paste to be taken from the sides of the main tube and brings it towards the center.

The cap, on the bottom of the brush, is designed so that it can be easily manipulated using only one hand. J-shaped grooves cut into both sides of the cap allow the pegs from the main tube to be locked into place by the compression force from the spring.

A key part of the design involves the brush head itself. In order for paste to flow from the main tube to the bristles the brush head must be hollow on the
inside with a hole coming up though the center of the bristle area. In the prototype model the head of an Oral-B Crossaction electric brush was used as is shown in Fig. 14.67 and again in Fig. 14.68. Brush heads on the production model shown in Figs. 14.69 and 14.70 are designed to be replaceable for maximum brush usage.

As is shown in Fig. 14.57 the Pastebrush is also equipped with ergonomic grips to make grasping it easier, and allowing for a better overall grip when brushing. A performance evaluation was done to see how our final product stacked up against our initial target values. These values were as follows: two brushings per day, one to two pea-sized amounts of paste per brushing, and a total of 82 to 165 brushings. The final design of the Pastebrush is 8” long and 7/8” in diameter. This allows it to hold 81 to 162 brushings worth of paste for an adult and a child respectively. The number of brushings is based on the dentist-recommended allotment of one pea-sized amount of paste for a child and twice that for an adult.

Current products on the market only hold 30 brushings worth of paste. Based on an average of two brushings per day, these brushes would only last two weeks. The Pastebrush on the other hand can hold six to twelve weeks’ worth of paste for an adult and a child respectively. Our design far exceeds that of our closest competitors. The Pastebrush can be refilled and the brush heads can be replaced, while the competitor’s brushes can do neither. The projected selling price of the Pastebrush could be as low as $3.45. This number is based on a 15% profit margin and the competition’s selling price of $3. Due to the quality of its design and added features such as ergonomic grips, refillable option, and twist n’ lock cap the Pastebrush could easily sell for $5. This is still a third of the price of the average electric toothbrush.

The final cost of producing the prototype was $27.24. However, this number is slightly inflated as it includes the price of PVC cement, Plumber’s Goop, and an Oral-B Crossaction brush of which only the head was used. Without those materials, the cost was $12.59. It should also be mentioned that the ball valve used in the prototype was purchased at Home Depot for $4.97 and is made of chromed brass. All of the parts on the production model are designed to be injection molded except for the spring.
UNIVERSAL TOOTHPASTE DISPENSER

Designers:
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Supervising Professor: Janis Terpenny, Ph.D.
Department of Mechanical and Industrial Engineering
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Amherst, MA 01003-2210

INTRODUCTION
A device was designed to aid people with one functional hand in brushing their teeth. It incorporates a motor to provide power to dispense the toothpaste.

SUMMARY OF IMPACT
With our product, brushing one’s teeth is made easy for both people with one functional hand and the use of both hands. For people with the use of one hand, however, it is a vast improvement from any other the current devices on the market today.

TECHNICAL DESCRIPTION
The device is a mechanical toothpaste dispenser that uses an electrical motor to dispense the toothpaste. Upon the depression of the button, the motor is activated, powering the gears. The gears then rotate a screw, which drives a plunger upwards. This plunger is located inside the toothpaste canister. It is forced to move upwards as it is prevented from rotating by the square design of the toothpaste canister. This moving plunger provides an increase in pressure within the canister, driving the toothpaste out of the top. The toothpaste travels through the affixed nozzle and enters the tubing. The tubing transports the toothpaste and delivers it directly above the button, and onto the toothbrush, which is depressing the button.

The whole process detailed above happens simultaneously. That results in an efficient dispensing of toothpaste. The motor used provides approximately two Newton-meters of force. Through the gearing, that torque is magnified 3.5 times, with the resulting torque that is delivered to the shaft is seven Newton-meters. The button used is a standard doorbell that completes the circuit and actuates the motor.

The prototype is primarily constructed using aluminum. This would prove costly to produce. However, in the model for production, it would be made out of injection-molded plastic and would be much less expensive than the prototype. It would cost approximately $15 for the final model, while the prototype cost about $30 to make.
Figure 14.73. Exploded View of Dispenser.

Figure 14.74. Prototype of the Universal Toothpaste Dispenser in Use.
CHAPTER 15
UNIVERSITY OF MASSACHUSETTS AT LOWELL

Department of Electrical and Computer Engineering
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INTRODUCTION
The object of this project was to design a voice activated television remote control that can help individuals who are physically challenged. The aim was to help a client with quadriplegia operate his TV by having a voice command remote operate most of the useful functions.

SUMMARY OF IMPACT
This project is to help individuals who have quadriplegia and any other individual who needs assistance in operating certain electronic devices. This device will allow a user to take advantage of five different functions such as volume control, channel control, and power control. This device is easy to operate.

TECHNICAL DESCRIPTION
The HM2007 voice recognition chip has six control functions of which four were used in this project: recog, train, result, and reset. In addition the HM2007, in the CPU mode, has a K bus and S bus which are connected to the I/O pins of the microcontroller through the receivers. When the microcontroller sends the train command to the HM2007, it begins training for a selected word. The recog command causes the HM2007 to initiate the recognition process for the word spoken into the microphone. The result command causes the HM2007 to send the recognition result to the microcontroller. The reset command will clear the patterns in the SRAM of the HM2007. Once the training mode is completed, the normal operating mode is as follows. When the user issues a voice command, the voice recognition system processes the voice input and sends the results of the recognition to the control unit.

The digital output is then selected through a four-line-to 16 line decoder which utilizes TTI circuitry to decode four binary-coded inputs into one of the sixteen mutually exclusive outputs when both the strobe inputs G1 and G2 are low. The de-multiplexing function is performed by using the four input lines to address the output line, passing data from one of the strobe inputs with the other strobe input low. When either strobe input is High, all outputs are high. These de-multiplexers are ideally suited for implementing high-performance memory decoders. All inputs are buffered and input clamping diodes are provided to minimize transmission line effects and thereby simplify system design.

The selected low output from the de-mux is fed into a one-shot timer. Upon applying power to it, the load is energized and the time delay cycle is initiated. At the end of the delay time, the load is de-energized. One could reset it just by removing the input power. The purpose of using the one-shot timer is to delay the input signal so that there is no need for several calls to activate a function at the remote end.

The output from the one-shot timer is connected to the base terminal of a bipolar junction transistor to pull down a relay switch in parallel with functions of a universal TV remote control.

The device was successfully completed and tested with a Sony TV. Future work will address the problem encountered with the HM2007, including its poor performance in noisy environments.
Figure 15.1. Voice Activated TV Remote Control.
PRESSURE ACTIVATED LIGHT PAD

Designer: Akhuemose Otez
Client Coordinator: Tracey Ruth, Lowell High School, Lowell, MA
Supervising Professor: Walter McGuire
Department of Electrical and Computer Engineering,
University of Massachusetts at Lowell
Lowell, MA 01854

INTRODUCTION
The Pressure Activated Light Pad (PALPad) was designed to provide visual stimulation to children with multiple disabilities. It is a mountable mini wall of roughly two feet by two feet that lights up at the specific location at which it is pressed. The PALPad provides motivation to the students to participate in class activities by giving them a sense of reward or accomplishment for a small effort.

SUMMARY OF IMPACT
The design criteria for the PALPad were defined by the capabilities of the children and the needs of the center. The students spend most of their day at the center and therefore have to be occupied with activities most of the time to avoid boredom. Also, they require an activity center that operates on low voltage and is safe enough to be used without needing very much assistance due to the staff to student ratio not being one-to-one. The PALPad also had to be designed to fit the hand-eye coordination capabilities of the students. Most of the students have an easier time operating a toy or activity that can be operated with the palm and not the fingers and therefore, this was one of the considerations added to the design, reducing the dependence of the pad on the fingers. The students would therefore be able to enjoy the light and sound effects of the pad without experiencing much difficulty.

TECHNICAL DESCRIPTION
The PALPad has different light up effects in response to the amount of pressure exerted on it. It consists of three color coded sections: green, yellow and red. The green section of the pad is the main switch for turning on and off the device. It is green colored LEDs mounted around a push button switch underneath a plastic plate and filter paper. The yellow portion of the pad is an improved part of the project, which also gives buzzing sound effects as well as lights in response to pressure. This portion
is made up of momentary switches which go off as soon as the pressure on them is released. That way, the buzzing sounds can also go off as soon as the switches are released. The red part of the project is the main objective of the PALPad, which responds to pressure on a different level. It is made up of red LEDs mounted around “soft-feel” push-on-push-off switches. These switches respond to the slightest pressure and act like momentary switches when not enough pressure is exerted on them. The red LEDs light up as soon as this portion is pressed and can go off immediately after the pressure is released, or stay on depending on how much pressure is put on them. This part of the PALPad maintains its pattern if enough pressure is exerted on it even after the main switch is turned off and on again. The red LEDs only turn off when the exact location is pressed again. This pad can keep a student occupied for quite a while as he enjoys the light displays and sounds.

The PALPad is a parallel combination of switches, light emitting diodes (LEDs), buzzers and sound circuitry. One light connection is duplicated 16 times to give the full grid of red lights. The orange section of the pad had an additional buzzer connected in parallel across the LEDs below the push switch as shown in Figure 15.3.

The circuit for the sound generator is a little more complex than above, consisting of an SG3 chip, a resistor, some capacitors, and a transistor as shown in Figure 15.4.

The cost of parts/material is about $300.

Figure 15.4. Schematic of Sound Generator.
SHAPE SORTER WITH RECORDABLE MESSAGES
AND LED BLINKING ACTIVITY

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INTRODUCTION
A musical shape sorter, called the Shape Pro, was designed to improve the motor skills of students with disabilities. The device consists of four removable shapes; each shape has its own specific color which also helps in color coordination. These shapes must be inserted in the correct position in order to get sound and light feedback to the user. There are 20 LEDs positioned around the device with a speaker in the middle. Unlike other shape sorters on the market this device gives the users the opportunity to record their own messages. Another additional feature added to the device is the ability to control the rate at which the LED’s blink.

SUMMARY OF IMPACT
The Shape Pro will help the children and the physical therapists at a high school by introducing a new learning tool. The client will be able to play with the toy by himself while the physical therapist tends to other children. The device can also be used by a group of students, or by a student teacher group, depending on the needs of the child.

TECHNICAL DESCRIPTION
The device consists of an ISD1420 voice recording chip, a set of 4017 decade counters, four photo-reflective sensors, and two 74221 Dual Monostable Multivibrator. The photo-reflective sensors can sense a reflective object within a five-millimeter distance. The output of the sensors is sent to the input of the corresponding monostable multivibrator which then sends a pulse to the ISD via a four-input AND gate. This pulse initiates a playback sequence. The ISD1420 can store up to 20 seconds of sound from a microphone input. It has a non-volatile memory which means the device does not need a battery backup. The decade counters are controlled by the speaker output pins of the ISD1420. When there is sound output, the LED’s begin flashing. This is accomplished by connecting the speaker pins through an NPN transistor to the reset pins of the 4017. When the reset pins are high the counter is in an idle state. When the reset pins are low, the counter begins to advance depending on the rising edges of the clock pulse. The clock is supplied by an LM555 timer which has a variable resistor in place to allow the user to adjust the LED blinking frequency. The circuit also contains a tri state buffer and LM555 timer to block any input to the ISD until all devices have powered up, a two second delay gives enough time for all circuits to come up to operating voltage. This is done to prevent unexpected playbacks on power-up.

The total cost of the projects parts and materials is approximately $30.
Figure 15.5. Shape Pro.
INTRODUCTION
The voice-activated speakerphone is designed to enable phone conversation for an individual who is unable to pick up and hang up the phone because of a physical disability. This device requires a simple modification of a regular phone by projecting a switch for the speakerphone externally so that it can be stimulated by a desired external event such as voice. After designing this device, an individual does not need manual movement for receiving and hanging up a telephone.

SUMMARY OF IMPACT
The design was requested by a client who has scleroderma, a disease that causes contraction of skin, restricting body movement during peak reactions. She requested a phone that did not require manual lifting and hanging up.

TECHNICAL DESCRIPTION
The first step of the project requires modification of an existing telephone so that the speakerphone can be controlled remotely without lifting and hanging up the phone. Secondly, it requires a circuit that answers and hangs up a telephone by the use of either voice or sound. This telephone will be connected to the circuit that delivers the switching function by taking voice input. The microphone and speaker are also modified to make them user accessible.

In order to make the speakerphone voice activated, the keypad is modified. A keypad consists of several short circuits. Once a short circuit is completed, it creates an impulse that performs essential functions. Numeric keypad create DTMF tones, which completes telephone dialing. Dual Tone Multi Frequency (DTMF) is known as Touch Tones, an example of multi-frequency shift keying. In order to activate the speakerphone externally, wires are taken from short circuit keypad and projected externally. A hole is drilled in the telephone case and a jack is used.

The structure of relay controller is a black box which is 10x 6 x 4 inches. A circuit board is mounted inside
the box. Jacks are installed for power, relay switching and microphone operation. The circuit board operates with 9-12 volts DC which are provided with either battery or wall current. A 12V DC adapter is used to provide power to the circuit.

This part of the circuit is connected to the jack that is being projected externally off the keypad. In this circuit, a microphone picks up audio signal and it is fed into operational amplifier LM358N. This is connected as a non-inverting amplifier with a gain of 151 or +43.6 dB. RF is eliminated by a 100pF capacitor across 150K feedback resistor that rolls off the high frequency above 10KHz. The output pin 1 feeds to diodes D1 and D2 which functions as a half-wave voltage doubler. These rectify the audio signal to produce a DC voltage across the 2.2uF ecap, C2 which is directly proportional to the input audio sound level.

This DC voltage is fed to pin 5 of the Op Amp. This is connected as a comparator. A resistive voltage divider applies about 2V to pin 6. Once the DC voltage across the 2.2uF ecap rises above the voltage at pin 6, pin 7 pulls high. This turns on the transistor Q1 which activates the relay and turns on the LED. Q1 remains on while the DC voltage at pin 5 is about that at pin 6. The high op-amp gains if IC1a, the voltage doubler gains the circuit and has a fast response time. The release time takes about three seconds which is determined by the time constant of C2 and R5 and the pin 6 threshold voltage. D1 is connected across the relay to protect Q1 when the relay turns off. A 12V power is used. D4 is a protection for the circuit in case power is connected the wrong way. Sensitivity of the microphone is varied with the 200K trimpot. The off delay time is adjusted by varying R3 and R4. Reducing R3 results in longer release time.

The cost of parts and material is approximately $108.
AUTOMATED TOOTHBRUSH

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INTRODUCTION
An automated toothbrush was designed for a young man with Duchenne muscular dystrophy, an incurable genetic progressive disorder. He uses an automated wheelchair that he controls with a joystick. He has limited range of motion in his upper body, but has excellent cognitive skills and is able to play video games and operate a game controller. Prior to having this device, the client relied on his family for hygiene assistance – including brushing his teeth once in the morning and once at night.

Nothing on the market was found that the client was able to manipulate, given his limited range of motion. While there are battery operated toothbrushes on the market, the client could not hold the toothbrush in the correct position or grasp it with enough agility to control his motions. Therefore, an electrical and mechanical device was designed that mounts onto his wheelchair and supports an automated toothbrush. He can control all aspects of this movable brushing system (including a shut-off switch) with one small homemade controller.

SUMMARY OF IMPACT
The client still requires assistance setting up the frame onto his wheelchair and loading the brush with toothpaste. Once set up, however, he can brush his teeth for as long as he chooses. When he used it for the first time, he said, “this is so cool!” and “I’ll be able to brush before bed all by myself now.” It should be noted that this automated toothbrush will be especially useful in the client’s household as his brother also has MD and similar physical limitations. The disposable, replaceable head of the toothbrush makes it a versatile tool that both brothers can use.

TECHNICAL DESCRIPTION
A servo pulsing circuit is the basis for this project. An LM555 timer was the IC chosen to make the required pulse train. This timer is chosen for its application of pulse width modulation. The 10k trimpot changes the pulse width. As the potentiometer is varied, the pulse width varies from one millisecond to two milliseconds. The resistor R1 is a shunt resistor that only allows the correct amount of current to pass into R2 that is sufficient enough to derive a pulse from one millisecond to two milliseconds. The output of the 555 (PIN 3) is connected to the white (control) wire of the servo motor. This is the pulse train that the servo needs in order to position itself properly.

The blocking circuit is implemented using basic logic design. An AND gate provides the proper logic output needed to implement this function. The inputs of the AND gate, and the Vcc are all tied to the positive terminal of the toothbrush motor just after the SPST toothbrush activation switch. The output of the AND gate is connected to the Threshold pin of the 555 timer which is also tied to the Trigger pin of the 555. The Reset pin of the 555 timer is changed to not being connected in order to give the circuit the proper operation. If the toothbrush is placed in the ON position than the AND gate sees two active high signals at the input side, and outputs an active high signal to the Trigger pin of the 555. When the Trigger pin of the 555 receives an active high signal from the AND gate it does not continue to produce a pulse to the servo motor therefore not allowing it to turn. If the brush is OFF than the AND gate is not in operation, and the Trigger pin sees no difference in signals, therefore it continues to operate sending a pulse to the servo motor allowing it to turn.

There are two safety switches that cut off power to the entire system. In order for the switches to cut power to the entire system they had to be placed closest to the +Vcc source. Each switch is mounted
in line with the +Vcc feed line, and has a green LED mounted between the switch side and ground.

All of the electronics of the system are mounted inside of the main electronics box with the exception of Switch 1 (the toothbrush activation switch), Switch 2 (safety shut down switch), D2 (Green LED), and the 10k potentiometer P1. The main box is a 4x4x4 inch PVC wet location junction box. The box is cut in half to make it stand 2.5 inches high. The box is waterproof and has a screw cover with rubber gasket. All of the electronics are soldered to an IC board and mounted inside of this box. One of the main safety switches is mounted to the top of this box along with a green LED. Three wires come out of the main box and are used for; power supply, toothbrush activation, and the remote control. All wires coming out of the box are coated with silicon sealant at the point of exit to ensure watertight integrity. Four rubber feet are adhered to the bottom of the box to keep it from sliding off of any surface.

The remote control is wired directly into the main electronics box with 24/4 pair CAT 3 cable. The remote is made from a small 3x2x1 inch project box. The components found on the remote are Switch 1 (toothbrush activation switch), Switch 2 (safety shut down switch), D2 (green LED), and the 10kΩ potentiometer P1. These components are drilled into and mounted to the surface of the project box. All wiring of these components is completed internal to the box, and the box is sealed with silicon sealant to produce watertight integrity. The remote control is the only means to operate the toothbrush on/off power, and to turn the servo motor.

The total cost for parts is $121.94.
INTRODUCTION
The pinball machine was to be retrofitted with voice recognition capability to provide a means of entertainment for children with physical disabilities. This voice-recognition technology will allow the user, after training the voice-recognition unit, to control the three components of the pinball machine, including the flippers, reset mechanism and the plunger, by the proper corresponding keyword.

SUMMARY OF IMPACT
The focus of the Voice-operated Pinball Machine as a game is to be available for children whose disabilities do not allow them to have an interactive engagement with recreational toys. This game may be a good motor-skills exercise, as the child coordinates the events gathered as he sees the ball travel the board, with issuing oral commands for a desired action. Moreover, this game may boost the emotional state of a child; a sign of such may be seen in the frequency of the time that he uses the game.

TECHNICAL DESCRIPTION
The pinball machine is an electromechanical, operated via pushbuttons that control its functions. It Zodiac model by Williams, manufactured in 1971. The buttons manage a network of rotating devices as well as solenoids, pulling shafts that give the flipping action to the flippers, and the plunging to the plunger that throws the ball onto the board. The game works on a 28VAC system, the flippers draw a current of 1.2 Amperes for each side while the reset mechanism and the plunger draw .5 Amps each. Part of the project involves designing an interface network that is able to switch the AC voltages, for this circuit relays would perform such job while a transistor would switch each relay according to the signal coming from the voice-recognition unit. After finishing the training mode, which is the process of recording the speaker’s speech patterns for each command word so as to later use those patterns in the recognizing mode, the voice-recognition unit continuously listens for a command word and outputs a logic 1 as a 3.14VDC signal onto the output port after a successful recognition of a spoken word. This signal turns on the transistor, which switches the relay and completes the circuit of the flippers, reset, or the plunger. The voice recognition unit is called Voice Extreme, and it is manufactured by Sensory. This kit allows for the easy programming of the unit in a high-level language called VE-C; it includes a development environment that allows the integration of wave files needed for the project. This unit operates on a power supply that takes 120VAC from the wall and rectifies it to 5VDC then to be regulated by the unit board down to 3.14VDC, which is the operating voltage of the board. Other minor components such as diodes and resistors are used in the design. A schematic diagram of the design is illustrated below.

The bulk of the cost of the project was the $140 for the voice unit; the relays cost approximately $8.
BUBBLE LAMP CAUSE AND EFFECT DEVICE

Designers: Edwin Corporan
Client Coordinator: Lowell High School, Department Of Special Education
Supervising Professor: Jay Fu and Alan Rux
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INTRODUCTION
The 'Bubble Lamp' was designed to help teach cause and effect to individuals with cognitive disabilities. The project consists of a water bubble lamp that generates bubbles, different color water, and different colors of light. It contains plastic fishes that swim around for a period of 5.6 seconds after a jelly bean switch is pressed. This is accomplished with capacitors, resistors, a 9V battery, a 120 AC power supply, an AC motor, an AC light bulb, an AC water pump, a relay, a phone jack adapter, a jelly bean switch, and a 555 timer IC.

SUMMARY OF IMPACT
The goal of this project was to build a fun and easy-to-use learning tool to teach cause and affect. This will enhance learning, allow teachers time to attend to other students who may need more attention, and provide a fun activity with which children can learn and play at the same time.

TECHNICAL DESCRIPTION
The lamp chosen for this project is a 3 feet tall and 4 inch wide spiral tubular model with a 1 foot tall, one foot wide circular base. All electronic components, except for the jelly bean switch are placed inside the base of the lamp.

By pressing the jelly bean switch, an input signal is send to an active low 555 timer. By using a 5.6 M ohm resistor and a one uf capacitor an output pulse is created by the 555 timer for a period of 5.6 seconds. This pulse is then sent to a 5 VDC/120VAC relay where it will create a closing path for the current to flow in the AC components of the lamp. In other words, once the relay is triggered it activates an AC motor, air pump, and light bulb for a period of 5.6 seconds. The bubbles generated by the air pump enable the fish inside the lamp to swim for 5.6 seconds. In conjunction with the air bubbles, an AC motor rotates around a piece of plastic that is divided into different color sections. At the same time the AC light bulb in collaboration with the motor, generates different colored lights. As the fish swim around, different colored lights will be displayed in the water for 5.6 seconds.

The cost of parts/material was about $109.
TALKING CLOCK

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Supervising Professor: Jay Fu
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INTRODUCTION
The “Talking Clock” (Figure 15.10) is a device that allows a user to set the time of an analog clock and have that time read back to them in words through a speaker. The user will also have the capability to see a digital readout of that time. This process will help the user learn how to read an analog clock. The Talking Clock is specifically designed for a special needs classroom.

SUMMARY OF IMPACT
The design criteria for the talking clock were specified by the client coordinator. The clock had to be safe for the children to use independently. Also, the speed of the voice could not be too fast, and the device had to run off batteries. Ideally, the device will help children with special needs learn to read analog clocks.

TECHNICAL DESCRIPTION
The material used in for the enclosure is quarter-inch finished plywood. The dimensions are as follows 24 inches by 16 inches by 4 inches. The box is drilled and cut for the components that need to be mounted to it. All of the wood is sanded down for safety reasons and then coated with polyurethane to protect the wood.

The power for the project comes from two sources. There is a battery pack for 4 D cell batteries, which is mounted on the bottom of the enclosure that powers all of the circuitry. There is also a 9V battery which just powers the digital readout. A range of 4.5 to 6V works for most digital circuits, but because of the high power output needed to light the large seven segment displays the 9V battery was added.

The hours and minutes are activated using an electronic circuit that encoded the time set buy the user and addresses it to a segment of voice recorded to an ISD Voice Record/Playback Intergraded Circuit. The hour voice is recoded to one IC and the minute to another.

In order to activate both the hour and the minute by a single pushbutton, a time delay circuit is needed so that the user could hear the hour first followed by the minute. This is accomplished by integrating a 555 timer circuit.

The last aspect of the project is to output the set time to a digital display. This is accomplished by taking the encoded output and bringing this to four Binary Coded Decimal to Seven Segment Display ICs. The display is shown in Figure 15.11.

The cost of parts and material was approximately $275.
Figure 15.10. Talking Clock.

Figure 15.11. Digital Display.
INTRODUCTION
The Musical Fun Box is a learning device designed to give the client the joy and satisfaction of playing a musical instrument while learning basic educational fundamentals. It also fosters hand and eye coordination, and use of the arm muscles. It has large console control buttons (two and a half by two and a half inches) that can be removed and replaced with others.

SUMMARY OF IMPACT
The motivation for designing such a device was to help provide children with disabilities the opportunity to improve their academic skills and musical creativity.

TECHNICAL DESCRIPTION
The major areas of focus in the design are electrical and mechanical control and digital electronics. The design process included PC board layout and fabrication, manufacturing, testing/troubleshooting, and computer programming.

All the wires will be tied up together inside the device to keep the child safe, and also to protect the Musical Fun Box from any damage. At first it was running on 3.5V, and was not giving enough power to the speakers. The 3V was changed to 5V, which makes the speakers sound louder and clearer. The on switch is visible and easy to reach.

The cost of parts and material was approximately $150 - 250.
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Figure 15.12. The Musical Learning Device.

Figure 15.13. Block Diagram.
INTRODUCTION
The wireless wheelchair table switch is designed to provide additional mobility to individuals with disabilities. The switch consists of a wireless RF transmitter attached to a wheelchair table with two big switches firmly attached on top with the wires concealed under the table cover. The matching wireless receiver provides a range of over 50 feet of mobility to replace traditional wired switches. The device is designed for a client who requires the use of switches to activate toys and electrical devices. There could not be any exposed wires as he tends to chew on them. This device’s design philosophy is based on simplicity and ease of implementation.

SUMMARY OF IMPACT
An important design criterion for the wireless wheelchair table switch is that the final product must not have any exposed wires. The switch enables the client to activate devices independently such as the radio or television without the need for constant supervision by the care provider. The wireless switch is also used as an educational tool as it allows the client to learn to make choices and provide fulfillment because the client is able to have control over when he wants to activate certain devices.

TECHNICAL DESCRIPTION
The RF components of the wireless switch consist of a matching transmitter and receiver by Linx Technologies. The transmitter used is the TXE-433-KH 433MHz transmitter with on-board encoder and the receiver was the RXD-433-KH 433MHz receiver with on-board decoder. Both the transmitter and receiver use the ANT-433-SP “Splatch” planar antenna.

The KH series of transmitters and receivers from Linx Technologies is used as it needs little or no other external RF components except the antenna.
encoder then detects the logic states of the data and address lines of the IC and these states are formatted into a three-word transmission cycle which continues until the Transmit Enable line is taken low. The project requirements call for two switches to be connected to the transmitter, thus only the first two data inputs of the usable eight are used in this project. The remaining inputs are left floating; the corresponding data output of the receiver are also left floating. Each data input line is independent of the other.

The two data lines are connected to VCC through their respective switches. Therefore, when the switch is pressed, the input detects a high logic state. The inputs are tied to the Transmit Enable pin through a dual-input OR gate acting as a buffer.

When data are received on the receiver module, the incoming address data is compared with the local address settings. If the addresses are different, the data are tossed out and ignored. If the address data are identical, the receiver module’s eight data outputs are set to replicate the state of the transmitter’s data input lines. In addition, the Transmission Verify pin goes high to indicate reception and decoding of data. The two output data lines used are each connected to a NPN transistor switch. The transistor switch is connected to an eighth-inch standard mono jack.
TWO-BUTTON TELEVISION REMOTE

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INTRODUCTION
A simple TV remote was designed for an intelligent 12-year-old child who is not able to walk and uses a powered wheelchair. Due to limited strength and coordination, he requested a simplified TV remote with just two large control buttons and an infrared signal that could be detected anywhere in the room.

SUMMARY OF IMPACT
Since the client can only use his elbow to turn the TV ON/OFF or change the channels, the regular remote control does not work for him. The jelly bean buttons are ideal because they are big and thus easier to push. They also reduce the chance of his making a wrong choice on the remote control.

TECHNICAL DESCRIPTION
An existing remote control was modified to suit the client’s needs. The TV remote has the power and Channel UP and DOWN connected to the designed circuit to allow the client to use the jelly bean buttons instead.

The switch is connected to a DM74LS21 one shot that creates a pulse. This is connected to a flip flop that is either on or off depending on the option selected. The FF output is an input to an AND gate whose other input is a 555 timer. This increments the counter that is decoded by a 4/16 DM74154. The decoder is connected to a transistor, which is connected to an LED (three different kinds for ON/OFF, Channel Up and Down). Depending on which LED turns on, the output of the decoder connects to another flip flop. This is a D flip flop that has a clock. This running clock comes from the 555 timer. This is connected to an AND gate that turns the one-shot circuit. This one-shot turns a relay ON and OFF. The relay is then connected to the TV remote control and this sends the desired message to the TV. To communicate with the TV, the user has to press the jelly button twice. The first time it starts the sequence of turning the LEDs and if the desired LED came on, the user has to press the jelly bean button and either turn on the TV or change the channels.
Figure 15.15. TV Remote Control.
INTRODUCTION
The sensory stimulation gym is designed to provide stimulation for children with multiple disabilities. The device is an activity desk (Figure 15.16) with an opening big enough for an electric wheel chair. On the top of the desk, within reach of the children, are varied activities. Once the child performs one of the activities, sensory feedback is activated.

SUMMARY OF IMPACT
The physical therapists at the school are often busy tending to all the students, and as a result, are unable to spend long periods of time with any one child. To resolve this problem, they requested an activity center to which they can wheel a student, letting him or her play as they tend to other students. Three different senses are stimulated and the user experiences a sense of control.

TECHNICAL DESCRIPTION
The gym is constructed from sturdy metal workbench legs with a wooden kitchen tabletop. The desk (44 inches long by 27.5 inches wide, and 32 inches high) is capable of supporting the weight of a full-grown person. All additional components are mounted to top of the desk.

The exercises are four horn push buttons, each big enough for an entire hand to fit on, and one toggle switch, big enough to be hit with the back of a hand. The switches activate two different items, depending on which way each is hit. The circuit is wired as follows: One horn button turns on the two blue utility lights. The second horn button turns on the two red utility lights. The third horn button turns on the back-up alarm and the two amber utility lights. The fourth horn button turns on the amber strobe light. If the plow switch is hit forward, it turns on the two white utility lights, and if it is hit back it turns on the car fan.

The power source for this project is a power adapter that takes a 120 VAC and outputs a max of one amp and 12 VDC. The adapter is carefully selected to be safe to humans and be enough to power all the components. All the wiring is kept in the back of the desk away from the students. All the wires and power adapter are fastened to the bottom of the desk.
To make sure of the safety of the project, a five-amp car fuse is wired into the circuit. The car fuse connects the power adapter to the rest of the circuit. The power adapter only outputs a max of one amp. As a result, if more than five amps tries to pass through the fuse, the fuse will blow and the entire device will turn off and remain off until the fuse is replaced. Also, if the circuit becomes grounded, it will also blow the fuse and turn off the device. To connect all components, 14 gauge wires are used (black for ground and white for positive). To reduce the amount of wires in this project, universal ground and positive bolts were made. All of the grounds are connected in the circuit to one point, a universal positive bolt. A metal bolt is fastened to the bottom of the desk. The other end of the 5-amp car fuse is attached, connecting it to the power source. On one end all the switches are attached, and the other end is attached to their corresponding feedback signals.

The cost of parts/material is approximately $72.
INTRODUCTION
The Moving Mirror (Figure 15.18) was designed for a 10-year-old client. It is a rotating mirror powered by two pushbutton jellybean switches. When the switches are depressed, the mirror rotates until the client lets go of the switch or it hits 45 degrees. There are also four colored LEDs incorporated into the device that light up with respect to four colored jellybean switches. The LEDs light up while the jellybean switches are depressed.

SUMMARY OF IMPACT
The device allows the client, a boy with vision and hearing impairments, who uses a wheelchair most of the time, to look to his side and back with the push of a button. Previously, he had to rely on assistance to look around. Additionally, the device helps encourage the client to use the movement of his upper body. This movement promotes exercise and helps to strengthen the client’s upper body as well as improve his circulation. There are also colored LEDs that are meant to help the client associate colors.

TECHNICAL DESCRIPTION
The structure for housing the electronics and holding the mirror is of hard wood. Wood is easy to work with and relatively inexpensive. The client wanted the ability to plug the toy into the wall to provide the power for the toy. A 15 volt, DC plug in a style transformer is used to run the motor and the circuitry. A five-volt regulator is needed to power the ICs, so a 7805 voltage regulator is used to step down the 15 volt input from the transformer.

To rotate the motor in the clockwise and counterclockwise directions, an “H” bridge circuit was developed. The circuit allows for current to pass through the coil of the motor in both directions, depending upon which two transistors are saturated at the same time. The transistors used in the circuit, the TIP 120, are rated for higher current than that required by the motor. The motor current is only about 150 milliamps, and the TIP 120’s are designed to handle five amps. TIP110’s would have certainly worked, but the TIP120’s were surplus parts, so in an attempt to keep the project price down, the TIP120’s are used. In order to saturate the two desired transistors to rotate the motor in a certain direction, a logic circuit needed to be designed that would enable the two transistors with the push of one, normally open, pushbutton jellybean switch. The logic circuit that is designed contains two Hex Inverters, and two AND Gates. For the Hex Inverters, an LM7404 is used, which is a Quad Hex Inverter. For the AND Gates, an LM7408 is used, which is a Quad AND Gate. If both switches are in the normally open position, then the motor is not rotating. If he depresses one of the switches, then either X or Y and A or B goes high, depending on which jellybean switch he pushes down. If he happens to depress both jellybean switches, then A and B go high, which just causes both sides of the motor coil to be grounded. In order to provide the logic high and low signals for the switch inputs, two relays are used to toggle between ground and five

Figure 15.18. LED Panel.
volts from the regulator. Ground, which is zero volts, is a logic low signal, and the five volts from the regulator is a logic high signal. This is done so that when the two motor switches are in the normally open state, then the two relays provide low signals to both the A and B inputs, keeping the motor from rotating in either direction. The outputs from the logic circuit are connected to opto couplers, which are 4N27’s. An opto isolator uses an infrared LED that can be powered with as little as 20 milliamps, so the transistors will conduct when the output of the logic circuit is high. When the transistors are active, they pull the 15 volts down from the supply and 10K ohm resistors provide the 1.5 milliamps to the TIP 120’s that is necessary for saturation. The final product can be seen in Figure 15.19 below.

The cost of parts/material is approximately $320.
VOICE CONTROLLED WHEELCHAIR WITH OBSTACLE AND DROP-OFF DETECTION

Designer: Jeffrey J. Sawyer
Supervising Professor: Walter McGuire
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INTRODUCTION
The voice controlled wheelchair with obstacle detection and avoidance (VCWODA) is designed to allow an individual with quadriplegia the ability to control an electric wheelchair by voice. The VCWODA has collision and drop-off detection, which gives it the ability to be able to detect and avoid obstacles and drop-offs (stairs, curbs, etc.) in its direction of motion; this ability provides additional safety to the user. The goal of the project is to allow the user the freedom from the use of a sip and puff interface or a head switch interface, which can be uncomfortable, while adding new safety features to an existing electric wheelchair.

SUMMARY OF IMPACT
The project will enhance the lives of individuals with quadriplegia by allowing them the freedom from using any external devices that may be uncomfortable or awkward to use. The project is easy to operate and safe.

TECHNICAL DESCRIPTION
The purpose of the VCWODA with obstacle detection and avoidance is to allow individuals who are unable to operate an electric wheelchair through the use of a joystick an optional mode of operation. The voice recognition system allows the user the ability to control an electric wheelchair through the connection to its onboard digital interface. The voice recognition system is made from the Sensory, Inc. Voice Extreme™ Module and it is programmed to be speaker dependent; it is trained prior on the first use. After the first use, the user’s data are stored in memory and there is no need for additional training. The microphone used for the voice recognition is a throat microphone that attaches around the user’s neck; the microphone is unaffected by outside noise. The commands used in the VCWODA allow the user the ability to control to varying degrees the wheelchair’s forward and reverse motion along with the left and right motion too. All the timing of the wheelchair’s movement has been tested on an Invacare Ranger X wheelchair. Note that if a movement command is given and it is given again before its movement time ends, it will reset the movement time to its first value. For example if the user says “forward” and then waits 30 seconds and says it again, the time until the wheelchair stops will be reset to 35 seconds. Other commands used allow the user the ability to navigate through the verbal menus programmed into the voice recognition system. A listing of the voice commands recognized is given below.

- Forward - Move forward for 35 seconds
- Reverse - Move in reverse for 10 seconds
- Ar - Turn right for 0.4 seconds if the wheelchair is stopped or 0.175 seconds if the wheelchair is moving forward
- El - Turn left for 0.4 seconds if the wheelchair is stopped or 0.175 seconds if the wheelchair is moving forward.
- Right - Turn right for one second if the wheelchair is stopped or 0.3 seconds if the wheelchair is moving forward
- Left - Turn left for one second if the wheelchair is stopped or 0.3 seconds if the wheelchair is moving forward
- Hard Right - Turn right for two seconds if the wheelchair is stopped or 0.7 seconds if the wheelchair is moving forward
- Hard Left - Turn left for two seconds if the wheelchair is stopped or 0.7 seconds if the wheelchair is moving forward
• Faster - Only active while the wheelchair is moving forward. Increases the speed of the wheelchair if it is below its greatest speed

• Slower - Only active while the wheelchair is moving forward. Decreases the speed of the wheelchair if it is above its slowest speed

• Go - Move forward for 1.2 seconds with no sensor interruption

• Back - Move in reverse for 1.2 seconds with no sensor interruption

• Go To Sleep - Change the mode from listening mode to sleep mode, the wheelchair must be stopped first

• Wake Up - Change the mode from sleep mode to listening mode

• Main Menu - Change the mode from either sleep mode or listening mode to main menu mode

• Stop - Stop the wheelchair from moving

• No - Only active when the system asks “Are you Sure?”, causes the AreYouSure function to return false

• Yes - Only active when the system asks “Are you Sure?”, causes the AreYouSure function to return true

• One - Only active in the main menu, used to select menu selection one

• Two - Only active in the main menu, used to select menu selection two

• Three - Only active in the main menu, used to select menu selection three

• Four - Only active in the main menu, used to select menu selection four

The sensor control system uses a Basic Stamp 2 to control a combination of infrared and sonar sensors used to detect obstacles around the wheelchair as well as the lack of ground in the front and rear of the wheelchair as when the wheelchair comes close to a curb or a set of stairs. The two sonar sensors used on the VCW are mounted on the front and rear of the wheelchair. The front sonar sensor is programmed to detect two different ranges. The first range is 80 inches and will cause the wheelchair to slow to the lowest speed. The second range is 45 inches and will cause the wheelchair to stop. The rear sonar sensor is programmed to detect at one range of 40 inches and will also cause the wheelchair to stop. The infrared sensors on the wheelchair are used to detect the ground in the front and rear of the wheelchair, if they do not detect the ground in the front or rear of the wheelchair while they are moving in the direction of the sensor they will also cause the wheelchair to stop. The last of the infrared sensors are used on the left and right of the wheelchair to detect objects to the left or right. If the sensor detects an object to the left of the wheelchair while moving forward, the chair will automatically adjust the movement of the wheelchair to the right until it no longer detects the object and vice versa for the right sensor. If both left and right sensors detect an object at the same time the wheelchair will stop.

The sensor control system and the voice recognition system are programmed to communicate with each other through the use of a simple two-bit op-code. The information that is transmitted from the voice recognition system to the sensor control system is whether the voice recognition system is in forward, reverse, or neutral mode. The information that is transmitted from the sensor control system to the voice recognition system is the ready, slow down, or stop command.

The cost of parts for the voice recognition and sensor control system is $350.
INTRODUCTION
The five sample voice recorder is designed to accommodate stories with sounds that are read to children who have multiple disabilities. The main purpose of the device is to make listening to stories more fun and enjoyable. The device can record five separate sound effects and be played back one sound at a time. Upon completion, the five sample sound recorder was presented to a school for children with cognitive and physical disabilities. The ages range from small children to 21 years of age.

SUMMARY OF IMPACT
The design criteria for the five sample sound recorder were defined by the school librarian. She requested a device that could record multiple sounds that could be played back one after another. She asked that it be simple to use and require little or no maintenance.

TECHNICAL DESCRIPTION
The device consists of three main components: 1) record playback chip, 2) microcontroller, and 3) audio amplifier. The playback record chip is an ISD2560 and can record up to 60 seconds of audio. The microcontroller used is the Basic Stamp 2. It has 20 I/O pins and a voltage regulator with an output voltage of five volts. The LM386 audio amplifier is used to produce sufficient audio sound levels.

The ISD2560 is a 28-pin record playback chip. It has an input sample rate of 8kHz, which is sufficient to output clear undistorted sound. The chip is completely controlled by the microcontroller. The audio output of the chip is limited to only 50mW. Because the device must be able to fill a small room with a sound, the LM386 audio amplifier is used. The amplifier can output 1.25W of sound with a total harmonic distortion of 10 percent. This high gain is achieved by installing a 10 μF capacitor at the two gain pins of the amplifier. The audio level can be controlled by a 100 kΩ potentiometer installed in parallel with the audio inputs of the amplifier.

To record messages, an electret microphone is used. It requires external circuitry because it cannot produce a current flow or a potential to be developed from sound wave pressure. The manufacturer of the ISD2560 provides a circuit that will produce a dc bias for the microphone to work properly. The circuit consists of seven components. Two 1μ F capacitors are used for blocking dc and are connecting to the microphone and microphone reference pins and a 22 μF capacitor is used for filtering. Two 10 kΩ resistors are used for common mode rejection of the microphone preamplifier.

The microcontroller is used to power the ISD2560, as well as provide the proper addressing for record and playback. It is programmed using the PBasic programming language. Five pushbutton switches are connected to five pins of the microcontroller. When one of the five buttons is pressed, it sends an active low signal to the pin. When this occurs the program distinguishes which button has been pressed and sends the proper address to the ISD2560. At the same time, the chip enable turns active low, which activates the ISD2560, and the previously recorded sound in the corresponding space in memory is played.

To power the circuit, a 9.6V 1aH rechargeable NiCd battery is used. Due to the relatively high amperage rating, the device can be used multiple times before the battery needs to be recharged.

The cost of parts and material is approximately $150.
Figure 15.20. Five Sample Sound Recorder.
INDOOR NAVIGATION DEVICE FOR A PERSON WITH VISUAL IMPAIRMENT

Designers: Yichi Au, Ting Jen, John Wong
Client Coordinator: Dana Bernor, Lowell, MA
Supervising Professor: Walter McGuire
Electrical and Computer Engineering Department
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INTRODUCTION
VoiceNav is an infrared indoor navigation system for individuals with visual impairments. The idea of VoiceNav is to help an individual who has low vision navigate inside unfamiliar buildings, such as hospitals, museums, or schools. VoiceNav (Figure 15.21) is a three-component system, including the Direction Upload Station (Crystal), the Receiver (Scope) and the Transmitter (Star) (Figure 15.22). The Crystal uploads the request information to the Scope; in this case, a complete route to any point within the building will be uploaded to the Scope. As the user walks down the hallway, Stars that are mounted up on the ceiling will emit infrared signals. Then the data transmitted from them will be picked up by the receiver, and will initiative a vocal direction through the speaker to the user.

SUMMARY OF IMPACT
The purpose of VoiceNav is to help an individual who has low vision to navigate around an unfamiliar indoor building. This project is implemented primarily by using off-the-shelf components.

TECHNICAL DESCRIPTION
A general design block diagram is provided in Figure 15.23. The Crystal unit will send the route information through the serial link to the Scope unit. Then, the decoding unit within the Scope unit will process the data and store them in the PIC. When the person walks close to any of the Star units, Star will send out its unique location information to the Scope. Scope unit will pick up the signal and decode, then send the location detail into the RAM in the Scope. The PIC unit will compare the two sets of data from the Crystal and Star units, and generates a corresponding response from the ROM.

Figure 15.21. Physical Overview of Star.

The PIC unit will gather the audio output information from the ROM, and send it to the sound...
card. Once the sound card processes the data, it plays aloud to the user an instruction for movement. The cost of parts or material was about $1624.
ENLARGED TELEPHONE KEYPAD

Designer: Krishna Upadhyay
Client Coordinator: Ms. Kathy Finnigan, Kennedy Day School, Brighton, MA
Supervising Professor: Walter McGuire
Electrical and Computer Engineering Department
University of Massachusetts at Lowell, Lowell, MA

INTRODUCTION
An enlarged telephone keypad was designed to offer telephone key matrix learning experiences to children with visual, physical, and cognitive disabilities. The device will offer auditory feedback to guide dialing.

SUMMARY OF IMPACT
The final device is shown in Figure 15.24. Ideally, it will help children develop telephone skills in an enjoyable way.

TECHNICAL DESCRIPTION
An existing telephone was modified. Plastic materials were used for durability. Plastic switches were added to one side of a plastic container to make a keypad. Fourteen holes a half an inch in diameter were drilled at two and a half inches from each other. The push button switches were placed in the holes. One of the smaller sides was cut to make room for the charger and handset. To make the product compact, the telephone’s base unit and other circuitry were put inside the container. The container was sealed with special glue and assembly was completed.

For the power supply and distribution, the telephone is connected to a wall outlet. The +9V goes into a voltage regulator LM78L05. The output +5V from the voltage regulator becomes the input of the ISD 1100 chip. The voice chip is connected to an audio amplifier LM 386 that outputs voice using on eight Ohm speaker. There is some amount of voltage applied to the switches of the keypad and the phone at all times. The wiring connection is completed with a telephone keypad and the enlarged keypad. The ribbon wires are used for a parallel connection between the telephone keypad and the enlarged keypad. When a key is pressed down, the closed contacts supply voltage. The closed keypad contacts give the indication of the key not being pressed. A voltage regulator provides a constant dc voltage between its output terminals. The output voltage is required to remain as constant as possible in spite of changes in the load current drawn from the regulator output terminal and changes in the dc power-supply voltage that feeds the regulator circuit. LM78L05 is used because it offers a fixed output voltage of +5 V. Current limiting is included to limit the peak output current to a safe value. Small value resistors are used in the circuit for current protection.

ISD 1110 is a single chip voice record/playback device. It gives 10 minutes of recording with a sampling frequency of 6.4 kHz. The device operates on a 5V power supply. The messages are stored in stable memory. The circuit is connected to the device for an auditory response. When the Record button is pressed or in other words, REC is pulled low, the device records until either the REC is pulled high or the end of the message is reached. A capacitor of low value - 0.001 μF is used for safe recording. The capacitor that is connected to Vcc brings pin voltage up with power up. This eliminates any unexpected recording. Instead of
using edge-activated playback, level-activated playback has been used so that, when the PLAYL is pulled low, the playback cycle begins. As soon as PLAYL is pulled high, the playback stops right away. The device has a pull-up resistor of about 100 kΩ that pulls the voltage to Vcc. RECLED has output low when recording to the device. An LED signals by lighting up the record cycle in progress. SP+ and SP- provide direct drive for loud speakers with an impedance of 8Ω.

A LM386 power audio amplifier is used. Usually, the gain is set internally to 20 in this 8 pin DIP. However, by adding an additional capacitor of value 10 μF between pins one and eight increases the gain to 200. This capacitor bypasses the 1.35 kΩ internal resistor and makes the amplifier more resourceful. The device takes +5 V DC as supply. Given that the LM386 is used with higher gains, it is necessary to bypass the unused input to prevent reduction of gain and instabilities.

The cost of parts/material is approximately $181.

Figure 15.25. Inside View of Phone.
POURING CUP

Designer: Mher Ketchedjian
Client Coordinator: Special Education Department, Lowell High, Lowell, MA
Supervising Instructor: Mr. Jay Fu
Department of Electrical and Computer Engineering
University of Massachusetts-Lowell
Lowell, MA 01854

INTRODUCTION
The Pouring Cup is a special tool that allows anyone to pour virtually any substance into another cup or bowl (Figure 15.26). It could be used to pour substances such as liquids, sand or flour. It is switch activated, and it tilts when activated and returns back to the original position with a reversing switch. The Pouring Cup consists of both mechanical and electrical parts. Since many individuals with disabilities have a difficult time moving their wrists or hands it will be useful for pouring and learning the measurements from the tilting cup. The project is for the special education department at a high school. This is also a risk-free tool because it does not use AC power.

SUMMARY OF IMPACT
Measuring substances will help students learn more about measurements and volumes that are used for cooking or baking. The cup is wired to a joystick with two switches: one for the activation of the motor and the other for the direction, to tilt the cup down (counterclockwise) and tilt the cup back up (clockwise). The cup has measuring lines. The project will be placed on a kitchen countertop. It will be used by the students with the help of their instructors.

TECHNICAL DESCRIPTION
A 5- by 8-inch wooden box includes the motor, wiring, circuit, and a battery pack on the back side. It has a 9- by 11-inch wooden base on which the box rests. Transparent epoxy glass is mounted on the facade of the main box, in a color that matches the paint on the wood. The wooden area is nailed together while epoxy glass is mounted with a screw. The motor is powered by a 7.4V DC electric power with a gearbox. The gearbox on the motor is to control the speed of the motor slowly and produce higher torque than what the motor is already powered. Speed control and safety are the main reasons why a DC motor is chosen over an AC motor. The circuit is powered by 6V DC that is four alkaline 1.5V batteries going to the chip and two pairs of transistors. The four transistors are used to control the motor in both directions. They are wired along with two capacitors, two resistors and two diodes. The transistors receive the impulses that are sent by the 555 timer and uses that impulse to time the turns of the motor. A 555 timer chip is implemented in order to create the Pulse Width Modulator. This chip is used to approximate a low frequency modulating signal that produces a square waveform which is proportional to the input voltage. Since the design concerns low voltages, the 555 timer is chosen because it has an operating voltage at 1.5 volts. The output signal is determined by the operating state of the MOSFET switch. The frequency in which the timer is outputted depends on the values of the resistors and capacitors. VCC is the input voltage supplied by the output of the charge motor. The output voltage of the circuit is sent to the gate of the MOSFET. Depending on the value of the threshold voltage, therefore, the transistor turns on and the switch is closed. When the switch is closed, current flows through the circuit; otherwise, the transistor is off, resulting in an

Figure 15.26. Pouring Cup.
open switch. Pin 5 is the control voltage, dependent on the duty cycle when a high or low signal is inputted.

The cost of parts is approximately $120.
SENSITIVE CANE

Designers: Mohammad Ali Shah
Client Coordinator: Yuka, Boston Homes, Boston, MA
Supervising Professor: Jay Fu
Electrical and Computer Engineering Department
University of Massachusetts, Lowell
Lowell, MA 01854

INTRODUCTION
A cane was designed to be able to sense certain distances to surrounding surfaces and thereby alert a user of obstacles. The design involved the use of infrared sensors and an OOPIC microcontroller integrated into the cane.

SUMMARY OF IMPACT
Although the project was a success, there was still room for improvement. Given that the weight of the cane is concentrated toward the bottom, it was difficult to carry for an extended period of time. A counterbalance was added in the project to help lessen the strain. Another improvement that could have been made involves expanded programming with a reduction in complex circuitry and hardware.

TECHNICAL DESCRIPTION
The product has been designed to be user friendly. To activate the cane, there is a simple on/off switch located on the attached box. Once activated, a user holds the handle and then slightly swings the cane back and forth in front of him or her to trigger the infrared sensors. A user will know when an obstacle is approaching, and the type of obstruction they are confronting, because they will hear a buzzing sound from the box that varies with changes in depth. A louder beep in the front of the handle signifies that an object has come within less than one and a half feet of the user; a single beep signifies that an object has come within one and a half to three feet of the user. In the event that the power source fails, the battery can be replaced with a new nine-volt battery located inside of the box on the front of the cane.

The cost of parts and material was approximately $120.
Figure 15.27. Sensitive Cane.

Figure 15.28. Cane Sensor Mechanism.
INTRODUCTION
The function of the sound activated bubble (Figure 15.29) is to generate a bubble upon sound activation. The circuit operates on a 12volt DC power supply. The activated switch is turned on by clapping the hands or by making any sound, and it turns off after a specified time delay. The audio sound is picked up by a microphone, which, in turn, feeds it to an amplifier. The amplified signal is fed to two diodes, which function as a half wave voltage doubler to produce a 12-volt output.

SUMMARY OF IMPACT
Upon activation the device generates multicolored bubbles. It is being used by children with disabilities in a classroom. An initial problem with the sensitivity of the sound-activated switch, was resolved by use of a potentiometer that reduces background noise.

TECHNICAL DESCRIPTION
A wooden box was made to enclose the components of this device, including the sound-activated switch, a DC motor, a multicolored bulb, a wire connection. The components are mounted on the same board (see Figure 15.30). The circuit is powered by a 12-volt DC adapter. The bubble tube is made of clear plastic. It is supported by a strong and stable wooden base. Sound sensitivity is adjustable.

The cost of parts and material was approximately $400.
Figure 15.30. Voice Activated Bubble.
VOICE-ACTIVATED ENVIRONMENTAL CONTROL SYSTEMS

Designer: Monika Patel
Client: Cindy Tatelman from commission of Disabilities
Supervisor of the Project: Mr. McGuire, Walter
University of Massachusetts at Lowell
Department of Electrical and Computer Engineering
Universities of Massachusetts,
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INTRODUCTION
The Environmental Control System was built for an individual who has limited mobility. She uses a wheelchair and needs assistance for controlling environmental devices and appliances, such as lights or fans. This project provides the client with the ability to control multiple electrical devices without assistance.

SUMMARY IMPACT
This project is controlled with speech output that allows the user to operate (hands-free) electrical appliances, including light switches, lamps, radios, televisions, fans, stereo systems, and kitchen appliances. The system uses voice command to control multiple televisions, numerous lights, a telephone, an automatic door and various other appliances.

TECHNICAL DESCRIPTION
The project consists of two parts: software and hardware. The hardware portion consists of an X-10 transceiver, and the software portion consists of two Microsoft programs: Visual Basic and Microsoft Speech SDK 5.1. Microsoft Speech SDK 5.1 consists of a voice recognition system that allows spoken words, letters and phrases to serve as an input to the computer. When the system receives an utterance that it recognizes, it initiates a computer function, such as “LIGHT ON,” created in Visual Basic code. This function sends signals to the serial port through the X-10 to run all electrical appliances that are connected to the X-10 module. Figure 15.31 presents a flow-chart.

Hardware Description:
One X-10 transceiver is connected to the computer via a parallel port, which transmits wireless signals to all X-10 appliance modules, which are plugged into a standard wall outlet. Each X-10 module must be connected with an electrical device.

Software Description:
The Voice-Activated Environmental Control System Software takes input from a microphone. Using speech recognition technology, it finds the text input corresponding to the voice input. After finding the appropriate operation, it displays the command on the screen and sends a signal to the X-10 Active Home kit to perform the operation. Microsoft Speech SDK 5.1 is used to implement speech recognition technology. Microsoft Visual Basic 6 is used to create user friendly GUI as well as programming functionality. Visual Basic code is written for each command, such as “ON,” “START,” “STOP,” “OFF” and others. The user trains the speech recognition system.

The total cost of parts and labor was approximately $4600.
Figure 15.31. Voice Activated Environmental Control System.
SWITCH-ACTIVATED TALKING CLOCK AND CALENDAR

Designer: Nitin Goyal
Client: Lowell High School, Lowell MA
Supervising Professor: Walter McGuire
Department of Electrical and Computer Engineering
University of Massachusetts at Lowell
Lowell, MA 01851

INTRODUCTION
A switch-activated talking clock and calendar was designed to provide assistance to individuals with visual impairments. The project is a portable device that can be easily carried. It has two switches: one for time output and one for date output.

SUMMARY OF IMPACT
The design requirements for the talking clock were defined by the supervisor of a center for children with disabilities. The object of the project was to foster time telling and cause and effect learning for children who are visually impaired.

TECHNICAL DESCRIPTION
The project was made of a plastic case 3.5 inches in length, 2.5 inches in width and 2 inches in height. Overall, the project (Figure 15.32) used only three chips: one PIC16F84A microprocessor, one 2560 ISD chip and one LM386 audio amplifier. The microprocessor was programmed to address an ISD chip in M0 mode and was also programmed for the regular clock function. A total of 58 commands were stored in the ISD for calendar and time output. A 4 MHz crystal was used for the PIC because, using this crystal, it takes the microprocessor \(1 \mu s\) to compile one line of command. Four AA batteries were used as a power supply.

The program was written in a way that it checks the switches and updates the second, minute, hour, day, and month in every loop. Two switches were used: one for the calendar and one for the time output. If any switch was pressed, it took two seconds for the time or calendar output. Time was added into the regular clock cycle to maintain accuracy. Final accuracy of the project was approximately 95%.

Final cost of the project was $30.
Figure 15.32. Final Circuit Design.
COLOR RECOGNITION TOY

Designers: Parth Patel
Client Coordinator: Lowell High School
Supervising Professor: Jay Fu
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Department of Electrical Engineering
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INTRODUCTION
The goal of this project was to create a toy that would help give audio and visual stimulation to children with cognitive and motor disabilities at a high school. The toy must also be durable, flexible, and simple.

SUMMARY OF IMPACT
This device provides audio and visual stimulation to children with disabilities.

TECHNICAL DESCRIPTION
A Stamp Chip is programmed to send inputs and outputs to different components. The first two randomly assign three different LEDs to be lit up for each pushbutton. There are six permutations of LED lighting orders. The random number generator takes a seed number, which is originally defined by the programmer, and creates a random number. This number is used to determine which of the six cases it will match. Once this case is set, the program uses another seed number from the variable YNUM to create a new second random number. This random number is used to determine which of the colors is selected. These selected colors are put into three cases under the six original cases. This makes a possible 18 combinations for the student to play with. Once the desired color is selected, the Basic Stamp chip outputs 10 signals to the ISD2590. The color is then played through a speaker. For each case a color is selected. That color corresponds to a certain pushbutton. The program then loops until the correct pushbutton is pushed. If an incorrect answer is pressed, the program loops back and repeats the desired color through the ISD2590. If a correct answer is selected then the program falls out of the loop and goes to a Correct function. The Correct function turns off all of the lights, then randomly picks a third number. The Correct function also increments the three random variables. This produces a new seed number for the next time the program is run. This third random number is used to determine a random song to play using the ISD2590.

The cost of parts and material is approximately $203.
Figure 15.33. Color Recognition Toy.
MOTORIZED STANDER

Designers: Philip L. Sliney II (in conjunction with my partner John P. Thomas IV)
Supervising Professor: Walter McGuire
Electrical and Computer Engineering Department
University of Massachusetts at Lowell,
Lowell, MA 01854

INTRODUCTION
The motorized stander is designed to allow children with multiple physical and cognitive disabilities to easily move around while standing upright. This device is similar to a motorized wheelchair in nature, but the user is held in an upright position instead of sitting down. The motorized stander allows the user to be held in an upright position, which may help with improved posturing and also promote more equalized height when interacting with others.

SUMMARY OF IMPACT
Multiple tests were carried out throughout the design and construction phases to demonstrate the safety and reliability of this project. Another important criterion was modularity. This project had to be easy to fix in the future, and also it had to be easy to add future attachments if necessary.

TECHNICAL DESCRIPTION
The project had a foldable design for easy disassembly and transport. It incorporated a unique suspension system that allowed all six wheels to be in constant contact with the ground at all times, allowing the motorized stander to have no problem navigating over door frames and elevator thresholds.

A design for control of the motors using PWM was constructed and tested. This design incorporated 14 potentiometers for various adjustments, including turning radius and speed, acceleration rate, deceleration rate, maximum speed, FET saturation level, and etc.

The motorized stander project has been thoroughly tested and reviewed by a number of people. It has been used by a child with a cognitive disability, as well as other children from ages nine to 14 and some adults.

All moving parts and all wires were covered to help prevent safety hazards. An impact-absorbent bumper system was conceived and incorporated into the final project to reduce potential safety problems. Impact tests yielded positive results.

The cost of parts/material was approximately $1000.
Figure 15.34. Original Manual Stander.

Figure 15.35. Motorized Stander Prototype.
INTRODUCTION

The purpose of designing a Fiberoptics Light was to provide children who have disabilities with an experience through which they can relax, learn, and explore in a multi-sensory approach.

The Fiberoptics Light is activated with a press of a single large jellybean switch. Upon pressing the switch, music is activated and played while colored LEDs light up in sequence and travel through a fiberoptics bundle arranged as peacock. The time interval for this occurrence is 120 seconds.

SUMMARY OF IMPACT

The Fiberoptics Light provides the children with visual and audio stimulation while giving them an experience of self control. The Fiberoptics Light is portable and lightweight, which enables the therapist to bring it to the rooms where the children receive therapy.

TECHNICAL DESCRIPTION

The safety of the children is the most important factor in designing this product. A compact nature and portability are also important. Finally, it had to be cost effective. Optical fibers arranged as a peacock are enclosed by a protective clear plastic casing that provides a visual display. This clear casing is concave in shape with measurements of 9 by 11 inches. The electronic circuit is placed on the bottom of the fiber arrangement, and it is enclosed by a black plastic casing that measures 4 by 11 inches. A small hole is drilled on the front left side of the black casing in order to install the jack for the jellybean switch, and a similar hole is drilled on the right side to accommodate the volume control switch.

Thirteen small holes forming a diamond shape are drilled on the center to provide the sound outlet for the eight Ω speaker. A single hole is drilled on the back, right side, to mount the AC adapter. For safety reasons, an AC adapter with an output of 5VDC regulated is used as a power source for all the integrated circuits used in this design.

An electronic timer consisting of an LM555 integrated circuit is used to generate the time delay pulse of 120 seconds. Another LM555 is used to build a stable circuit oscillator, which oscillates at a
frequency of 63 HZ. The frequency of this oscillator determines the speed with which the LED chaser lights up in a sequential manner. The CD4017 decade counter/decoder is used to build the light chaser. The LEDs used in this design have to provide 10 candella, 7000 mcd and wavelengths of 530nm, due to the fact that the light emitted has to travel through the fiber optics bundle and still provide high luminosity at the output. Finally, the ISD25120 with sampling rate of 4.0 kHz is used to store a children’s song with duration of 120 seconds.

The cost of parts and material is approximately $160.

Figure 15.38. Schematic Diagram.
INTRODUCTION
The Video Switch is designed to facilitate the monitoring of a child for a person with multiple disabilities. This device is an infrared controlled video switch that allows switching between video signals to monitor an apartment. By pressing a button on a remote control, different views of the apartment can be seen. Once completed, the project was installed for a client unable to monitor his child during certain times of the day. The goal of this project is to provide a way for the client to monitor his son as well as other individuals entering the apartment building.

SUMMARY OF IMPACT
The range of movement of the client limited the design and control of the switch. From early evening to mid-morning, the client was located in one spot in his apartment and could not check on the status of his child. By having an infrared controlled video switch, he is able to check, from his location, the entire apartment and also the front door. This keeps him from having to try to shout to locate the child’s location and status.

TECHNICAL DESCRIPTION
The main part of the system is located in a small eight by five by three-inch plastic case. Inside, two small printed circuit boards are mounted to the bottom cover of the case (Figure 15.39). The input and output jacks for the audio and video are mounted on the side of the case. The power jack is mounted on the side and allows access to a wall-mounted transformer for power. Also on the side of the case is a pushbutton switch that allows the source to be manually changed in the event that the infrared control fails.

The infrared signals are received on a PCM Photo Module, and then fed to an infrared decoder. The infrared decoder is chosen for its compatibility with Sony Television remote control codes. The control is set up to accept channel up and down, volume up and down, and channel buttons zero through nine. All of these buttons operate the same output to make changing the source an easy task. A small digital logic circuit consisting of some OR gates and some J-K Flip Flops create the input that the video and audio switching circuitry uses. The video and audio switching is facilitated via two multiplexers. Both multiplexers have built in decoders. This makes it easy to scroll easily sequentially through the four video feeds. The video multiplexer is selected has a built-in amplifier, good off channel isolation and ease of installation and use. The audio multiplexer is chosen to deal with audio signals that are of much lower frequency than the video multiplexer. The power to the circuit is both +5VDC and -5VDC. The +5VDC is provided via a wall transformer and regulator. The -5VDC is provided via a DC/DC converter.

The rest of the system is composed to different video feeds. A small camera is placed with the ability to move from side to side and up and down (Figure 15.40). This allows monitoring several rooms of the apartment with one camera. The camera can be moved remotely via a RF remote control. A lobby camera is accessed as one of the feeds to allow monitoring of people entering the building. The system allows more sources to be added in the future.

The total cost of the project, including a camera system and all the electronic parts, is $400.
Figure 15.39. Video Signal Switch Project Enclosure.

Figure 15.40. Small Movable Camera.
INTRODUCTION
The voice record and playback (VRP) is designed to allow the programming of messages to correspond to specific activities planned in classrooms. It can also be used with battery-operated toys and appliances to give children with disabilities a way to participate in activities, control their environment, or even just play and discover cause and effect relationships. This device is a black box to which a toy and a switch can be connected (Figure 15.41). Once the switch is pressed, a pre-recorded message is played and the toy or appliance is activated. Ultimately, the VRP is intended to give children with disabilities a sense of interaction with their environment.

SUMMARY OF IMPACT
The design criteria were defined according to the capabilities of the children and the needs of the client school. The instructors often need to say a specific message several times to the children before they can perform a particular activity. As a result, the teachers desired an easy to use, portable device that both the children and instructors will feel safe using. Furthermore, it was considered especially stimulating for the children, as well as convenient, if the children themselves had control over the device and the connected toy.

TECHNICAL DESCRIPTION
The design is based on the use of a single chip voice record/playback device (ISD2500 ChipCorder series), which offers a high quality of voice reproduction. Due to the fact that the chip is designed with several operational modes, it is simple to use with minimal external components.

The cost of parts and material is approximately $160.
Figure 15.42. Voice Record and Playback Circuitry.
INTRODUCTION
The design of the device is intended to help a child with a disability in a way that is challenging and rewarding. The device must be customized to meet the needs as well as abilities of a particular child. As the child learns, revisions and improvements in the device would be an option to help the child in different capacities.

The Talking Clock allows the user to set the time and announces that time when the user presses a talk button. The face of the clock as well as its hour and minute hands have to be large enough for the user to easily set the time. The design is simple and user friendly so that children of varied abilities are able to use the device.

SUMMARY OF IMPACT
This Talking Clock will help children with disabilities to participate in time-telling activities and interact in setting the time on a clock.

TECHNICAL DESCRIPTION
The external hardware is mounted inside an eight-inch by eight-inch by four-inch box as shown in Figure 15.43. It is a cubic structure, containing a top, a bottom, and four sides. The top has big numbers, one to twelve, in a circle with plastic plate protection. It has an eight-inch by eight-inch square size of birch plywood three-quarters inch thick installed on the bottom.

On the top right hand of the front side of the cube box is a red squared Turn-On switch. On the top left hand, it has a green indicator that lights up while the device is on. On the bottom left side of the device is a momentary switch hookup for sending signals to the device. On the middle of the front side, it has a four-digit LED display with a thin plastic filter. On the backside, it has a plug for the power source. On the left and right sides, are several holes for auditory signal to pass through. The assembly is given a final sanding and painting. For a final coat true blue gloss paint is added.

The device contains six main components: Rotary Switches or Magnetic Switches, Button Trigger, Microcontroller, Speech Synthesis IC, LED Display, and Speakers. When the user rotates the switches to the desired time, the switch input generates the BCD, which then signals the microcontroller PIC16F84A. After the button is pressed, the microcontroller sends a message to the speech synthesis ISD. The ISD looks up the words in the memory address and signals back to the microcontroller. The microcontroller processes the information, and then announces the desired time through the speakers, and displays the desired time on the LED display.

The cost of parts/material is approximately $160.
Figure 15.43. Talking Clock.
RADIO CONTROLLED TOY WHEELCHAIR WITH SPEED CONTROL

Designer: Sharbel Azzi
Client Coordinator: Lowell High School Rm#418, Lowell, MA.
Supervising Professor: Walter McGuire
Electrical and Computer Engineering Department
University of Massachusetts at Lowell
Lowell, Massachusetts 01854

INTRODUCTION
The radio controlled toy wheelchair with speed control is designed to help students who have limited arm mobility and slow reaction time to learn cause and effect. The toy is designed so that it can be controlled with a joystick. This enables the user to move the toy wheelchair with only one hand instead of regular controllers that require the use of both hands. Speed control allows the students to determine the speed at which the wheelchair moves, giving them ample time to react to changes in direction.

SUMMARY OF IMPACT
The design criteria for the radio controlled toy wheelchair are set by high school teachers of the children with disabilities as well as the design engineer. The aim of this product is to assist the teachers in teaching cause and effect. This toy is a fun learning tool for the class.

TECHNICAL DESCRIPTION
The design of the toy wheelchair relies heavily on existing radio controlled cars. The car's transmitter and receiver are modified so that the speed of the DC motor can be varied externally. The transmitter is modified so that a joystick can perform the functions of the previous switches, which require the use of both hands. Speed control allows the students to determine the speed at which the wheelchair moves, giving them ample time to react to changes in direction.

To be able to control the speed of the motor, the use of two LM555 ICs is incorporated. These chips are used to control the duty cycle of the voltage and thus the current going to the motor. By varying the duty cycle and the voltage using a potentiometer, the speed of the DC motor can be controlled. The 555 timers are turned ON and OFF depending on the signal outputted by the receiver. A forward signal turns one of the LM555 chips ON while the other timer is turned ON when a reverse signal is sent to the motor. Two LEDs placed on the wheelchair provide a visual display of the period of time the voltage is being turned on and the period of time it is being turned off. Each LED is for one direction (one for forward the other for reverse).

Total cost of parts and materials is approximately $75.
Figure 15.44. Wheelchair and Controller.
ASSOCIATION STATION

Designer: Timothy P Dineen Jr.
Client Coordinator: Bonnie Paulino, Kennedy Day School, Brighton, Ma
Supervising Professor: Walter McGuire
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INTRODUCTION
The Association Station (AS) was designed to teach color association to children with multiple disabilities. The problem is that there are few toys that teach colors that are specifically designed for children with disabilities. This device is a toy for the teacher and student to use together. The teacher chooses a color for the student to find; if the student chooses correctly, a same-colored light blinks and a positive reinforcement message is spoken. The intent of this device is to be enjoyable and educational.

SUMMARY OF IMPACT
The Association Station was designed to meet the requirements of the client school. Among the requirements was that the device allow for use by many different children with many different disabilities.

TECHNICAL DESCRIPTION
The physical structure of the AS is that of a rectangular wooden breadbox. The front faces the teacher and has four color selection switches, four different colored LEDs, and an on/off switch. The back side faces the student and has four different colored LEDs, a speaker mounted in the top center, and four mono headphone input jacks. The mono inputs allow for various types of modified switches, which allow children with different disabilities to use the device.

If the teacher and student choose the same color, a signal is passed to a timing circuit (LM555) for that color, which makes the corresponding colored LEDs blink. That signal is also passed to the addressing pins of a voice chip (ISD2560) to access the correct message, and finally the signal also goes to a logic circuit (CD4002B), which, in turn, sends a signal to the voice circuit to play the message.
Figure 15.48. Circuit Schematic.
SOUND ACTIVATED CAROUSEL

Designer: Nha Tran
Supervising Professor: Walter McGuire
Client Coordinator: Kennedy Day School, Boston, MA
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INTRODUCTION
The basic function of the project is to activate a relay through sound. Once the relay is on, a carousel spins with an AC motor operated at low speed and the light surrounding the carousel turns on. In the process the power supply converts the 24 V AC from the output step down transformer to a 12 V DC, which is used for the sound activated circuit. A music box is used as an option when the sound activated switch is not on. The user can control it via a switch. Figure 15.49 shows the device.

SUMMARY OF IMPACT
The children at a client school have many disabilities and use wheelchairs. The students have limited motor skills. The sound activated carousel is a source of entertainment for the children. All they have to do is either clap their hands or make noise to activate the device.

TECHNICAL DESCRIPTION
The overall circuit was powered by AC and DC voltage. The AC voltage was used for the motor to spin the carousel, and the DC voltage was used for the sound activated switch. For this reason a power supply of 12 vDC was built for the sound activated switch. In the process, due to unwanted noise from the carousel when it spins, the sound activated switch could not operate properly. There were two different ways to solve this problem. First, the potentiometer was used to adjust the sensitivity on the sound activated switch. Secondly, the microphone was moved one foot away from the carousel to reduce the noise. In the process, a two by one foot wooden box was built to accommodate both the carousel and the microphone.

Figure 15.49  Sound Activated Carousel.
MUSICAL CAUSE AND EFFECT TOY

Designers: Stephanie Viera
Client Coordinator: Lowell High School, Department Of Special Education, Lowell, MA
Supervising Professor: Walter McGuire & Alan Rux
Electrical and Computer Engineering Department
University of Massachusetts Lowell
Lowell, MA 01854

INTRODUCTION
The goal of this project is to build a fun and easy to use learning tool to teach children with disabilities cause and effect. The toy consists of four switches of different colors (blue, green, yellow and red), and LEDs with switches of the same color. Each LED is connected to the switch of the same color. Each switch has different musical sounds. When the toy is turned on, LEDs start lighting up in a random sequence. Only one LED lights up at a time. When the user presses the switch of the LED that is lit up, the toy plays songs to reward the user. If the user presses any other switch that does not correspond to the LED that is lit up, it makes no sound.

SUMMARY OF IMPACT
This toy would benefit the students in many ways. Pushing the buttons on the toys strengthen fine motor skills and eye-hand coordination. The music focuses the student’s attention and teaches them to use their hearing effectively. The music generated as they push the buttons helps reinforce cause and effect learning. The colors stimulate visual development. This toy is a great benefit for the students with disabilities to stimulate their senses as they have fun playing with the toy.

TECHNICAL DESCRIPTION
Turning on the circuit automatically triggers the counter to start up the LEDs. The LM555 timer tells the counter how long the LEDs are on. The sound is recorded in the ISD chip in four different addresses. Each address is triggered when the specific LEDs connect to the address that is lit up. The LEDs and switches are connected to the ISD by an AND-Gate, which sends an active high signal to the four input NOR-Gate when both the LED and switch are high. The NOR-Gate sends a signal to the ISD to start playing the song of the LED that is lit up.

The cost of parts and material is approximately $250.
INFRARED TOGGLE SWITCH FOR A MUSIC BOX

Designer: Tuyen D Truong
Client Coordinator: Leona Geovanni, Abraham Lincoln Elementary School, Lowell, MA
Supervising Professor: Jay Fu
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Department of Electrical and Computer Engineering
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INTRODUCTION
Instead of requiring a switch to be pushed to activate a device, such as a toy or music box, infrared (IR) remote control devices produce continuous coded stream of pulses. In this project, the coded stream is converted into a single pulse and that single pulse is used to turn a relay on and off. The relay then acts as a switch to turn on a secondary device, a music box.

SUMMARY OF IMPACT
The goal of this project is to design, build, and manufacture a wireless remote control that children with disabilities can use. This device helps the children to participate in activities and control their environment. Once these children understand that they can make things happen in the environment by pushing a button of a remote control, then they are ready to move on to more sophisticated interactions.

TECHNICAL DESCRIPTION
All modern IR remote control devices produce a continuous coded stream of pulses at 37.9 kHz when any button on the module is pressed. These IR pulses are detected and decoded by a receiver (TV, VCR, etc.) and the appropriate function is activated. In this project, the coded stream is converted into a single pulse and that single pulse is used to toggle a relay on and off. The coded information is lost. Only the fact that a button is pressed on the remote control unit is detected.

This single pulse is then used to toggle the output of a flip-flop. A high on the output of the flip-flop turns on a transistor, which, in turn, operates the relay and the LED. The relay acts as a switch connecting the wires of the power supply that produces power to turn on the music circuit.

The IR toggle circuit and music circuit are mounted into a box (20.32x15.4x7.6 centimeters). A DC power jack is in the back of the box for a 9 V adapter. On top of the box is the IR receiver, which senses the signal from any remote control. A speaker and a volume controller are also mounted on top. The device is shown in Figure 15.50.

The cost of parts and material is approximately $130.
Figure 15.50. Infrared Toggle Switch.
INTRODUCTION
The voice recognition feature on the Ameriphone Dialogue RC 200 was designed to allow an individual with motoric disabilities to utilize the phone with greater efficiency. The built-in voice recognition feature was far too sensitive, so that, when the phone rang, it picked up even if someone other than the client said hello or even with noise in the room. Also, the phone did not hang up unless there was complete silence and, in the meantime, it was connected to the operator, causing great inconvenience to the client. Hence, the built-in feature was turned off and an external voice recognition feature was developed. This feature requires only one word or a multi-word to be recognized for execution. Hence this development will allow the client to pick up, hang up and dial conveniently.

SUMMARY OF IMPACT
The remote transmitter performed all the required functions. It required a single click to pick up, hang up or dial. The client trained the device using one unique word to pick up, hang up or dial the phone as needed. This made him more self-reliant and capable of making and receiving phone calls without assistance. Also, it did not pick up the surrounding noise or anyone else’s voice.

TECHNICAL DESCRIPTION
The Voice Extreme Toolkit, made by Sensory Inc., is utilized for the voice recognition feature. The kit consists of: a Voice Extreme Development Board, Module, Power Supply, a Serial Cable for PC RS-232 connection, and a software CD containing required files and documentation for programming. It enables the application program to be written in a higher level language on a PC with the help of built-in functions. The application program is then linked with built-in data files. The program has access to several I/O ports and timers. The program is then downloaded via the serial cable onto the module, which has a built-in integrated circuit, 64KB ROM and 2MB flash memory for permanent storage of the program onto the module. The module has several I/O pins, which act as an output for the program, connected to the development board. The output of these pins can be used for hardware application.

The application consists of a program that begins with a training session and checks for a previously trained command to see whether a word is initially trained. If a word is initially trained, then it directly jumps to an infinite execution loop, where it constantly looks for a word to execute. If the user speaks the trained word, the RED LED on the development board goes ON for a designated period of time (0.5 sec), showing the user that the word is recognized. The RED LED is connected to a NAND gate via a 220 $\Omega$ resistor. The NAND gate is
connected to the output pin, which goes LOW every time a word is recognized. The output pin can be used for hardware application. If there is no trained command, the program enters a training process where it asks the user to train a word, stores it in FLASH memory and then proceeds to the infinite execution loop.

The output on the development board is used to trigger the remote transmitter via an opto-isolator. The opto-isolator has an NPN transistor output, which amplifies an approximate 8mA current received at its input through a current limiting circuit. The amplified current acts as a switch on the remote transmitter circuit, turning it ON every time a word is recognized for the same period of time. The remote is a RF transmitter, the RF receiver located in the phone. It works well over a distance of 20 feet. A RED LED on the remote indicates its execution. An external microphone is used for the user to speak in the trained word for execution. The microphone uses two AA batteries and the power supply for the remote transmitter is tapped from the development board. The entire circuit is placed in a black box as seen in Figure 15.53.

The cost of parts and materials is approximately $175.

![Figure 15.52. Voice Recognition System (Black Box and Microphone).](image)

![Figure 15.53. Internal View of Voice Recognition System (VE Kit, Remote, Microphone).](image)
INTRODUCTION
The Program Timer is designed to provide an environmental control system for a client who has physical disabilities. This device uses her appliances and lights to turn on or off from a Visual Basic Program that runs by X-10 modules. The modules make the home appliances and lights work with wireless control. Upon completion, the Program Timer was delivered to the client.

SUMMARY OF IMPACT
The design criteria for the Program Timer were defined by the capabilities of the client and her needs at home. A portable device was designed to help the client feel safe while controlling her home environment. It also allows her to take part in the decision-making about her environment.

TECHNICAL DESCRIPTION
The project integrates appliances and lights in the home. The project is used by individuals with disabilities to control their surroundings by a handheld device or by computer commands. One method of controlling a device is by communicating to it using X-10. X-10 is a language that allows devices to talk to each other using the electrical wiring in the person’s home. The theory of X-10 is the transmission of a message that occurs close to the zero crossing of a 60 Hz power line. There is a binary one that is represented by a one millisecond burst of 120kHz at the zero crossing point. There is a binary zero by the absence of a 120 kHz burst. The complete code transmission goes 11 cycles of the power line. The first two cycles represent a start code. The next four cycles represent the house code and the last five cycles represent the number code, one through 16, or a function code, on or off. The appliances and lights accept the X-10 signal and decode it. A microcontroller decides what to do with the signal.

The total cost of material and labor is $1006.
INTRODUCTION
A talking photo album was designed to enhance students’ cognitive and motor skills. The device consists of a page detection system, addressing system and a record/playback system. The basic idea behind the project is to take the input from the reflective sensors, then convert the 10 binary input signals to four binary signals that will be inverted and then sent to the ISD, signaling the addressing bits, resulting in a sound signal that is amplified and relayed to the speaker. The unique characteristic that separates the album from its competitors is the page detection system.

SUMMARY OF IMPACT
The talking photo album is designed to enhance students’ cognitive and motor skills. The album is to be used under supervision of therapists, especially with the recording process.

TECHNICAL DESCRIPTION
The main features of the album include record and play functions. The album is in the form of a booklet with single still images on each page. The user can record and play a message for each still image. The messages can be stored permanently or deleted. The record/playback functions are controlled via the ISD2560 voice recording chip. In addition to ISD2560, different chips, such as 257090 and 120, also can be used, depending on the length of the messages to be recorded. The schematic is the same for each chip, except the addressing varies accordingly.

Another important feature of the album is the page detection system. The user does not have to press buttons to play messages for each picture. The system consists of reflective detectors located on the left side of the booklet. The detectors consist of phototransistors and LEDs, with reflective strips at the border of each page. When each page is turned, it covers the phototransistor, and the LED turns on, indicating which page is being observed. The detectors are then connected to the encoder that takes the input signals and converts them to four binary output signals that are then inverted via hex inverter.
TELEPHONE PAD

Designer: Jonathan S. Lilley
Client Coordinator: Megan Leiberwirth, James S. Daly School, Lowell, MA
Supervising Professor: Jay Fu
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INTRODUCTION
The telephone pad is designed to help children learn to dial their phone numbers. The device is a tabletop box set up like a telephone. It has oversized buttons. When a button is pushed, it displays the number to a seven-segment display and presents an auditory verbal output of the number to a speaker. The box also has a standard telephone, where the same process can be implemented. The project was presented to the classroom, and the children and teachers are pleased with it. Figure 15.54 shows a photograph of the final project.

SUMMARY OF IMPACT
A project was requested to help the children learn their telephone numbers. The teacher wanted a toy that the children could use without constant supervision. There were only three teachers in the classroom at any one time, and it was difficult to be with all 10 students at once. Current learning tools included large sticky numbers for the floor, where the student stepped on the number and the teacher told them if they were correct or not. They were also using numbers on a piece of paper and the teacher had the students point to a series of numbers that make up their phone number. Both of these were good learning tools; however they both required the teacher to be with the student. The teacher’s main requirements were that the toy be safe and appealing to children.

TECHNICAL DESCRIPTION
The physical structure of the box was made out of half-inch plywood. 8-32 machine screws and 1/16-inch aluminum were used to make the large buttons on the pad. These buttons were SPST switches used to activate a 16-key encoder on the circuit. This encoder, when activated, sent out a binary coded decimal (BCD) over the output bus. This address went to a pick micro-controller (16F84), which lit the seven-segment display and activated the ISD voice chip. The ISD voice chip, when activated, output the number or symbol corresponding to that address to a 16 Ω speaker.

The other input to this circuit was a standard telephone, which was connected through an RJ11 connector. The telephone was powered using eight volts, and was connected to a DTMF touchtone decoder. This chip decoded the tones from the telephone and output a BCD address over the output bus. This output also went to the pick microcontroller, which displayed the number and activated the ISD chip.

The cost of parts and material was approximately $150.

Figure 15.54. Telephone Pad.
DEVELOPMENTAL ELECTRONIC TOY

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Supervising Professor: Walter McGuire
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INTRODUCTION
The electronic toy was designed and built to provide audio stimulation for children with multiple disabilities. The toy will help children with disabilities to sharpen their fine motor skills by grasping and releasing the toy shapes. There are four shapes in the toy, each of which needs to be placed into its correct position on the playing surface. As each shape is placed correctly, a message is played to reward the student.

SUMMARY OF IMPACT
The toy entertains the students while helping increase their independence because of its ease of use. Also, the toy frees the teachers to spend more time with other children who have more severe disabilities.

TECHNICAL DESCRIPTION
The basic structure of the electronic toy is made from yellow pine wood (1 by 12 by 6 feet). The material provides high strength, low weight and workability. The top, bottom, and four sides are all screwed together with 1.5 woodscrews to allow for repair or disassembly with little effort. The structure is painted blue to enhance the toy’s appearance. In addition, the shapes are color matched to their corresponding placement on the playing surface.

The student reward, when a shape is placed correctly, comes from prerecorded audio messages. The recording and playback of the messages is accomplished using ChipCorder® technology by the ISD Company. The CMOS technology is an information storage device that has unlimited applications. The IC chosen for this design is the ISD 1420, which has 20 seconds of voice record/playback capabilities. This IC also allows multiple messages to be recorded and played back, which is accomplished using the fully addressable zero-power 128k multilevel storage array. For this design four messages were recorded onto the IC, one message per each shape. For example, one message is “That’s correct, square.”

The design calls for four messages each about four seconds in time duration, so only 16 of 20 seconds are needed. The IC has eight pins that are used to access 160 address spaces. The messages are recorded onto the IC using four address pins. The same four pins are implemented when a shape is placed correctly and a playback occurs.

The cost of parts and material is approximately $90.
CHAPTER 16
UNIVERSITY OF NORTH CAROLINA AT
CHAPEL HILL

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Principal Investigator:
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COUNTER REVOLUTION: THE AUDIBLE COUNTER

Designers: Ken Bradley and Sirin Yaemsiri
Client Coordinator: Judy Stroupe, Orange Enterprises, Inc.
Supervising Professor: Dr. Richard L. Goldberg
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INTRODUCTION
The audible counter was developed to provide audio and visual counting for individuals with physical and/or cognitive impairments who work at a supported employment center. There was a need for a counter to help an individual keep track of work accomplished. With audio feedback, this device is particularly valuable for individuals who are unable to read a numeric display, or for individuals who benefit from audio stimulation.

To use this device, the user presses a large button on the front of the counter every time he or she completes a task, such as stuffing an envelope. The device responds by incrementing the count shown on the LCD display, and announcing the count with an audio message. Additional audio messages provide encouragement every five counts, as well as prompts when the device is idle for a period of time. For employees needing a custom increment switch, the supervisor can plug in a commercial switch into a standard one-eighth inch jack on the unit. Additional buttons on the unit are used to reset the count to zero or place the device in “sleep” mode.

SUMMARY OF IMPACT
According to the client coordinator, “the counter will increase the employees’ earning power and also increase their independence in their work by relying less on a supervisor to keep up with the count.” When an employee finishes a task, he or she can press a button on the audible counter and the device will output the current count both visibly and audibly. The counter is designed to be simple to use, and will save the current count until the user presses a reset button.

TECHNICAL DESCRIPTION
The custom circuit is designed on a pre-printed circuit board that minimizes noise during recording and playback. It also makes the circuit more robust and less prone to wires breaking. The device is controlled by the PIC microcontroller (Microchip, Chandler AZ), which receives input from the increment switch and provides the current count visually on the LCD screen and audibly through a speaker. Custom digital recordings are stored in the ISD record/playback chip (Winbond, San Jose CA).

The program works using timer and input interrupts from the microcontroller itself. At start, the program initializes all variables and then enters an infinite while loop. The loop can be interrupted by the PIC timer, which increments the idle time, or by user inputs, which include the “sleep”, “reset”, and “increment count” buttons. Every time the count is modified, either by reset or increment, the count number is stored in flash memory on the PIC to prevent data loss via power failure. Upon power up, the count is loaded from the flash memory. The microprocessor PIC and ISD voice record/playback chip can go into a sleep mode where they draw microamps of current. The other components, such as the inverter, speaker, and amplifier, run off a 5V supply. The PIC turns the 5V regulator on and off, which saves battery life when the device is not in use.

For the numbers “one” through “ninety-nine”, professionally recorded audio files were obtained from BeVocal Café (http://cafe.bevocal.com/). There are three custom recorded audio encouragement messages, including “excellent work,” “good job,” and “you’re doing great.” These messages play every five counts. There are three custom-recorded audio prompts, including “do another,” “keep going,” and “get back to work.”
These messages are played every 30, 60 and 120 seconds without user input. There are also custom recorded messages for “hello” and “goodbye” when the supervisor presses the awake/sleep button.

The enclosure is a 9.92 inch x 4.76 inch x 2.75 inch project box with a cutout for the LCD display (EAI Enclosures International, Libertyville IL). The box has a battery compartment for four AA batteries. The LCD count display, increment button, and speaker are mounted on the top panel of the enclosure. The LCD cutout is wide enough to fit the 20 characters by four line display. The increment button, the only button that the employee will have access to, is a green pushbutton switch. It has a 1-3/8 inch activation surface and activates no matter where it is pressed for easy access by employees who have limited motor control. The speaker is mounted on the inside of the enclosure and covered by a wire mesh. The supervisor controls the reset button, awake/sleep button, volume control, and alternate switch jack are mounted along the side of the enclosure. The reset and awake/sleep buttons are flush against the surface of the enclosure to prevent accidental pressing. An on/off switch to the battery is also mounted to the top of the enclosure.

The total cost of this project was $261.
INTRODUCTION
An agency employs individuals with cognitive and/or physical disabilities to perform tasks, including packaging of the PEP-R Autism Test Kit. This kit includes several jars filled with small items, such as blocks and dowels. In order to assist employees in packaging the kit, a device was designed to help the workers count and package these items. The device can be set to count a specific number of items and to indicate when the proper number of items has been counted.

To use this device, a supervisor sets the “goal count” to indicate the number of items, i.e., blocks or dowels, which should be packaged in the jar. Then the employee drops the items, one at a time, onto a slide. The item proceeds down the slide and passes over a transducer that detects its presence and increments the count; it then falls into the jar for packaging. The supervisor can place different templates over the opening of the slide to restrict which items can be inserted there.

SUMMARY OF IMPACT
This device will assist employees who have disabilities, such as autism or cerebral palsy, to package small items more accurately and efficiently. Because employees at the client agency are paid on a per-unit basis, increasing the speed and accuracy with which they perform will translate into increased pay. According to the client coordinator, “The small item counter will allow people with severe and multiple disabilities to assist with the configuration of the PEP Kits, increasing their independence and also [increasing] their pay.”

TECHNICAL DESCRIPTION
The primary component of the device is a PIC microcontroller (Microchip, Chandler AZ), which is connected to the input switches, the LCD screen, and an optical sensor that detects the passing of small objects down a slide.

In order to be counted by the optical sensor, each object must pass within close proximity to the sensor at a sufficiently slow rate to allow detection. Furthermore, the objects must follow a well-defined path, and be in such an orientation that they are recognizable by the sensor as they pass over it. An aluminum slide was created to accomplish these tasks. The proper orientation of each object is established by one of four different templates that are placed over the opening (see Figure 16.2), corresponding to the four different objects that are counted for the PEP kits. Because the slide is rectangular rather than cylindrical, the objects lie flush against the inner surface of the slide, thus maintaining the proper orientation. The angle of the slide also helps to maintain the proper orientation, so they cannot rotate freely during their progression down the slide. The resulting design ensures that the objects will be reliably detected by the sensor.

The optical sensor is a reflective photo-interrupter, which is sensitive enough to detect small and large, as well as translucent and opaque objects. Switches for Reset, Power, Up, and Down connect directly to the PIC.

One of the limiting factors of the PIC microcontroller is having it run fast enough to detect slight changes in signals from the photo-interrupter. To enhance the program’s execution speed, the buttons are attached to interrupts that intervene in the program only when pushed. Additionally, in its current configuration, the LCD is updated only when the count or goal count is changed. The PIC is programmed in C.

The display and the buzzer are the two ways that the device indicates the goal has been reached. Since the device has no auxiliary lights to alert the user,
the incorporated LCD screen is capable of writing in large, bold letters to enhance visibility. When the goal count is reached, the display reads “DONE” in letters that consume the entire screen. This message is accompanied by a subtle beep. One of the requirements for the device is that it will be used in a work setting, so it should not disturb or distract other workers. The display and the buzzer convey a clear message that the user is done in an appropriate manner for the working environment.

The total cost of the device is $381.94.
CHAPTER 17
UNIVERSITY OF ALABAMA AT BIRMINGHAM

School of Engineering
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Principal Investigator:

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TRANSITIONAL WALKER

Designers: Juanita Titrud, Michael Putman, Laura Chamlee
Client Coordinator: Scott Sall, Children’s Hospital of Alabama
Supervising Professor: Alan W. Eberhardt, Department of Biomedical Engineering
University of Alabama at Birmingham, Birmingham, AL 35294

INTRODUCTION
A physical therapist who specializes in motor coordination and balance of children with cerebral palsy found that many of the children he works with have a difficult time improving their gait with a traditional walker, and even more difficulty transitioning from a walker to hand canes. Common four-wheel pull-behind walkers are designed to hold the upper body rigid, placing all of the weight in the arms and dragging the feet along. After using the walkers for a prolonged length of time, many children develop a rigid upper body and are unable to adjust to the upper body movement required to walk with hand canes. The aim of the present project was to develop a transitional walker that would allow arm movement (flexion and extension) as in contrary walking (where the arm that swings forward is on the opposite side of the foot moving back). This new walker is designed to help children develop the upper body movement necessary to walk with a cane, while still providing the stability of a four-leg walker.

The design was subject to the following criteria:

- Adjustable in height for children ranging from 14-30 inches,
- Able to withstand a 70 pound child (at maximum),
- Enabling arm movement, so that the arms can move forward (extension) five inches and backward (flexion) five inches,
- Having stability and easy maneuverability, and
- Appealing to children and free of sharp edges or exposed bolts that might affect the child’s safety.

SUMMARY OF IMPACT
The walker is currently being used at a children’s hospital. If the design is successful, it will provide a child-friendly device with which children may transition from a traditional walker to hand canes, thereby allowing a greater degree of independence.

TECHNICAL DESCRIPTION
The design involved a modification to the Gator® brand walker. The Gator® was chosen because the two back wheels had small metal brakes that could be locked to prevent the walker from rolling backward with the child in it and the two front wheels had a pin lock that could lock into place so that they only roll straight. The Gator® frame was stainless steel, painted with a colorful veneer, and weighed only 13.5 pounds. The walker had a weight capacity of 70 pounds. The Gator was 18 inches wide and could adjust to heights between 13.5 and 26 inches.

To connect the forward and backward handle movement, plastic cording was looped through the back tube of the Gator walker and attached at the same point on both handles. The arm bars and handles were made from pediatric hand canes. This way, when one arm was pulled forward, the other arm would be automatically pulled back. Rubber stoppers were attached at the end of the back arm bar and the rubber cord was fed through holes in the center of the stoppers. These stoppers cushioned forceful arm movement and kept the child from overextending the arms. The arm handles were attached to the base of the walker with pin joints. Flanges were fabricated from A36 steel metal, which was wrapped around the frame and welded at the desired location. A steel cylinder with concave sides was machined and welded to the frame inside the two wings of the flanged steel. A 3/8th inch bronze bearing was fit inside and machine bolts (Grade A A307 steel) served as the axle for the arm canes. The final design is illustrated in Figure 17.1.

The total cost was $501.
Figure 17.1. Transitional Walker.
BATHCHAIR TRANSFER SYSTEM FOR ADULT WITH CEREBRAL PALSY

Designers: Jeremiah Haswell, Tania Ortiz-Fonseca, and John Skates
Client Coordinator: Dr. Bharat Soni, Chair, Department of Mechanical Engineering
Supervising Professors: BJ Stephens, PhD, Department of Mechanical Engineering, Alan W. Eberhardt, Department of Biomedical Engineering
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INTRODUCTION
A mobile shower chair/bath lift was requested for a client who has severe cerebral palsy (CP). The lift was to be used by a caregiver to assist in moving and bathing an adult client. The caregiver had been lifting and lowering the individual in and out of the bathtub, which placed strain on her back. The purpose of this shower chair/bath lift was to move the client from the bed to the bathroom, lower him into the bathtub, and then to raise him to the edge of the bathtub and transport him back.

The design constraints were to:

- Lift and lower the adult weighing 100 to 120 pounds, 5.5 feet in height, with a depth of 13 inches;
- Be made of materials and systems compatible with a bathing environment, with materials and systems that will not corrode, degrade, malfunction, or exhibit any other changes in water; and,
- Be safe for the adult or the caregiver.

There was to be no risk of drowning as a result of using the device. The client remains in the device until intentionally removed by the caregiver. There are no sharp or rough surfaces, corners, or edges on the device that might cut or otherwise harm the skin of the client or caregiver. Clearances are such that none of the adult’s body could be caught between the bathtub and the device during normal operation.

SUMMARY OF IMPACT
Many caregivers of individuals with cerebral palsy or other motor control problems have back pain as a result of regularly lifting a heavy person from a bed and into and out of a bathtub. The device has helped the caregiver in moving and bathing the adult, relieving the strain on the caregiver’s back.

TECHNICAL DESCRIPTION
A large shower chair was purchased from Flaghouse (Hasbrook Hts., NJ). The chair was made of PVC tubing with a blue mesh set on a PVC frame. This chair was mounted onto a rolling cart made of extruded aluminum provided by Parker Hannifin Corp. There were no welds on the cart; aluminum corner brackets with stainless steel bolts were used for the connections to provide stability and strength.

A pneumatic lift was designed to lift a maximum load of 200 pounds. The lift was made of a rectangular frame, two cross bars, and a pneumatic cylinder, which was mounted onto the bottom of the frame and connected to a center bar. The system is shown in Figure 17.2.

The total cost was $858.
Figure 17.2. Bath Chair Transfer System.
FLOOR MATERIALS TO PREVENT HIP FRACTURES

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Client Coordinator: Alan W. Eberhardt, Department of Biomedical Engineering
Supervising Professors: J. Barry Andrews, Gregg M. Janowski, Uday K. Vaidya
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INTRODUCTION
Fall-related hip fractures are a major source of injury in elderly persons. The current design was intended to develop flooring materials that remain stiff under normal walking conditions (low strain rates) and soften to provide cushion during a fall (high strain rates). The use of shear-thinning fluids in sandwich composites offers a promising method for such floor systems. Shear-thinning fluid is a strain rate sensitive material, which caters to a flooring system that will absorb impact. Based on understanding this fact, the present design study was performed to investigate new materials’ abilities to minimize the peak force seen during impact and to maximize the amount of energy attenuated. The target force values utilized were based on research conducted by Hayes and coworkers who showed hip fractures occurred within 0.78 – 4.00 kN range at energies of 5-50J.

SUMMARY OF IMPACT
An adult day care center was the main client for this design. Three falls had occurred in the facility in the previous year. The facility to be floored was an eight by eight foot restroom in a high traffic area. The goal was a flooring system to help minimize or prevent injury (i.e. hip fracture) in elderly people.

TECHNICAL DESCRIPTION
The floor would consist of a shear-thinning fluid component encased in a silicone rubber liner. The silicone rubber selected for this project was uncured Smooth-SilTM 930, (Smooth-On Inc). The ratio for mixing rubber and catalyst was 10:1. The rubber cured in 16-24 hours. The shear-thinning components tested were Laponite® RD (Rockwell Additives) and Carbopol® (Noveon). Laponite® RD is a synthetic silicate clay that mimics the naturally occurring smectite mineral called hectorite. The open network structure of Laponite® RD allows the chains to align under high shear rates, which causes a thinning response in the material. Carbopol® acts in a similar manner. Previous analyses of the rheology of these products with water alone, suggested that Laponite® has a greater capacity to shear thin. By mixing both the silicone rubber and the shear-thinning component, a composite material could be developed, exhibiting the strength and resiliency (of the rubber) and shear-thinning ability (Laponite® RD or Carbopol®). In essence, the flooring system was designed to be a shear-thinning rubber.

The silicone rubber/powder mix was poured into seven centimeter aluminum containers. The samples were degassed in a vacuum chamber for five minutes and allowed to cure for 16 to 24 hours. The samples were then post-cured in a recirculating air furnace for two hours at 80º C then one hour at 100º C. All samples were made at a thickness of 1.27 centimeters (0.5 inches).

Testing was performed according to ASTM F 1931-98, using a drop tower (Dynatup Instron Model 830-1). The initial setup incorporated the use of a striker head affixed to a load cell to determine energy, force, and velocity values during an impact. A high speed motion detector, operating at 300 Hertz, was also used to record rebound information during the testing. Both the load cell and motion detection data were recorded electronically and converted to spreadsheet form for further review. Testing for comparative values of impact force and time to peak load was performed using a 3.5 kilogram mass dropped from a height of five centimeters. A rectangular (seven by ten centimeter) striking surface was attached to the load cell. Each sample was impacted three times with a minimum of one minute between each successive strike.

The TUP software generated several key values for the samples tested. Among these values were peak force (kN) and energy produced at peak force (J).
Peak force values from the six trials performed on each sample were plotted as function of the amount of shear-thinning agent present. Figure 17.3 shows the peak force values of all the silicone rubber/shear thinning agent samples tested. The 12.5 weight percent silicone rubber/Laponite® RD samples showed the lowest force out of all the samples tested (see Figure 17.3).

The results achieved during this project indicate the mechanical properties of the silicon rubber/Laponite® system are a potentially viable solution for this type of a flooring system. Further testing and characterization of the compound is needed to fully quantify the role Laponite® contributes to energy absorption. Advantages of the silicone rubber/Laponite® compound over the close cell foam include sanitation and ease of fabrication.

The primary disadvantage is cost. The projected production cost is in excess of 16 times the cost of commercially available closed cell rubber foam mats.

Projected costs of the flooring system (eight by eight foot room) are given below.

- Material Cost/Square Foot $38.73
- Estimated Fabrication Cost/Square Foot $3.49
- Estimated Installation Cost/Square Foot $2.00
- Material Cost for 8' X 8' Floor $2,478.78
- Installation Cost for 8' X 8' Floor $128.00
- Total Cost for 8' X 8' Floor $3,180.97
- Cost/Square Foot $44.22

Figure 17.3. Laponite Containing Material Exhibited the Lowest Impact Force (left) and Second Highest Energy Dissipation (right).
JOYSTICK CONTROL TOY VEHICLE WITH REMOTE OVERRIDE

Designers: Eranga Devasurendra, Grant Harwell, Walter Reggel, Brian Rinne, Jide Emiola, Brad Hammond, Brent Hand, Juan La Rota, and Alva Kepple.
Client Coordinator: Sonya Parker
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INTRODUCTION
The client is a 22 month-old child diagnosed with cortical blindness and hypotonia. Cortical blindness is a term used to describe an apparent lack of visual functioning, in spite of anatomically and structurally intact eyes. The cause is assumed to be that the visual cortex of the brain is non-functional. The client is unable to crawl or walk due to hypotonia in her hips. Her mother also has a medical condition that limits the amount of time she is able to carry her child. The client’s mother requested a toy vehicle with the ability to self operate using hand joystick controls instead of foot pedals. Furthermore, the parent wanted to be able to operate the vehicle using a remote control that overrides the joystick control.

SUMMARY OF IMPACT
The child is able to control the car on her own, which gives her greater mobility. Her mother can actively override the child using the remote, in cases where the child may be in danger or “stuck” somewhere. The mother stated, "Thank you … this will provide a means of self-mobility/transportation for her. I cannot express the level of excitement that you have infused in our home and support family."

TECHNICAL DESCRIPTION
Furnished equipment included a toddler vehicle, battery charger, and owners’ manual. The first design aspect was steering, and it was proposed to use a RC servo motor and speed controller. The advantages included operating voltage 4.8 to 6Volts DC, it was readily available and inexpensive, and included a feedback system for positioning. It provided sufficient torque for steering a one-fourth scale car model (HS-805BB 343 oz-in) and could have additional gearing if necessary (4:1 or 5:1 gear box). RC servo motors have a standard interface that may be linked directly to a receiver for remote control. Disadvantages included the fact that the positional control signal was a pulsed signal, which required an additional interface between the potentiometer signal and the servo.

The second design component was the control system for remote control. This was accomplished by connecting the motor speed controller and the servo motor to a receiver and local control from the joystick pots through an interface board. Switch-over was accomplished by using a three-channel receiver, in which channel one linked to the servo, channel two to the speed controller, and channel three to a switch module or forward speed controller. The speed controller powered a relay with contacts connecting to the output of the local interface board. PWM signals the servo and speed controller when powered. When not powered, the relay contacts connect PWM signals from the receiver to the servo and speed controller. Local control was through an interface board that converts a potentiometer signal into the proper PWM signal. A combined switch and signal pot interfaced to a single board computer takes the pot signals and the receiver PWM signals and creates a PWM from the pots. It also does the switching based on the on/off module connected to the receiver. The finished product is shown in Figure 17.4.

The total cost was $1061.
Figure 17.4. Joystick Controlled Vehicle with Remote Override.
CHAPTER 18
UNIVERSITY OF TOLEDO

College of Engineering
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INTRODUCTION
The purpose of this project was to design and construct a lift system for a wheelchair user. The goal was to enable him to be lifted unassisted from the second level in his garage to the level of the house. An arcing lift system has been developed for this purpose. It consists of a fixed frame with four arms connected to a moving frame that supports a moving platform. The platform, when lifted, follows the path of an arc to the level of the house, while the platform itself remains level. A self-contained hydraulic piston is used as a linear actuator to power the lift. A three-way momentary contact switch is used to allow the lift to be operated independently. The platform is covered with slip-resistant slips for additional safety.

SUMMARY OF IMPACT
Individuals who use wheelchairs are faced with the challenge of maneuvering over steps. The client has T3 paraplegia. He has no use of his legs, but has good use of his arms. He currently lives in a house that has a front entrance ramp. He had no way to enter the home from his garage because of a step between the second level of the garage and the door into the house. A lift system was developed to allow him to be lifted from the second level in his garage to the level of the house, so he can enter unassisted.

TECHNICAL DESCRIPTION
The lift system was designed according to the client’s individual needs. Two main factors needed to be considered. First, a second door that leads to the outside (outside door), but swings into the garage, crosses the entrance to the doorway that leads inside the house. This is shown in Figure 18.1. It is because of this door that a simple ramp could not be built to enable the client to enter his house from the garage. If anything is constructed that is above the second level of the garage, it would make the door leading to the outside unusable. An area in front of the doorway that leads inside will be dug out to install the lift system, and all design aspects needed to take into account that the lift will be flush with the second level of the garage when not in use. This will allow the outside door that swings into the garage to cross the area in which the lift is placed. This feature also benefits the client’s family since their entrance to the house will remain unobstructed.

Second, there is a set of unmovable pipes that run along the floor beneath the door of entry. This is shown in Figure 18.1. They total 3.5 inches in width, measured up to the wall beneath the door, meaning that the lift could not be placed directly in front of the door.

Several design concepts were explored including a scissor lift, a hydraulic lift and an arcing lift. In order to clear the pipes, scissor and hydraulic lifts require attaching a flap from the moving platform to bridge the gap between the edge of the platform and
the door. Instead, an arcing lift system, illustrated in Figure 18.2, was selected because it allows the platform to move horizontally 3.5 inches as it is raised vertically to meet with the doorway. The lift was designed to lift the user seven inches, as shown in Figure 18.2. The height of the lift when not in use could not exceed 10 inches to allow it to sit within the concrete, given that the thickness of the garage concrete floor is 10 inches.

The main components of the system are a fixed frame that is built into the floor, a moving frame, four arms, a platform attached to the moving frame, a linear actuator, a battery and a charger, and electric controls. When the lift is in the down position, the moving frame is flush with the concrete floor. Four arms are used to connect the moving and fixed frames. When raised simultaneously, these arms allow the moving platform to go up and move horizontally at the same time. Instead of using a motor to drive the lift, which would have required a gearbox, a hydraulic linear actuator is employed.

A quarter-inch thick steel platform, measuring 36 inches x 42 inches and weighing 200 pounds, was used. Two brackets are welded underneath the platform to allow it to be connected to the moving frame using cotter pins. This enables easy removal of the platform, which allows for cleaning underneath, and for lift maintenance. The platform is covered with slip-resistant material for additional safety.

The frames are made using one-inch square steel tubing. Steel was chosen due to its strength and low cost. The fixed frame is a simple rectangle measuring 42 by 34 inches. It consists of four bars that are welded together using fillet and butt welds. The moving frame, or top frame, is also a simple rectangle, but with three extra supporting members to keep the platform from deflecting. The moving frame has the same outer dimensions as the fixed frame with two supports on the longer side of the frame, equally spaced at 12 inches apart, and one support on the shorter side. The four arms are connected to the fixed and moving frames with eight bearings, encompassed in bearing support assemblies. Based on a structural analysis of the system, the bearings selected are rated at 2600 pounds. The bearing assemblies within the moving frame are situated opposite to those within the fixed frame.
The linear actuator is attached to the moving frame using an in-house mounting bracket and to the fixed frame using a mounting bracket supplied by the actuator company. On the fixed frame, the bracket is located on the back and at the center of the frame. On the moving frame, the bracket is located at the center of the long support (the support on the shorter side of the frame).

Stress analysis was conducted to insure that all welds and bolts will not fail. The critical welds are those used to attach the bracket connecting the linear actuator to the moving frame. Calculations were performed based on a design load of 800 pounds. Maximum shear stresses in the weld were calculated assuming a weld thickness of a half-inch, and a factor of safety exceeding 10 is estimated.

The four arms carrying the platform along the arcing path are also made of one inch square steel tubing and are all the same length, 10.5 inches. The critical load that can be sustained by each arm is calculated using buckling formulas. It was found that the factor of safety against buckling failure of the arms exceeded five. One half inch bolts are selected to connect the arms and bearing assemblies to the frames. Figure 18.3 shows a picture of the lift that has been developed.

The lift is also designed to be user-friendly for the client and his family. The power source chosen is a linear actuator, also known as a single hydraulic piston that requires little or no maintenance and is reliable. The linear actuator consists of a small electric motor and a single hydraulic piston with a travel of 12 inches. The electric motor is powered by a 12-volt battery, which makes it reliable even during a power outage. The battery is a 12-volt car battery with gel acid cells instead of liquid acid. This feature improves the longevity of the battery. This battery is connected to a charger at all times.

Because of the possible safety risks of people or objects getting in the way of the lift while it is in motion, the controls for the lift are momentary contact switches. This enables the occupant to stop the lift at any time, in case he becomes unstable, or if something gets in the way of the travel. With this mode of control, it was decided that having a wall-mounted control would be impractical, so a handheld control was made. Four relays and a three-way momentary contact switch were purchased and assembled to make the control switch. The switch enables the client to hold the switch forward to raise the lift, let go to stop the lift, or hold the switch the opposite way to lower the lift. Also, an amperage cutoff is incorporated into the control so that if the load on the platform exceeded 1500 pounds, drawing more than 30 amps, the control switch would cut off power to the actuator.

The cost of all parts exceeded $1200. Some parts were secured through in-kind donations allowing this project to be completed within its allocated budget of $750.
Figure 18.3. Arcing Lift System.
COMPACT MOBILE WHEELCHAIR SCISSOR LIFT

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INTRODUCTION
The purpose of this project was to design and construct a unit that will allow an individual using a wheelchair to move independently from the wheelchair to the deck of a pool and vice-versa. A small compact scissor lift was designed and constructed. The lift uses one linear actuator to lower the scissor frame to 5 ½ inches from the pool deck and raise the frame to the height of the wheelchair. Two twelve-volt rechargeable batteries were used to power the linear actuator. Two 24 inch wheels were added in the rear and two small wheelchair caster wheels were added to the front of the unit. Locking brakes were added to the rear wheels of the unit to prevent it from moving during transfer. The unit itself functioned fully as a manual wheelchair and as a powered lifting device, as shown in Figures 18.4 and 18.5.

SUMMARY OF IMPACT
A 17-year-old female with C6 tetraplegia is a competitive swimmer. She has good use of her upper arms, little use of her lower arms and hands, and no use of her trunk and legs. This individual practices at a swimming pool three to five times a week, which requires her to get from her wheelchair to the deck of the pool so she can get in the water. Her previous transfer system was dangerous and stress-inducing, as she transferred manually from her wheelchair to an intermediate step approximately half way between the seat height and floor, which required the assistance of another person. No product is available on the market to allow the client to independently make the transfer from her wheelchair to the pool. Seat lifts are available on the market; however, such devices are primarily used in assisting an individual out of a chair and are intended primarily for the elderly. Since the client has no use of her legs, such a device would not be appropriate. One option would be the use of a scissor-lift mechanism, which is primarily used in construction applications. However, the scissor lifts on the market deal with large applications and loads; and they are heavy, cumbersome and expensive. Since no commercial item fits the needs of the client, it was therefore necessary to develop a small, compact scissor lift to raise and lower the client from the height of a wheelchair seat to the deck of a pool and vice-versa. The client is very pleased with the unit that was developed. It gives her the ability to transfer from

Figure 18.4. CAD Drawing of the Unit.
Figure 18.5. The Constructed Unit.
her wheelchair to the pool independently and comfortably.

**TECHNICAL DESCRIPTION**

The design requirements specified by the client were that the unit be stable on wet surfaces, easily and independently set up by the client, durable, and rust-proof. Additionally, seating must not be slippery or irritating to the skin, and the unit should be lightweight for transportation. The initial design is an automated system that has a scissor lift frame powered by either locking gas charged springs, a linear actuator, or hydraulic cylinders. A switch or lever arm within reach of the client activates any one of these motion generation mechanisms. This design requires only minimal effort to be exerted by the client to operate the system and provides great stability. A House-Of-Quality approach was used to evaluate the different methods of powering the scissor lift. The linear actuator was found to be the best choice. Aluminum framing is used with a cloth seat.

As shown in Figures 18.4 and 18.5, the unit includes a lower frame and an upper frame. Both frames are made from one-inch diameter round aluminum with 1/8 inch wall thickness. The aluminum is wheelchair grade aluminum. Cross members are added to provide stability. They are attached to linear slides that are connected to the upper and lower frames. This allows the cross members to slide along the top and bottom frames as the unit is raised and lowered. One linear actuator is attached to the fixed lower frame and the moving upper frame. As it extends, the cross members slide along the upper and lower frames and the upper frame rises. Two twelve-volt rechargeable batteries are used to power the linear actuator. The batteries are attached to the lower frame and are wired to a toggle switch within the reach of the user. The linear actuator is rated to provide 1350 pounds of force to lift 250 pounds.

The unit is 19 inches from the seat to the floor, 15 inches wide and 20 inches deep. The lower frame is elevated four inches from the floor. To facilitate transportation, two 24-inch wheels are attached to the rear of the unit, and two small wheelchair caster wheels are added to the front. To provide a stable unit during transfer, locking brakes are added to the rear wheels of the unit. The brakes are activated by a single lever within the reach of the client.

The unit has been tested by the client as shown in Fig. 18.6. It was found to be stable. Transfer to and from the unit is easy and comfortable. The unit itself functions fully as a manual wheelchair and as a powered lifting device. The unit can be easily disassembled for storage. For this purpose, the seat is moved to the lower position as shown in Figure 18.7, and the wheels are removed. The scissor lift can be picked up and rolled away.

Total cost for all parts and material is approximately $1,300.00. Several parts secured through in-kind donation allowed this project to be completed within its allocated budget.
CAMERA SUPPORT SYSTEM FOR A WHEELCHAIR

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INTRODUCTION
The purpose of this project was to design and construct a wheelchair-compatible camera support system for an active outdoorsman with C6 tetraplegia. This system, shown in Figure 18.8, is designed to be detachable and to be transferable between different wheelchair models. It features a simple, non-permanent clamp that can be attached to nearly any point on the one inch diameter leg rest of a typical wheelchair. The system as a whole is designed for minimal interference with the client’s use of his wheelchair. To facilitate the client’s independent use of camera and system, a secondary connection is included in the system near the front left side. The two components that form this interlocking connection are the upright arm and the support arm. These components are designed to form a framework between the clamp and the camera mount, located at the opposite ends of the respective components. Except for the attachment mechanisms, the system has only one moving part: the adjustable camera mount which is the only portion of the system that the client will need to manipulate in order to position his camera for the perfect shot.

SUMMARY OF IMPACT
As an outdoor enthusiast, enjoying a beautiful vista is important to the client. The use of a camera allows a person to share images with others. Good photography, however, requires steady support of the camera. The client, a 42-year-old male with C6 tetraplegia, has good use of his upper arms and wrists, and limited use of his hands. Although he can position and manipulate objects, holding something in place for prolonged periods of time is challenging. The system allows this individual to carry and support his camera during activities such as park visits, camping, and charter fishing trips. The system is designed to interface with the client’s current digital camera and manual wheelchair. The non-permanent clamp was chosen so the client can easily remove the system and use it with different wheelchairs. An attachment for binoculars, initiated during the final build, greatly increases the client’s potential usage of the system. The system was tested by the client, as shown in Figure 18.9, and found to meet all design specifications.

TECHNICAL DESCRIPTION
One of the most important functionality aspects considered is that the system should not interfere with the client’s normal use of his wheelchair. With its relatively compact structural design, the camera support system does not interfere with the client’s normal movements while seated. Other important functionality considerations include detachability and compatibility of the system with multiple wheelchair models. A simple clamping mechanism, described below, proves the ideal solution to these requirements. Physical design considerations include: mounting location, arm mechanism, and clamping mechanism. The mounting location selected for the final design is the left leg rest post. This location is chosen specifically to satisfy the client’s desire for the system to be transferable from his current wheelchair to any other models he may own in the future. Mounting the system on the leg rest provides an adequate clamping location that does not interfere with the client’s space requirements. The left leg rest is chosen in particular so that the system can be used with electrically powered wheelchairs; the motion controller is generally located on the right side of the chair.

The clamping system used to attach the system to the leg rest is patterned after a bike rack clamp. The mechanism, made from a block of 1010 carbon steel,
consists of front and back clamping blocks connected by a quick-release power screw. The quick release/power screw design is included for quick installation and removal, and to prevent slippage between that clamp and the leg rest. Foam rubber padding is added to the inside of the left clamp indent. This feature is added to increase the coefficient of friction and to prevent scratches to the finish on the leg rest. The power screw/quick release is located at the center of the clamp. Left and right side circular contours are cut out of the block. As the screw is tightened, the steel portions of the clamp come together, gripping both the post of the wheelchair leg rest and the upright support arm simultaneously.

The main support mechanism, consisting of an upright arm and a support arm, extends vertically from the clamp. The upright arm, made of 1010 carbon steel, is welded directly to the clamp, extending upwards along the angle of the leg rest to approximately two inches left of the client’s left knee. At this point, the arm bends so that it is perpendicular to the ground. A bolt is threaded into a bolt hole approximately four inches from the top of the upright arm. The support arm, an L-shaped section of 6061 aluminum, is inserted into the upright arm. The notch cut out of the bottom of the support arm seats over the bolt threaded into the upright arm, effectively interlocking the support system. The support arm extends about 14-3/4 inches vertically from the notch to a 90 degree bend and about 16 inches horizontally from the bend to the camera. The interlocking dual arm mechanism is selected to give the client the ability to remove the support arm and camera for short periods, eliminating the need to constantly unclamp the entire system.

A camera mount similar to those found on camera tripods is secured at the end of the support arm. To provide easier use, a modified lever, which the client can manipulate with his right wrist and palm, is threaded into the camera mount. The camera can then be panned and tilted by manipulating this lever. Should he so desire, the client is able to lightly rest his left forearm on the support arm and guide or steady the camera with his left hand while manipulating the camera mount lever with his right.

Once the camera is positioned to his satisfaction, the client locks the camera mount lever with a twist of his right wrist and snaps the picture using the heel of his left hand.

The system is designed for loads not to exceed 30 pounds in any direction. For the safety of all concerned, leaning on the camera support system by anyone other than the client is strictly prohibited. The client and his family were informed of these restrictions prior to their taking ownership of the system, and a written caution was included with the system.

Total cost of parts and material was approximately $100.00.

Figure 18.8. Complete Camera Support System.  
Figure 18.9. Client Demonstrating System.
MECHANICAL VALVE TO DRAIN A CATHETER COLLECTION BAG

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INTRODUCTION
The purpose of this project was to develop a valve system that allows a 37 year old male with C5 tetraplegia to drain the leg storage bag on his own with the limited use of his biceps and shoulder muscle control. This individual’s disability has eliminated the feeling from his chest down and thus made him unable to control his bladder. An indwelling Foley catheter drains into a collection bag on his right leg. However, since he has no use of his hands and fingers, he cannot drain the bag on his own and is dependent on his family for assistance. The client can move his biceps in a pulling motion, and use his back and shoulders in a rotating motion to move around in his wheelchair. However, he cannot use his triceps to push and cannot control his hands or fingers. A pure mechanical valve system has been developed so the individual can fully operate. A lever action cable system (like a bicycle brake) is utilized to actuate a brass micro valve using a brake lever. The components of this mechanical valve system are shown in Figure 18.10. The valve chosen is a roller lever micro valve with an internally spring loaded handle to keep the valve closed when not in use. The valve system is mounted on the wheelchair so that it is protected by its structure to avoid any damage during transportation of the chair.

SUMMARY OF IMPACT
Dehydration is a daily concern for this individual. He does not drink enough water and his health is at risk. He usually refrains from drinking water because he is home alone and cannot empty his catheter bag himself. Also, because the client has C5 tetraplegia, the nerves from the C5 disc down remain intact with reflex loops and muscle tone, but no signals are sent to the brain. Because these reflex loops are still intact, his legs sometimes spasm uncontrollably. Significant amounts of water must be taken when using the medication to control these spasms. The valve system should allow him to empty his catheter bag at any time and therefore would encourage him to drink necessary amounts of water.

Figure 18.10. Valve System Mounted on Wheelchair.
TECHNICAL DESCRIPTION

One of the client’s requests was to conceal the valve system as much as possible and make it aesthetically pleasing. In addition, the client requested to run the drain tube from the valve so that it drains under the footrest. His wheelchair is an Invacare Terminator that is designed for sports and recreation. Its structure is mostly three-quarter inch aluminum tubing, which makes the chair lightweight and allows its user to maneuver around without much strain on his muscles. The client also desired to accommodate the design of his leg bag setup. He uses a Foley catheter that collects into a Bard Medical 32 oz. large reusable leg bag. It is 12 inches long and is strapped to his lower right leg using fabric leg straps. It drains from a Flip-FloTM anti-reflux nozzle at its bottom.

The valve system had to attach simply to the Bard Medical leg bag and had to be easily operated and adjusted to meet the user’s biceps muscle capacity. An electrical solution and a mechanical solution to the design problem were proposed. The electrical setup had many options, ranging from actuation devices to valves. The first idea was to install an electric solenoid valve that opened and closed upon the push of a button. It could be a chair mounted button, a pressure switch or a “bite” switch. However, the added weight of the required battery source represented a problem. Adding approximately 20 pounds to the lightweight chair by mounting a 24 volt battery would increase the risk of muscle strain to the client. The trouble of often having to recharge the battery would be an inconvenience; also the client would not be able to recharge the battery by himself.

Mechanical solutions to the design problem included a variety of different valve choices. A knife-edge valve, a ball valve, a gravity valve, or a butterfly valve could have been used. A spring or damper system could have been used as the actuation device. Since the client has no use of his hands and fingers, there was a need for a lever arm that could be pulled using the client’s biceps or another muscle that he can use. The merits of the mechanical system were that it could be adjusted easily to meet the client’s muscle capabilities, was human powered and did not rely on an external battery source, and would not add much weight to the wheelchair.

An internally spring-loaded microvalve from Barworth, Inc. was chosen. Because of resistance to corrosion from weather and cleaning solutions, brass internals with a brass valve body were chosen for the materials used in the valve. It was mounted at the lowest section of straight tubing (approximately four to five inches above the ground) on the client’s wheelchair. Because the client’s leg bag was positioned on his right leg with the bag’s nozzle at his calf, the valve system was mounted on the right side. The hose that attaches the catheter bag nozzle to the valve system had to run down and exit the bottom of his pant leg. A cable mechanism was chosen as the actuation device because of its reliability and versatility, which allowed the most options for the mounting of a lever either behind or under the wheelchair seat. A Diatech Tech 99 brake lever with a hinged clamp mechanism (split perch) was used as the remote actuator. An advantage of the split perch system was that it could be directly mounted to a pipe of up to one inch diameter. The brake lever, which uses a cable to pull the valve open, was mounted under the right side of the client’s wheelchair seat and shims were included to give a snug fit. One of the client’s expectations was for the valve setup to be concealed and drain from under the footrest. The valve was mounted on the chair using a simple U clamp in a way such that the wheel chair frame itself provides protection from damage and unintended use. This mounting device was chosen because it can be universally used on any similar wheelchair (with pipe diameters ranging from one-half inch to one inch).

The valve was tested using a calibrated fish scale and found to require approximately one and a quarter pounds of force to open. The system was fully tested for operation and performed to expectations, except that flow time for the entire system was slightly slower than desired. The time to fully drain the leg bag varied from about one and a half to two minutes.

The total cost of all parts was approximately $200.00.
INTRODUCTION
The family of a young client who has progressive encephalopathy-edema-hypsarrhythmia-optic atrophy (PEHO) syndrome requested a removable bathing system installed in a first floor bedroom of their two-story home to lift the child from her bed or wheelchair and safely move her to a bathing station. The system included a bathing station, plumbing and ventilation components, and a lift and transfer mechanism to safely move the client. The first area of concern was the size of the bedroom. The room was 10 feet long by eight feet wide. There was a hospital bed that sat along one wall, and the bathing station was on the opposite side of the room. Another challenge was the need for the entire system to be removable so that the family could take it with them if they move to another home. The last concern was to provide a system that would be unnoticeable, and would leave space for the family members to freely move their child around the room in a wheelchair. A hoist and rail mechanism was used to move the child while carried in an attached sling. Figures 18.11 and 18.12 show the bedroom before and after installing the system, respectively.

SUMMARY OF IMPACT
Previously, the parents had to carry their child upstairs to a second story bathroom in order to bathe her. This is not extremely difficult at the present time because the child is only three years old and weighs 40 pounds. However, the child is expected to grow to an estimated weight of 125 pounds, and soon they will be unable to safely carry her up and down the stairs or lower and raise her into and out of the bathtub. The child is also unable to control any of her movements except that of her head. The sling that is attached to the hoist is able to comfortably constrain the child and free the parents of the strain exerted in holding the child in place while bathing her. The successful completion of this project provides the clients an easier method to bathe their child.

TECHNICAL DESCRIPTION
The system had to be easy to use, portable (in case the family moves), and safe for the child and the caretaker. The bedroom is a rectangular room, ten feet long by eight feet wide. The room is adjacent to a bathroom, so the bathing system must be installed along the wall shared with the bathroom in order to run plumbing and ventilation from the bathroom into the bedroom. Opposite from the bathing station is a hospital bed in which the child sleeps. The entrance to the room and the middle of the room must be open in order to make the area wheelchair accessible.

The system that was developed to move the child from the bed is that of a hoist and rail mechanism. It consists of a rail that is mounted to the ceiling of the room and held in place by five six-inch long lag bolts drilled into the second story floor joists. The rail stretches from one side of the bedroom, atop the bed, across to the other side of the room, atop the bathing station. The rail is painted the same color as the ceiling to keep it as inconspicuous as possible. Attached to the rail is an electric hoist, suspended from the rail by two free moving rollers. The group of students worked with a contractor, hired by the family, to ensure proper system installation.

The movement of the hoist is controlled in the vertical axis by a series of hand controls. Horizontal movement is manually controlled by the operator, who is able to push it along the rail with little effort. Attached at the bottom of the hoist is a spreader bar that supports a sling, which carries the child. The sling consists of straps that comfortably constrain the child from rolling out. The child is placed in the
sling while lying on the bed, and is secured so that she is safely ready to be moved. The operator of the hoist then lifts the child up and pushes her along the rail to either the wheelchair or the bathing station. The sling is to be unstrapped when the child is placed in her wheelchair. While the child is bathed, the sling remains intact.

To select the hoist motor, the power required to lift the child’s weight was determined. The power calculations were based on a 400-pound maximum load, the force due to the sling and residual water, and any uncertainties. The power required to lift the child at an estimated safe speed of 6.67 feet per minute was calculated as 0.081 hp. A Waverley Glen Transactive hoist was used. It has a Valeo® Motor rated at 0.125 hp. The maximum deflection at the end of the rail was calculated as 0.0071 inches and the maximum deflection of the rail between lag screws was calculated as 0.0182 inches. The maximum tensile stresses in a section of rail between two lag screws were calculated as 2229 psi and the maximum compressive stresses as 2503 psi. SAE Grade 2, 3/8 inch diameter lag screws were used. The maximum stresses in the hoist strap were calculated as 3200 psi, corresponding to a factor of safety of four. The life of the Nachi bearings used in the hoist was calculated as 3,400 hours, based on the design load of 400 pounds. The installation was done at a cost of $200.00. The clients tested the lift and transfer system and were very pleased with the ease of use and safety that the system is able to provide.

The bathing station was purchased and installed by the client as her parents received a grant providing them with the funds necessary to implement a special bathing system in their home. They chose to purchase and install a Dolphin Shower Trolley as opposed to a traditional bathtub. The plumbing and ventilation materials priced at $150.00 and labor cost of approximately $400.00 were also incurred by the client and covered by the grant. The seat that sits in the bathing station to support the child as she is being bathed was acquired by the client. The project team acquired the hoist valued at $1200.00 from a previous senior design group whose project was terminated. The sling, valued at $100.00, was donated by the Young Medical Equipment company. The rail and brackets were purchased for $300.00. This includes two six-foot sections of rail, one of which is cut down to four feet, one six inch bracket used to join the two sections of track, five three-inch brackets used to support the track to the ceiling, and two end stops and caps.
ADAPTATION OF A WHEELCHAIR TO SUPPORT A HARMONICA STORAGE UNIT

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INTRODUCTION
The goal of this project is to design and construct a harmonica storage unit for an individual with Multiple Sclerosis (MS) who wants to pursue a career as an entertainer playing the harmonica. Currently, the client has no method of storing or exchanging harmonicas. He must rely on the assistance of someone or something to hold his harmonicas. The client is able to grasp and play a harmonica simultaneously, but he desires something in which to store these harmonicas while exchanging them during and between songs, as several harmonicas are used in each song. A storage system that holds 36 harmonicas was developed. The system, shown in Figure 18.13, includes a rack that is mounted on a support arm connected to a wheelchair. The supporting system allows the storage unit to be moved to the chest level of the client, within grasp of his hands, while playing the harmonicas, and to be moved to the side allowing an easy transport in and out of the wheelchair when he is finished performing. Figure 18.14 shows unit in use.

SUMMARY OF IMPACT
The harmonica storage unit helps the client in his pursuit of a professional career playing the harmonica by allowing him to focus on his performance rather than sorting harmonicas. The unit relieves the client of holding 36 harmonicas in his lap. The positioning features of the unit allow the client to easily and quickly exchange harmonicas without over-extending or uncomfortable positioning. The unit is removable, and does not restrict client motion. The unit does not prevent him from passing through doorways and entering and exiting his van. A lightweight design prevents excess weight from being added to the client’s wheelchair. Most importantly, the storage unit functions safely.

TECHNICAL DESCRIPTION
The client uses an electric wheelchair because he has had a double amputation from the knees down. In addition to these limitations, other physical limitations include, shortness of breath, trouble speaking and difficulties grasping items. These limitations were taken into consideration while developing the storage unit. Other factors considered included ensuring that the client will still be able to transfer in and out of his van and in and out of the wheelchair while the storage unit is attached to it. Also, the storage unit, when installed on the client’s wheelchair, cannot prevent him from passing through doorways. It should also be lightweight, and easily assembled and disassembled. The unit should also allow for storage of harmonicas and easy and quick exchange of harmonicas during or between songs without over-extending or uncomfortable positioning of the client.

The main components of the storage unit are shown in Figure 18.13 and include the actual storage rack unit, a removable clamp for mounting purposes (two by three inches), a cross member, and a support rod. The storage rack unit is mounted on an arm
(cross member) that is connected to a rod (support arm) mounted to the front of the wheelchair with a clamp. The support arm of the design extends up from the base of the wheelchair, while supporting the storage rack unit and cross member. The actual harmonica storage rack unit moves within grasp of the client’s left hand, even though it is mounted on the right-hand side of the wheelchair, as shown in Figure 18.14. The box is chest level with the client and is able to accommodate up to 36 harmonicas.

The storage rack unit is made from aluminum sheet metal and is 9 inches by 11 inches. The unit consists of two identical plates with 36 machined cut-outs for supporting the harmonicas. Each cut-out is evenly spaced across the unit. The depth of the unit allows for the harmonicas to extend from the opening and the client to easily grasp the harmonicas.

The cross member and support arm are made from ½ inch steel rod. Each of these rods is 10 inches long. The cross member is mounted to the rear of the storage rack unit and then connected to a coupler at the top of the support arm. This coupler, which is machined from aluminum stock, holds the cross member and support arm at a 90 degree angle. The support arm extends from the coupler down to an aluminum machined clamp, which is mounted to the frame of the client’s wheelchair. Both the cross member and support arm are secured to the coupler using set screws.

ANSYS8.0, a finite element analysis (FEA) software package was used to perform the structural analysis. A load of 15 pounds was applied to the storage rack unit. The effects of gravity were also incorporated into the analysis. All of the components made of aluminum were subjected to minimal stresses. The equivalent Von-Mises stresses ranged from 0 to 12530 psi. The corresponding factor of safety was calculated as 2.87. The shear stresses ranged from 0 to 6,459 psi, which corresponded to a factor of safety of 3.22. The maximum deflection was found to be about ¾ inch. However, the actual maximum deflection is much less because a vertical rod of 18 inches and an applied load of 15 pounds were used in the analysis. The actual rod is only 10 inches in length and the applied load is less than 10 pounds.

Most parts were donated allowing this project to be completed at virtually no cost.

Figure 18.13. Schematic of The Harmonica Storage Unit. Figure 18.14. Harmonica Storage Unit in Use.
INTRODUCTION
An active individual who once enjoyed target shooting has had quadriplegia for over 20 years. He has full range of motion of his head and neck, no movement from his shoulders down, and limited motion capabilities of his right arm. Due to these limitations, this individual uses a wheelchair and has not shot a rifle in over 24 years. There are few trigger release devices with activation mechanisms designed to enable people with physical disadvantages to shoot a firearm. The client is dissatisfied with the current sip-and-puff design because there is no “feeling of tension” during the trigger actuation. The purpose of this project was to create a trigger release mechanism, along with an apparatus to initiate the trigger pull, while enabling the client to endure a sensitive feeling when shooting a 22-Ruger semi-automatic rifle. The components of the trigger release mechanism, shown in Figure 18.15, are made from aluminum. It is assembled with standard bolts and fasteners, which permit the device to be detachable from the rifle. A bite mechanism, designed in scissor pattern, as shown in Figure 18.16, is used for activation. A bicycle cable is used to connect the bite actuator and the trigger release device, as shown in Figure 18.17. Figure 18.18 shows the client using the bite mechanism to actuate the trigger of the gun.

SUMMARY OF IMPACT
The client wanted to shoot a rifle again; however, he did not want to use the sip-and-puff method that is already on the market. Using a lever/cable apparatus as the trigger mechanism allowed the client to feel the trigger being pulled, which enabled him to experience, once again, the power behind shooting a 22-Ruger semi-automatic rifle. The client was also pleased that the trigger release device was not permanently mounted to the rifle. A bite mechanism (the client’s preferred method) was developed to activate the trigger mechanism. This allowed the client to maintain his sight-picture when actuating the trigger. Developing the system based on the client’s needs and preferences allowed him to enjoy a favorite pastime under the conditions he prefers.

TECHNICAL DESCRIPTION
The most crucial area of safety is the bite mechanism itself. The danger of a choking hazard is real and the structural soundness of the device is viewed as a top priority. Several design concepts were evaluated, including a hydraulic mechanism that has an oral bite piston which is to sit between the front teeth and is squeezed until the trigger is pulled. However, this option was disregarded since toxic fluids could leak in the hydraulic mechanism, which may harm the client. Electrical actuation was considered; however, the electrical components would be far too expensive. A bite device designed in a scissor pattern with overall dimensions of three inches by one inch by one inch, shown in Figure 18.16, was been selected as the method of choice. It is constructed of quarter-inch polycarbonate plastic making it lightweight, yet safe and durable. Being
lightweight prevents the client from having to keep a heavy, uncomfortable bite piece in his mouth while firing the rifle. The device has two pieces of the polycarbonate, each piece hinged in the center on a pin that is supported by a piece of 3/8-inch polycarbonate and stabilized with two 6-32 set screws. The portion that rests in the user’s mouth has relief cuts in the plastic to offer a tooth rest that prevents the device from slipping out of the user’s mouth.

The trigger release mechanism is the most intricate portion of the design process. It is based on an action-arm mechanism. The device is made with aluminum. One aluminum plate is machined and assembled to the right side of the trigger guard. It is attached to the rifle with two clamps; one at the front and one at the back of the trigger guard, with quarter-inch bolts (entering through a 5/16 inch tapped hole in the side plate). Inside the trigger guard, in front of the trigger, is an action-arm. The arm’s overall measurements are 2" by ¾" by ½". A pivot hole is tapped to quarter-inch-20 at the top of the action-arm. This allows the lever to engage the trigger in order to be pulled back until the sear breaks. A coil spring is placed around the cable in between the action-arm and the rear clamp. This allows the mechanism to reset automatically. Figure 18.15 displays the finished trigger release mechanism.

Connecting the mouthpiece to the action-arm is a bicycle cable consisting of roped stainless steel and rubber sheathing that helps with corrosion prevention. It should be noted that the clamp at the back of the trigger guard also provides tension against the sheathing, enabling the cable to pull the trigger. The cable is then run to the bite piece, roughly three-feet from the back of the trigger guard. A small portion of the cable (without sheathing) was run through the bottom front portion of the polycarbonate, held in by a ¼"-20 screw. Then the cable runs straight-up through the top piece of polycarbonate. A small bead is welded at the tip of the cable to avoid slippage back through the plastic.

The finished product operates in a simple manner. A mount for the rifle had already been created. Therefore, the firearm is stationary when being used. The user places the bite device in his mouth so that his teeth rest in the designated grooves. He then aims. Once ready, he bites down to initiate firing. When he bites down, the cable pulls back ½". Due to this displacement, the action-arm pulls back ½" also. This engages the action-arm and the trigger, which travels a ¼", which then breaks the sear and fires the rifle. Figure 18.18 illustrates the client testing the device. The final product is safe and functional. It is also cost-efficient, easy to use, and easy to manufacture.

Total cost of parts and material is approximately $75.00.

Figure 18.17. Instrumented Gun Mechanism.  
Figure 18.18. Client Activating Gun Using Bite.
WHEELCHAIR LAPTOP TRAY ADAPATION

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INTRODUCTION
An individual with Multiple Sclerosis (MS) uses a Tarsys electric wheelchair. He had had a double amputation at the knee and has good use of his left arm and hand but little use of his right arm and hand. He uses a laptop while in his wheelchair. He had difficulty balancing the laptop on his lap due to his MS and amputated appendages. The goal of this project was to design and construct a laptop storage compartment that would be permanently mounted to his wheelchair. A Daedalus pivot arm was attached to the wheelchair to support the tray (Figure 18.20). This allowed the tray to pivot either in front of the client or to the side of the wheelchair if the tray needed to be stored on the chair. The tray and the pivot arm could be removed from the chair if desired.

SUMMARY OF IMPACT
An individual diagnosed with MS 15 years ago enjoys using his laptop to access his e-mail and for other tasks. He previously had no comfortable way to use his laptop while in his wheelchair. In the past he used a thin sheet of plywood on his lap to support the laptop. This was awkward and was another piece of gear he had to carry with him when he traveled. A second problem was that he had no storage place for papers or medicine while traveling in his wheelchair. He thus carried a bookbag on his lap to keep papers and medicine together when he was in his wheelchair. This added an additional weight to his lap and it was uncomfortable as well.

There are laptop trays on the market. Unfortunately, they are not designed to be permanently mounted to a wheelchair and hence do not offer protection for the computer. Also, they do not offer any storage solutions for papers or books. The tray that was developed has an upper compartment to house his laptop and a second lower compartment for papers or medication. This allows him to have his computer readily accessible at all times. This tray design also has an additional benefit, as he no longer has to carry a backpack on his lap to hold his belongings. An added benefit is that the top of the tray also functions as a flat, sturdy work surface. The client tested the tray and found it to be comfortable and easy to adjust to his
TECHNICAL DESCRIPTION

Adapting the client’s wheelchair to allow him to permanently mount his laptop to the chair involved the construction of a stable work surface and pivot mechanism to adjust the placement of the work surface. A box made up of two separate compartments stacked on top of one another was constructed. Unlatching a small lever style latch and then pivoting the associated lid away via piano hinges on the backside of the box allowed access to each compartment. The two sections of the box were each constructed from two sheets of high-density polyethylene. The sheets were one-inch thick and 14 inches square. This gave the box an overall height of four inches. Each section was constructed by milling out the center of two sheets to form a cavity. Then one of the sheets was turned upside-down on top of the other corresponding sheet, creating a cavity with a depth of one and three fourths of an inch. A piano hinge was then screwed to one side to form a pivot between the two sheets. Small lever style latches were then placed on the opposite side of the compartment as the piano hinge. After two identical sections were made, they were stacked on top of each other and attached together.

An aluminum sheet was attached to the bottom of the box to add rigidity. It also served as a mounting base for an aluminum quick release adapter bracket, which attached the box to a pivot arm that was attached to the wheelchair. A Daedalus Pivot arm that is specifically designed for use with wheelchairs was employed. A quick disconnect mounting bracket was supplied with the pivot arm, which allowed the box to be easily removed from the pivot arm if so desired. An aluminum bracket was designed and machined to fit into the locking collar and to utilize the spring loaded locking pin. This quick release aluminum adapter bracket was then through bolted to the bottom of our dual compartment box with carriage bolts.

The vertical rod of the Daedalus Pivot arm was connected to the wheelchair via a custom designed clamping mechanism. It consisted of a piece of square tubing, one and one-fourth inch square by three inches long with a one-eighth inch wall. It had a hole machined in one end for the vertical rod of the pivot arm to slide through; the other end was bolted to a piece of rectangular steel bar stock. The one-inch by one-half-inch wide bar stock ran under the seat of the wheelchair and was fastened with U-bolts to a piece of the wheelchair frame on each side of the seat. This assembly formed the mounting bracket for the pivot arm. By attaching the bracket to each side of the seat frame the load was better distributed.

Using Integrated Design Engineering Analysis Software, a structural analysis of the tray and support structure was conducted. A distributed load of 20 pounds on the surface of the box, representing a book or similar object, was used. A second point load of 50 pounds was added to the far left side of the box to represent someone leaning on the outer surface. Numerical calculations have shown that the unit was safe with a factor of safety of approximately two. The unit was tested by the client, as shown in Figure 18.21, and found to meet all the design requirements.

Total cost of parts and material was approximately $1,500.00. However, the client supplied the most expensive component: the Daedalus pivot arm, which cost $800.00.
INTRODUCTION
An individual with C-5 tetraplegia is a professional web-page designer and the writer and editor of an online newsletter dedicated to people with spinal cord injuries. There are many times when he prefers to use his desktop computer with the monitor and wireless keyboard positioned in front of him while he sits in a reclined position on his adjustable bed. The goal of this project was to develop a system to mount his LCD computer monitor and keyboard within easy access while he is in his bed. The unit includes a telescoping arm attached to a mobile cabinet. The cabinet houses the desktop computer and the printer. The LCD monitor and a keyboard platform are rigidly attached to the telescoping arm, which can be swung over top of the bed manually. A picture of the cabinet is shown in Figure 18.22 and details of the telescoping arm are shown in Figure 18.23.

SUMMARY OF IMPACT
The “Cabinet with a Telescoping Arm” allows the client to use the LCD monitor of his desktop computer and wireless keyboard from a sitting position in his bed. Since the mobile cabinet and telescoping arm attached to it are portable and easily assembled and disassembled, the unit also allows him to take his desktop computer with him on trips, giving him the option of using his computer from any bed he chooses.

TECHNICAL DESCRIPTION
By reviewing the different products available in the market, it was found that the Volker Bedside Cabinet is a currently available product that costs near two thousand dollars. However, the product does not have the ability to mount a monitor or keyboard for the client to utilize comfortably. The lack of features and high cost of the product caused this solution to be ruled out. The computer cabinet with a telescoping arm was based off the idea of the Volker Bedside Cabinet. It consists of two main components: a cabinet and a telescoping arm. The cabinet is easily moved, strong and lightweight. Its frame consists of four pillars of 90 degree angles, quarter-inch thick, 2.5 inch by 2.5 inch legs, aluminum channeling and three levels to make the cabinet bottom, shelf and top surfaces. These pieces are welded together into a 42.7 inch high by 30 inch wide by 19.5 inch deep cabinet with two channels between the top and bottom of the cabinet. These channels are fitted with two full extendable drawer
slides that allow a shelf for a printer to be within easy reach of the client. Four heavy-duty swivel lock wheels are mounted to the base using four \( \frac{1}{2}'' \)-20 torx head bolts per wheel; this allows the system to be easily moved. The wheels can also be locked to keep the cabinet from moving when the client is using it. The lower section of the cabinet houses the computer tower and is 24.125 inches high. The upper section houses the printer and measures 11.5 inches high.

A 47.5 inch high, 2" by 2" by \( \frac{1}{8}'' \) rectangular aluminum tube has been welded to the base of the cabinet and extends vertically up through the top surface. This tube is used as a pillar to mount the arm to, and has a quarter-inch thick aluminum plate welded to its top. On top of the quarter-inch plate is bolted a steel turntable, which is rated for 1500 pounds. The turntable allows the telescoping arm, which is bolted to its top, to rotate. The plate is notched at 10-degree increments for different positioning of the arm.

The telescoping arm is made to rotate and then to extend directly over the client’s bed. It has four main sections: body, pillow block system, sliding rods, and mounting block. The body, a 36 inch by 4 inch by 2 inch rectangular aluminum tube, is the main structure of the arm and is the part that gets bolted to the top of the turn table. The pillow block system consists of four linear ball bushing bearings press fitted into an ultra high molecular weight polyethylene (UHMWP) block, which is press fitted in its turn into the rectangular aluminum tube, as shown in Figure 18.23. Two holes are bored out of the UHMWP block to allow two rods to slide in and out. The rods are three-quarter inch diameter solid steel drill rods and extend 14 inches from the block to place the monitor and the keyboard directly in front of the client. To prevent the rods from pulling out of the block, the ends are drilled and tapped and a small rectangular plate is bolted to the ends. A 4" by 4" by 2" aluminum mounting block is used to mount the keyboard tray and the monitor. It is bored to accommodate the steel rods.

The monitor has a built in mounting bracket in which the pattern is copied onto a mounting plate that is mounted flush to the top of the aluminum mounting block. A bracket for the keyboard tray is mounted to the bottom of the mounting block. A handle is screwed into the mounting block to allow the client to place his hand into it and move the arm towards him. The arm can be locked into place using a lever connected to a cable system. The lever is bolted to the client’s bed to allow easy access. The cable operates a steel spring loaded plunger that fits into the notches of the locking plate that is welded to the top of the vertical tube. When the lever is pushed forward, the plunger drops into one of the drilled holes and effectively locks the arm from moving. When the lever is pulled back, it pulls the plunger out of the hole and allows the arm to rotate.

This whole system is operated manually by the client. When he is sitting in bed he pulls the lever back and unlocks the arm. He then reaches over and rotates the telescoping arm until it is in the desired position. The client then moves the arm forward and locks it into place. Once the arm is locked into place he then slides the monitor and keyboard tray out in front of him. When he is done working he simply reverses the process above and the arm would then rest over the top of the cabinet and is completely out of his way. Since the bed is a powered hospital bed, vertical adjustment could be done by moving the bed up and down.

To ensure the stability of the cabinet with the arm fully extended, adjustable feet were manufactured. Two 2-inch wide by 12.5-inch long by quarter-inch thick steel plates are bent to fit around the bottom channels of aluminum tubing. The ends are drilled and tapped to allow half-inch screws to be extended to the floor and add stability to the base. The feet can be moved to either side of the cabinet. The bottom sheet of plywood is milled on the underside to accommodate the thickness of the feet on either side of the cabinet. Also brackets are mounted to the bottom sheet of the plywood to allow nylon straps to be threaded through and secure the computer tower to the base.

The aluminum is painted with a hammered black finish spray paint and the cabinet is fitted with oak veneered plywood on the sides, the top, bottom and on the printer shelf. The plywood is treated with stain for appearance and protection. A network and phone mounting plate is attached and wired to the backside to accommodate broadband and Internet hookups.

Total cost of parts and material is approximately $1000.00. Some parts were obtained through an in-kind donation.
ADAPTED ARCHERY EQUIPMENT

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Rehabilitative Medicine,
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INTRODUCTION
The purpose of this project is to provide a person who has muscular dystrophy with adapted equipment that allows him to participate in archery activities. This individual has minimal upper body strength and limited use of his arms and legs. A stand that supports a bow is developed and consists of a platform that the user can roll onto, a tube to hold the bow, the bow and a release mechanism. Because of the physical limitations of the user, the stand is designed not only to hold his bow, but also to hold the bow string back for him. This allows him to release an arrow while not having to sustain any weight at all. The bow allows for both lateral and vertical adjustments. This is accomplished by attaching the bow to a Ram-mounting system consisting of two rubber spheres that are connected via an aluminum coupler. A draw-loc trigger release mechanism is mounted to the bow to allow the bowstring to be drawn and locked in place for safety. The setup requires someone to lock the string into position for the user. Figure 18.24 shows the unit that was developed and Figure 18.25 shows the Ram-mounting system that is used to connect the bow to the tube holding it.

SUMMARY OF IMPACT
The client has recently lost the ability to walk on his own and cannot participate with his family when they are enjoying archery activities. The archery stand developed gives him the ability to participate in archery. Specifically, the stand allows the user to release an arrow without having to keep tension on the bow string himself. The user is also able to aim and release an arrow with minimal effort safely and easily. The stand provides the user with a stable platform on which to fire an arrow. The Ram-Mount system provides an almost unlimited aiming
ability by virtue of the rubber balls and sockets.

**TECHNICAL DESCRIPTION**

The prototype was developed to allow the client to use the device from a wheelchair or electric scooter. The core idea of the design is to have someone assist in the drawing back of the string and locking it into place. This allows the bow to be fired without the client having to exert any force. The bow is supported by mounting it to a freestanding assembly as shown in Figure 18.24.

The unit consists of a platform that holds the bow and allows the user to release an arrow. The design allows the client to lock the stand in place by virtue of his weight on top of it. The bow is mounted to the top of a 3 ½' tall 2" rectangular aluminum tube that has been fitted to hold his bow. This tube is attached to the base with a machined adapter that is bolted to the base and cross-pinned through the aluminum tube with two 2" long quarter-inch “Fastlock” style push-button marine pins. These pins require no tools to insert or remove. The adapter is machined in such a way to allow for 6" of adjustment in the vertical direction. It consists of a 5.5 inch diameter aluminum disc, 1" thick, with a 1.73 inch by 1.73 inch rectangular pedestal rising up from its center. The adapter is secured to the platform with six 3/8 inch steel carriage bolts. The pedestal is machine to provide a slip fit with the aluminum tubing that holds the bow. It is through drilled with 6 ¼ inch holes starting 1" from the bottom.

The bow is then mounted to the top of the tube with a Ram-Mounting device that allows for free movement when the tension is released. Specifically the unit, by virtue of its design, allows for almost a complete 360 degree rotation in any direction. The Ram-Mounting system, shown in Figure 18.25, consists of two 2" spherical rubber balls attached to aluminum bases that are connected by a 7.5 inch coupler. The coupler has a wing nut style knob that allows for the spheres to be orientated in varying ways with respect to each other. One end of the Ram-mounting system is welded to the top of the 3.5 foot aluminum tube. The other end of the Ram-Mounting system is attached to an aluminum “L” shaped bracket. This bracket mates with the bow as shown in Figure 18.25. It attaches via a 5/16 fine thread bolt that goes through the bracket into a threaded hole in the front of the bow. This attachment has been chosen so that the bracket does not interfere with the bow’s grip.

The bow is adapted with a mechanism called a “Draw Lock”. This is an arrow rest that has a 24-inch aluminum rod attached to the string release. This unit is designed to lock the string and arrow back until the archer is ready to release. It consists of a mounting unit that screws into the side of the bow with a 5/16 fine thread bolt and has a rod that follows the string back and locks into place. This allows the bow to be drawn back and when the proper draw length is met it locks the string in place until the release is fired. The arrow when drawn back sits in a standard archery trigger release mechanism and is ready to be released when the archer is ready.

The platform is constructed of ¾-inch plywood that has been coated with rubberized paint to seal it from the elements. The platform is cut in such a manner that the edges of it were cut at a 45 degree angle to provide a ramp. Attached to the top surface of the platform is a 1/8 inch thick sheet of 3' by 3' aluminum diamond plate. The diamond plate is added to stiffen the plywood as well as adding a durable, visually appealing top to the base.

The cost of all parts exceeded $1200.00. Most parts were secured through in-kind donations.
CHAPTER 19
UNIVERSITY OF WYOMING

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INTRODUCTION
A noise level indicating system was designed to be used in an elementary school classroom or lunchroom. The system provides a user-friendly method of allowing students to self-monitor the level of noise within a room. It is especially useful for children with cognitive or hearing impairments to know when noise has reached an unacceptable level.

The entire system is contained within and on a standard traffic light. The traffic light is equipped with three 40-Watt light bulbs that illuminate corresponding red, yellow, or green faceplates. The stoplight is mounted on a stable stand with swivel wheels for mobility. The system stands approximately six feet tall and easily fits through any standard door. If necessary, the stoplight can be removed from the stand.

SUMMARY OF IMPACT
The system is controlled by a microprocessor, an HC11 by Motorola. It is complete with a user-friendly control plate. The plate displays the current noise level in dB within the classroom on a liquid crystal display along with the current ranges that correspond to various light colors. These range levels have light-emitting diodes mounted directly below each range for a visual representation of the light to which the range corresponds. The green range has a green LED below it, the yellow range a yellow LED, and the red range has a red LED. The range levels are fully adjustable by turning a knob. One potentiometer has control over the upper level of the green light and the lower level of the yellow light. A second potentiometer has control over the upper level of the yellow light and the lower level of the red light. The setup ensures that only one light is on at a time.

The system is equipped with a buzzer, which the user may turn off at any time. The buzzer will only be activated in the event that the red light has been on in excess of 35 seconds and will immediately be disabled when the light is no longer red or the toggle is turned off.

TECHNICAL DESCRIPTION
There are five inputs to the microphone outputs from the two different microphone amplifications. The original signal from the microphone must first go through an RMS to DC converter before it is amplified and inputted to the microprocessor. It is inputted into the analog to digital converter of the microprocessor which then compares the voltage to a series of thresholds to determine the current dB level in the classroom. The next two inputs are from the two potentiometers. These potentiometers set the ranges for the three lights of the stoplight. The two inputs are also sent into the analog to digital converter to compare the input voltages and determine corresponding dB levels for the various ranges. The first potentiometer sets the upper level of the green light and the lower level of the yellow light. The second potentiometer sets the lower level of the red light and the upper level of the yellow light. The last input to the microprocessor is the toggle switch, which allows for the buzzer to be activated in the event of a red light. The first three outputs are the connections to the lights of the stoplight through three solid state relays. These outputs are determined both by the microphone input and the user input. More specifically, the microprocessor assesses the current dB level in the classroom and determines which light needs to be activated based upon the ranges for each light as set by the user. The buzzer output, our fourth output, is determined by the microphone, the user input, and a timing system to activate the buzzer. The fifth output is the LCD. The first line of the LCD depends on the microphone input and the user input. More specifically, the microprocessor assesses the current dB level in the classroom and determines which light needs to be activated based upon the ranges for each light as set by the user. The buzzer output, our fourth output, is determined by the microphone, the user input, and a timing system to activate the buzzer. The fifth output is the LCD. The first line of the LCD depends on the microphone input. The first line displays the current dB level in the classroom. The second line of the LCD displays the current dB level in the classroom. The second line of the LCD depends upon the user input. This line shows the ranges corresponding to the various light colors. The last three outputs are the red, yellow, and green light emitting diodes that indicate how the ranges correspond to the lights (see Figure 19.1).
The total cost to build this system was about $80, with some of the key components, including the stoplight, donated by various organizations.

Figure 19.1. Block Diagram of Classroom Noise Level Indicator.
COMMUNICATION ASSIST DEVICE

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INTRODUCTION
The main objective of this project is to enable a child with cerebral palsy more communication ability with minimal help from others. The device uses a voice chip with limited memory to record messages that the child can play back. The messages can be recorded by anyone, such as a parent or teacher. Once the messages are recorded, the child will be able to use the device with little or no assistance.

As the child’s vocabulary grows, the messages can change. The device can hold many different messages. This is accomplished with laminated sheets of pictures or words placed over the 16-key keyboard interface. The child presses a key to play a message.

The number of pictures and words is adjustable, and the device can detect which sheet is on the keyboard. As the child’s skills increase, he or she can move to a larger number of squares per sheet, which eliminates the need to buy a new device.

The device uses batteries and is portable and.

SUMMARY OF IMPACT
The communication assist device helps children by helping them communicate with others. This device also gives children a sense of independence, because it requires little help from others to operate.

TECHNICAL DESCRIPTION
This project uses a DVM-58D digital voice module from Rayming to store messages. The device incorporates an MC68HC711E9 microprocessor from Motorola to control the voice chip and determine which memory location is needed. The code is written in C and then downloaded into the HC11.

The microprocessor uses four light emitting diode detector pairs to determine which laminated sheet is placed over the keyboard. Holes are placed in each sheet, with a total of 16 different combinations, and these holes line up with the detectors. When something comes between the emitter and the detector, such as a sheet, the microprocessor reads it.

This device has two modes of operation, play and record. It determines these modes with a pushbutton. When recording the user must press the record button and a key on the keyboard; this is intentionally made to require careful input so that messages are not accidentally changed.

The keyboard consists of 16 keys. The microprocessor can determine which key is pressed and, from there, calculate from which memory location it has come.

The total cost of the project was approximately $132.
Figure 19.2. Block Diagram of the Communication Assist Device.
ADJUSTABLE COMPUTER WORKSTATION FOR YOUNG CHILDREN

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Supervising Professor: David Walrath, Steven F. Barrett
Client Coordinator: Louise Velleau, Special Services for Albany County School District #1
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INTRODUCTION
A physical therapist for a school district requested a workstation for children of varying ages and sizes having a range of disabilities that require various accommodations. Accommodations must serve children using wheelchairs, children with cerebral palsy, and students with visual impairments.

SUMMARY OF IMPACT
The project provided one workstation that is user-independent and easy to move. It looks like a typical workstation, and accommodates a variety of children with disabilities.

TECHNICAL DESCRIPTION
Design criteria were that the workstation:

- Be safe, durable, and easy to use,
- Fit all the children with varying disabilities,
- Look like a typical workstation,
- Be large enough to be wheelchair accessible,
- Be small enough to be moved around easily,
- Be lightweight and durable for easy moving, and
- Include a desktop that varies in height, from 28.0 inches to 45.75 inches.

The base of the workstation was made from a c-shaped piece of 6061-T6 aluminum with caster wheels connected to each corner. The two front wheels have locks so that the desk will not move while the children are working on it. Birch, a lightweight and strong material was used for the top, and laminate was applied to the top for extra durability.

Actuators were chosen as the main lifting mechanism of the desk, as they can withstand the vertical forces applied to them. However, in order to eliminate the moments acting on the top of the workstation, telescoping legs, made of 6061-T6 aluminum, were built around the actuators, and then two bushings were placed inside the telescoping legs to eliminate the moments.

It was decided to tilt only half of the top of the workstation so that the other half could be used for a computer monitor. A scissor lift was chosen to achieve the requested tilt, 75 degrees. This was accomplished with a small motor connected to a piece of right-handed all-thread welded to a left-handed piece of all-thread. Located on these pieces of all-thread were two special nuts that were machined in the machine shop. There were also two special nuts machined for the top part of the scissor lift. These were placed on an aluminum tube connected to the top of the workstation. There are two aluminum bars between these two sets of special nuts to connect the top with the bottom. The top of the desk was hollowed out in order to fit the scissor lift and all the electrical boards for the scissor lift and actuators. The mechanisms were blocked from the children’s reach. The motor was connected to a toggle switch, turning the all-thread and moving the special nuts in and out to lift and lower half of the top of the workstation. This half can be raised to an 81 degree angle and lowered to a 0 degree angle and could be stopped anywhere in between.

The tilt was needed because many of the children have problems seeing their work if it is too far away, and many of them have a limited length of reach.
The two toggle switches, one controlling the tilt and the other controlling the height of the desk, are both located in the front of the workstation for easy access. These toggle switches were recessed so they cannot be bumped accidentally.
DIGITAL SHOWER TEMPERATURE CONTROLLER

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INTRODUCTION
Some people with disabilities also have difficulties working mechanical valves or sensing water temperature. Sudden changes in water temperature while taking a shower are not only annoying but can also cause serious injury. The digital shower temperature controller provides an easy-to-use interface, allowing a user to automatically control the water temperature in a shower.

SUMMARY OF IMPACT
The user enters a temperature into a keypad using the menu-based operating system displayed on a liquid crystal display (LCD). The controller then adjusts the water temperature until it is within three degrees of the user-defined temperature. The device maintains the user-defined temperature regardless of the input water pressure or water flow as long as the input hot water temperature is greater than or equal to the requested temperature.

TECHNICAL DESCRIPTION
The digital shower temperature controller consists of hardware, software and non-electrical mechanical parts. The hardware portion consists of the embedded controller, sensors, interfacing hardware, solenoid valves, and hybrid stepper motors with optical encoders. The non-electrical mechanical portion consists of the mechanical gate valves used to control water flow, a delay tank, and the copper pipes used to connect all of the components.

The HC11 is used as the embedded controller to control all of the hardware for this design. The software is programmed in C for simplicity. Located in a box, which is the only part visible to the user, are two LCDs and a keypad. The HC11 is directly attached to the two LCDs, which are used to provide a menu system that is easy to follow and use. A keypad is also directly attached to the HC11 to provide the user with the ability to interact with the embedded controller. All of the other hardware for the design is located in a separate box, which is installed into the wall where the shower is located.

The hardware, which is located in the box in the wall, includes the solenoid valve switching board, the temperature sensor signal conditioning board, the motor control board, the power supplies, and the hybrid stepper motor drivers.

The solenoid valves, located at several different locations, use 24 VAC, which required an interfacing board using mechanical relays. The relays are switched on and off using power MOSFETs because the coil voltage is 24 VDC. These solenoid valves provide safety features that shut down the output water if the system fails to control the temperature properly. They also give the user the ability to use standard knobs in the event that they do not wish to use the controller.

The temperature sensors are the LM34. Due to the analog-to-digital converter (ADC) resolution of the HC11 being 19.25 mV, a signal conditioning board was necessary to take full advantage of the ADC’s zero to five range. The signal conditioning board takes a voltage of 600 mV to 1.4 volts from the temperature sensors and converts it to zero to five volts going into the ADC. This transducer interface gives the system a temperature range of 60° F to 140° F and a resolution of greater than .5 °F.

The motor control board provides the Transistor-Transistor Logic (TTL) compatible signals necessary to control the hybrid stepper motor drivers. An interfacing circuit was required because the drivers require more current than the HC family can provide. The hybrid stepper motors used in conjunction with the drivers have a resolution of 1.8 degrees per step with a total number of 200 steps per revolution. When the drivers are used in microstepping mode the resolution of the motor is increased even further to 0.18 degrees per step. Optical encoders are also employed with the motors to provide feedback, providing the motors with the ability to automatically close without the need to
keep track of how far open or closed the mechanical gate valves are.

The non-electrical portion of the design is kept as simple as possible with two standard brass gate valves and a delay tank. The hybrid stepper motors are attached to the gate valve to provide for control over the water flow through the system. A tank is employed before the output of the system but after the mixing chamber to provide a delay in the output water and give the motors more time to adjust the temperature to the correct value. This tank is large enough to provide a delay of approximately 25 to 30 seconds.

The general operation of the design follows. First, the user enters the target temperature, from 65° F to a maximum defined by the user but no greater than 135° F. The user then enters the length of time the system is to run. The program then takes an average of several temperature sensors located throughout the system. Using this average, the processor does an error check to make sure the temperature measurements are within tolerances of their normal operation. Then, using the average provided by the temperature sensors, the processor adjusts the cold water flow using the stepper motors and gate valves until the temperature on the output of the system is within three degrees of the user-defined value. The hot water is kept constant through the entire process with the valve being open to an amount that is defined by the user through a separate menu option. The time it takes to complete the task of getting the temperature to within the three degrees varies between 30 seconds and two minutes, depending on the initial water temperatures. Once finished, the user can either press a button or wait for the time entered to expire. Once either of these two things occurs the system will automatically shut down and reset for the next use.

The total cost for the project is approximately $750.

![Figure 19.5. Block Diagram of the Digital Shower Temperature Controller.](image-url)
INTRODUCTION
A ski bra is a device that allows a person with a physical or cognitive disability to enjoy the sport of skiing. The ski bra clamps onto the tips of skis to keep the tips together.

The project objective was to design a more efficient and effective ski bra than those that are currently on the market. The current ski bras are a safety hazard because they often fall off the ski tips while in use. The plastic stopper has very little contact area on the ski tip, resulting in a weak attachment that is easily disrupted by slight movement. The plastic used in the stopper is a hard plastic, which does not allow for any give when the knob is tightened down. With no deformation, the stopper does not conform to the ski tip, forming a weak attachment. Where the steel rods meet between the skis, they clank and knock together with ski movement causing extra pull on the rods. The pull causes an extra force to be added to the rods, which then pull on the ski attachments weakening the connection between the plastic stopper and ski tip. If there is a strong enough pull the ski attachment can become loose or even fall off. When the ski bra falls off, there is less control for both the skier and the tetherer. This causes the ski bra to become unmanageable in ski lines and around lift equipment. The skier’s skis can also become separated, causing a loss of control or entanglement of the skis. As a result, the skier may fall and be injured.

Current designs do not allow for natural variations in the skier’s foot stance. Therefore, only one ski stance width is allowed and it is a close unnatural stance. A skier’s stance should be adjustable depending on the size and ability of the skier. When a ski stance is too close together, it causes a loss of balance and control. The close ski stance of current designs results in limited maneuverability of the skies, such as edging side to side during turns. The current ski bras are also difficult to manage by both the skier and tetherer. With the ski bras continuously falling off, there is an ongoing need to readjust them to either make sure that they are snugly on the ski, or to place the bra back on the ski. This is time consuming for both the skier and tetherer. Also, the current ski bra does not allow much adjustability for the different sizes and shapes of skis that are currently on the market. There are two sizes available: one for a straight ski, and one for a shaped ski. The shaped ski bra only fits a limited number of shaped skis. If the bra does not fit tightly around the ski tip, it will not stay on the ski. Also, if the ski tip has a plastic covering, the plastic stopper does not have enough room to clamp onto the ski, even if the metal encasement does fit around the ski tip. These limitations are a restraint to the use of the ski bra.

SUMMARY OF IMPACT
Individuals without sufficient leg muscle control do not have the ability to participate in sports such as skiing without assistance. The ski bra for individuals with disabilities can help them learn to ski. Additionally, the ski bra allows the user to actively use muscles, which may help some individuals regain the ability to use muscles on their own.

The ski bra has to be able to stay on the skis to reduce the possibility of loss of control. It also has to be able to accommodate the skier’s size and weight. The new design (Figure 19.6) has an adjustable stance to fit skiers of different sizes.

TECHNICAL DESCRIPTION
The ski tip attachment is 5000 series aluminum. The aluminum is 8 ½ inches long, 1/8 inch thick, with four bends each at 15 degrees to form a ‘box’ fit around the ski tip. On the inside sides of the attachment there is a thin piece of 60 durometer neoprene to help enclose the ski tip and provide a tighter fit around the ski. Neoprene is used due to its flexibility and resistance to water. For each single ski attachment there are two knobs with 10-24 inch threads that go through the aluminum and attach to...
a rectangular piece of 5000 series aluminum and neoprene. Using a rectangular piece of aluminum and neoprene, instead of a round stopper similar to what is currently used, increases the amount of contact between the plate and ski tip, forming a more solid clamp.

Each individual ski attachment has two parts: the inner and outer sides. The inner side of the attachment (i.e. the right side of the left ski attachment or the left side of the right ski attachment) has a fixed hole position, while the outer side has an adjustable hole position. A slit is milled at a 30 degree angle to allow for the ski attachment to adjust to fit a wide range of ski shapes. On the bottom side of the slit, a ½ inch wide 3/16 inch deep hole is also milled to fit a weld nut. Around the hole, 4-40 holes are drilled and set with a washer and a screw. The washer acts as a guide for the weld nut to slide up and down the slit without falling out. On the inside, a single hole is drilled and a weld nut was milled for the desired fit. The weld nuts provide stability when the knobs are turned while moving the rectangular plate up and down. In addition to the adjustable holes, the inner and outer sides are connected with a rivet acting as a pivot point. This connection helps facilitate in the movement of the separate parts to fit around multiple skis. On the inner side, a studded shielded spherical female rod end, 3/8-24 inch threads, is connected to the ski attachment. A shielded ball joint was chosen to help prevent dirt, snow and ice from getting into the joint. The ball joint allows the skis to be tilted on their edges and the ski tips to move back and forth. The skier may stand with tips pointing straight out, or with tips pointing at one another, forming a point.

The slider mechanism is used to control the forward/backward motion of the skis. The slider rod is 5/16 inch 6061 T6 aluminum in a closed U-shape. The rod is cut to 22 inches then bent at each end to close the loop. A three-point weld is used in the middle of one side to complete the loop. To hold the loop in place, one side is fixed. To obtain the sliding motion, a 0.8 inch long plastic sleeve is fabricated to fit along the rod. The sleeve is then press fit into a shaft collar. To absorb impact of the slider while sliding along the rod, rubber stoppers are placed at each end of the rod just before the bends. To hold the stoppers in place, the rod is grooved 1/16 inch deep and wire was wound on the outside to be sure that the stoppers have a tight fit to the rod. The sleeve is free to move a distance of eight inches along the rod. The adjustable ski stance mechanism is composed of telescoping rods that connect the ski attachment and slider mechanism together. The outside tube of the telescoping rod is threaded into the rod end, which is connected to the ski attachment and the other end has a threaded clamp collar threaded onto the outside. A rod is placed inside the tube under the threaded clamp collar, and the other end of the rod is threaded into the shaft collar on the slider mechanism. With the rod and tube joined together, the clamp collar is used to tighten and loosen the connection for a quick and easy adjustment.

When placed on skies, the ski bra performs well and shows many improvements over the current models.

Figure 19.6. Ski Bra for Skiers with Disabilities.
VOICE ACTIVATED REMOTE CONTROLLED CAR

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INTRODUCTION
A controller was designed to give children who have limited use of their hands the ability to play with remote controlled cars.

SUMMARY OF IMPACT
The microprocessor is the basis for the design. It is able to take a command from the voice recognition processor, determine what that command is, and tell the transmitter what signal needs to be sent to the car.

The voice recognition processor used in this design initially only had an 80 percent reliability rate, but it was improved to a 90 percent reliability rate in the final design.

TECHNICAL DESCRIPTION
Every remote controlled car comes with a transmitter that sends the signal from the microprocessor to the car. The microprocessor sends a pulse width modulated signal to the transmitter depending on what voice commands are received, and the transmitter then relays this signal to the car. Bringing the three main parts of the design together was the final obstacle that had to be overcome in order to make the design a success.

The HM2007 voice recognition processor is the device that receives a verbal command from the user of the controller, and then sends a number that corresponds to that command to the microprocessor.

The project includes the following features.

- Speed control of the car
  - “Faster” slowly increments the speed up to 1/3 of maximum
  - “Slower” slowly decreases the speed until the car stops
  - “Cruise” holds the car at its current speed
  - “Stop” stops the car
  - “Reverse” backs up the car
- Controlling steering
  - “Right” will incrementally turn the wheels right
  - “Left” will incrementally turn the wheels left
  - “Lock” will hold the car with the current turning radius
  - “Straight” will point the car straight ahead
- “Wheelie” is a fun command that makes the car’s front wheels pop up into the air for a short time.
Figure 19.7. Voice Activated Remote Controlled Car.

Figure 19.8. Voice Activated Remote Controlled Car.
INTRODUCTION
Some individuals who have hearing impairments do not have the ability to obtain auditory feedback of their voice volume level. A speaker volume display was designed to address this challenge. Two tasks are performed by this display. The first is to alert the person with a hearing impairment that his or her current voice level is too loud by way of a DC vibrating motor. The second is to alert the user of a high surrounding noise level by the way of an LED bar graph.

SUMMARY OF IMPACT
At maximum conditions, this device consumes no more than 155 mA from four, alkaline, 9V batteries. This device lasts for 30 - 40 hours operated at normal conditions (i.e., when the surrounding noise level is lighting half the LEDs on the bar graph and the vibrating motor is not activated more than once every 10 minutes).

TECHNICAL DESCRIPTION
This product is designed to be portable for the user and has two components. The first is the battery pack and circuitry. All the electronics are contained in a 6x4x2 inch plastic enclosure that mounts on a belt clip, which can then be placed on the hip for easy access. The second component is a microphone that is connected to the enclosure on one end and to a collar clip on the other (this is for the user’s volume level). A toggle switch, shown in Figure 19.9, allows the user to turn the device on/off. Once on, there are three levels of sound on the Speaker Volume Display. If the user enters different volume level surroundings, the Speaker Volume Display can adjust. The levels can be adjusted by a rotary switch shown in Figure 19.9. The first stage (low) adjusts the Speaker Volume Display to the lower dB range (55 – 85 dB). The second stage (medium) adjusts the display to the middle dB range (80 – 100 dB). The third stage (high) adjusts the display to the upper dB range (95 – 120 dB). Along with these features, the Speaker Volume Display alerts the user when voltage levels of the alkaline batteries are low. This is accomplished by a blinking green LED seen in Figure 19.9 and is mounted on the plastic enclosure. The Speaker Volume Display is lightweight and powered by fairly small batteries.

Two block diagrams are shown in Figures 19.10 and 19.11 to illustrate how the hardware will be set up for the Speaker Volume Display. Figure 19.10 refers to the surrounding noise level and 19.11 refers to the user’s voice level; a band-pass filter is used to allow only the human voice range frequencies to pass. Each diagram shows the basic schematics implemented. The full wave rectification for both is accomplished with a fast AC to DC converter and the averaging is done for two seconds. The
comparison block consists of a Schmitt trigger (comparator with hysteresis) for gradual switching. One block not included in either block diagram is the low battery voltage monitor circuit. Once the battery voltage becomes too low, or the batteries become discharged the green LED on the enclosure of Figure 19.9 blinks twice per second alerting the user a battery change is needed.

The Speaker Volume Display is very accurate with its corresponding decibel levels provided earlier. The first level is very sensitive. In level 1, the vibrating motor turns on when the user’s volume level exceeds 82 dB. In level 2, the vibrating motor turns on when the user’s volume level exceeds 95 dB. In level 3, the vibrating motor does not turn on since it is not practical for a person’s voice to be above 110 dB.

The overall cost of the Speaker Volume Display is $90.00.
INTRODUCTION
The Wrist Communicator is an easily programmable, portable, talking communication aid that is designed to be worn on the wrist. The device can play up to twelve, five-second prerecorded messages. The Wrist Communicator could be used in many applications, from making quick notes to helping children with speech impairments communicate with others who may not understand sign language to storing pre-recorded reminders for people with mental disabilities. The device has up to 75 seconds of recording time, and the messages can easily be changed for any situation. The messages are divided into four different categories, with three messages per category, for easy situational manipulation. The device is powered by long-lasting lithium batteries.

SUMMARY OF IMPACT
There are currently other devices on the market that accomplish similar tasks as the Wrist Communicator. In the Sammons Preston Rolyan Fall 2003 Pediatrics catalog there is a device for sale that has 75 seconds of recording time and is divided into 8 messages. It retails for $158.95, whereas the cost to produce a Wrist Communicator is around $40.

The Wrist Communicator (Figure 19.12) has 12 messages of approximately five seconds each. Other existing communication aids employ robotic or computerized voices to convey the messages which are not easily changeable and usually do not fit on the wrist. The social aspects involved for children using such a device is much better when the voice emanating from the communication aid is human rather than robotic. A common device employed by individuals with communication difficulties is often called the “big board,” and is awkward for children to carry.

TECHNICAL DESCRIPTION
There is a small four-pin dual inline package (DIP) switch that turns the device on, selects if the device is in play or record mode, and changes which category the device is currently in. The two category switches are the first two switches from left to right. Each category is set up to have three messages each, yielding a total of twelve messages. The categories could include a school environment, a home environment, or a play-time environment, for example. It is helpful to remember where messages are stored. Also, the switches reduce the amount of buttons needed to recall all twelve messages. The switches are employed in a binary manner. With the two switches there are four different possible positions that they could be in: both up, one up and one down, both down etc. There are two LEDs. One is a power on LED, and the other illuminates for five seconds to let the user know that a message is being played back or recorded. A microphone is included to conveniently record new messages when desired.

An Atmel AT90LS8535 (8535) is the microcontroller that controls the operation of the Wrist Communicator. The 8535 is a 44-pin microcontroller that has 32 I/O pins (four ports). The 8535 has eight Kbytes of programmable flash that has an endurance of up to a 1000 write/erase cycles. These programming cycles are accomplished using the on-board SPI system for in-system programming with a programming board. It has 512 bytes of EEPROM with an endurance cycle of up to 100,000 write and erase cycles, and 512 bytes of SRAM. The typical power consumption at 4 MHz is 6.4 mA, which is ideal for battery operation. Even though the Wrist Communicator is a micro-controlled device, a digital recording and play back IC is the center of the Wrist Communicator’s functionality.

Winbond’s ISD2575 (2575) ChipCorder provides high-quality, single-chip, record/playback solutions for 75 second message applications, and is the heart of the Wrist Communicator. The 2575 is a CMOS
device that is a 28-pin device which includes an on-chip oscillator, microphone preamplifier, automatic gain control, antialiasing filter, smoothing filter, speaker amplifier, and high density multi-level storage array. The 2575 is, of course, microcontroller compatible. Recordings are stored into one-chip nonvolatile memory cells, providing zero-power message storage lasting up to 100 years. The device is battery operated and portable. Also, it is convenient and cost effective to have batteries that do not need to be changed frequently. The batteries must be small so as to fit in a device that will be worn on a child’s wrist. The CR2430 is a lithium battery specific for electronic devices that meets the needs of the Wrist Communicator. This battery has a nominal voltage of 3.1 volts and a rated capacity of 300 mAh, so two batteries are connected in series to provide the needed five-volt supply. It is estimated that it would take approximately 15 seconds to turn the device on, replay the message, and then turn it off. For this to occur, approximately 350 mAs of battery life would be used per message and 7000 mAs per day. If this level of usage is sustained, the 350 mAh batteries should last for about five months.

Currently, a second prototype is being constructed to reduce the size of the wrist communicator.

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Figure 19.12. Wrist Communicator.
ADNON LIGHT WIRELESS DISPLAY UNIT

Project 1: Adnon Light Wireless Display Unit: Adnon Board
Designer: Fakhir Habib and Naveen Selvam
Client Coordinator: Richard Vasiloff, Goodwill Industries of Detroit
Supervisors: Dr. Robert Erlandson, Mr. David Sant, and Mr. Santosh Kodimyala
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Project 2: Adnon Light Wireless Display Unit: Workstation Switch Units
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Client Coordinator: Richard Vasiloff, Goodwill Industries of Detroit
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INTRODUCTION
The Adnon Light Wireless Display Unit was designed to allow supervisors at an agency for persons with disabilities to monitor their departments without being in the area the entire time. This project is an example of universal design in the workplace in that it increases productivity and quality for all workers, while enabling workers with cognitive disabilities to participate competently in a broader spectrum of jobs.

Individuals with cognitive impairments may have difficulty with a number of packaging jobs. If they run out of inventory, some individuals simply stop working and do not obtain or request additional inventory. If the machine stops or malfunctions, they may stop working. If workers need a toilet break, they may simply leave the work area. All these behaviors result in lost productivity and poor job performance. Work supervisors believe that many workers can adapt to pushing a switch if they run out of inventory, their equipment fails, or they need a break. The two Adnon Light Wireless Display Unit projects address this need.

The project has two distinct but related components: the switch unit for the worker and the Adnon board. Twelve workstation-based switch units were designed and built. Figure 20.1 shows an individual workstation switch unit. There are two switches: red for equipment malfunctions/emergencies and yellow for inventory replacement. Each switch is a different shape and color. The workstation units contain a wireless transceiver that communicates with one of two Adnon boards. Each Adnon board has displays for six workstations. Each workstation transceiver has a unique address as do the two Adnon board transceivers. Each column corresponds to a workstation. A supervisor can see who needs assistance and the nature of the assistance required.

SUMMARY OF IMPACT
The Adnon Board and Workstation projects started with an existing system. The X10 system components were scrapped, leaving only the Adnon board frames. A wireless communication system was designed for communications between the workstation units and the Adnon boards. The wireless system exhibited universal design in that it improved productivity and reduced non-value added activities for all workers.
TECHNICAL DESCRIPTION

Project 1: Adnon Board

The Adnon Light Wireless Display Unit consists of two display boxes that allow up to 12 stations to visually display the status of their machines. These four foot by six foot Adnon boards are hung from the ceiling and are visible throughout the work area. Each Board has six labeled columns, which correspond to one of 12 transmitters. There are two lights for each column. This allows for visual communication between supervisors and workers. There is one red light and one yellow light for each column. The yellow light indicates that the worker needs parts while the red light indicates that a station is down and needs assistance. Priority is given to the red light, station down, function. If the yellow light is on first and the red light is turned on, then the yellow light will turn off.

At the receiver end, the transceiver is used to receive the data that is then sent to the PIC16F876. The microcontroller decodes this data and illuminates the light(s) accordingly. This circuit uses triads with optoisolators to isolate the DC part of circuit from AC. The Figure 20.2 shows the receiver circuit. The LEDs at the bottom of the circuit correspond to the columns at the display board.

Project 2: Workstation Switch Units

There are 12 transmitters, which allow communication with each of the 12 columns on the display box. Each transmitter has two buttons: red and yellow. These buttons control the lights of the corresponding column on the display box. In the case that a transmitter should stop working, the transmitters have a programming mode, which allows them to be set to correspond to any one of the twelve columns on the two display boxes. The programming and reset switches are shown in Figure 20.3.

Each transmitter is also equipped with an indicator light, which has two functions. The first function allows the user to have visual verification that the transmitter is sending data, and the second function allows the user feedback on the energy left in the battery. The light stays on while the transmitter is sending data; the light turns off after the transmission is complete. The light remains green while the batteries are charged. It turns red when the batteries are running out of energy and need to be replaced.

Figure 20.1. Transmitter Unit.
When new batteries are added, the light becomes green again. Figure 20.4 shows the red and yellow push buttons, PIC microcontroller and the LED indicator on the top layer of the PCB.

Figure 20.2. Receiver PCB.
Figure 20.3. Transmitter PCB Bottom Layer.

Figure 20.4. Top Layer of Transmitter Board.
WEIGH STATION PACKAGING QUALITY CONTROL SOFTWARE AND HARDWARE

Project 1: Weigh Station Packaging Quality Control: Software Design
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Project 2: Weigh Station Packaging Quality Control: Hardware Design
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INTRODUCTION
The Weigh Station Packaging Quality Control Software and Hardware Design project demonstrates a universal design’s capability to support workers with and without disabilities while addressing quality, productivity, and efficiency. The project is designed to aid in packaging automotive license plate kits for a final auto assembly plant. A center for workers with disabilities packages 200 kits per large shipping container.

License plate kits are assembled at individual packaging stations. The assembled kits fall off a conveyor line into a large box. A worker collects the kits and places them in an organized fashion into large shipping containers. These containers are then weighed to ensure the proper number of kits per container.

SUMMARY OF IMPACT
The new Weigh Station Packaging Quality Control System utilizes a universal design approach to create a process that accommodates users with a range of cognitive abilities. Someone who cannot count or read can use the system. The system also error-proofs and reduces non-value added activity of the final count process by eliminating a per-kit weight determination procedure each time a final count is made.

Quality assurance is improved by the driver’s required “sign-off” procedure when the correct count is reached. The new system creates a database that keeps track of jobs completed and inventory shipped. The information in this database will be integrated into an evolving computerized inventory and quality control system.

TECHNICAL DESCRIPTION
To get an accurate weight using the previous system a forklift driver picks up a large shipping container. The container is placed on a large floor scale; the driver must jump off the forklift and push buttons on the scale to perform a tare operation (find the empty container’s weight). Then the driver writes the tare weight on a tag that is hooked onto the shipping container.

The driver then uses the forklift to pick up the carton and deliver it to a license plate kit assembly station. Here another worker places 200 kits into the container. When filled, the forklift driver picks up the carton and returns to the floor scale. The driver exits the forklift and goes through a process wherein the scale software can determine a per-kit weight. Then the driver places the shipping container onto the scale. Next, the driver again exits the forklift to input the container’s tare weight to the scale. The scale determines the number of kits in the container by subtracting the tare weight and dividing the remaining weight by the per-kit weight. If there are too many or too few license plate kits in the
container, the operator makes the final corrections by reading the scale. When the count is correct, the carton is delivered to the shipping area.

A wireless item identification process in conjunction with a digital weight scale, each interfaced with a computer, was implemented. All relevant data are stored on the computer to create a packaging and quality control system. While gathering important data, the system is designed to increase worker productivity while using existing weighing hardware.

Figure 20.5 is a block diagram representing the new system. It uses passive RF tags, an RF Reader/Scanner, and the computer control features of a digital scale to greatly simplify and improve the process described above.

Using the new RF tag system, the forklift driver picks up an empty shipping carton and places it on the floor scale. The driver then exits the forklift and places an RF tag onto the side of the carton. The RF Reader/Scanner interrogates the RF tag on the container and the control computer recognizes that the tag is being reassigned to a new container and records the empty container weight as the tare weight.

The system also requests that the driver enter a job number. System I/O is designed to be versatile. Information can be presented to the driver in iconic and/or written form, with additional verbal prompting if required. The driver’s supervisor can create user preferences unique to each user. Whereas the old process required the driver to go through a per unit kit weight determination procedure every time a new carton was brought for the final count, the new system requires the per unit kit weight be determined only once, when the job is originally entered into the system. Hence, after the driver enters the job to be counted, the system automatically associates the correct per unit kit weight with the RF tag. The system prompts the user when this assignment step is completed. The driver then delivers the container to an assembly station.

When the shipping container has been filled, the driver picks it up and returns it to the floor scale. While the container is placed onto the scale, the RF Reader/Scanner identifies the unique tag and recognizes that the container is being returned for a final count. The system detects the tare weight, the per unit kit weight, and total weight, so it can determine the kit count and inform the driver as to the required action. If any adjustments are required, the driver makes them after being prompted by the system. When the correct count is reached, the system prompts the driver and he/she must respond by entering a count-completed command to the system. This step is required for quality purposes.

Project 1: Software
Visual Basic 6 (VB) is used for the system’s software. This is a robust coding language that allows for a variety of ways to write code. For proper user interface, a number of VB forms (screens) are used. Communications procedures are built into VB for both RS232 communication and database manipulation. With the databases in this project, users are able to store, view, and back-up all relevant data.

For employees to maintain proper controls over the software, two different permission levels were created: administrative and user. Under the administrative permission level, users can find and edit all stored data, such as user information, job information, and tag associations. They also have the ability to generate reports based on specific dates and back-up the main database of information, as well as perform tare and piece-count functions. Mainly, the Materials Supervisor will be performing these operations. For each individual job, the supervisor will be required to initially go through a calibration process. This is used to find the individual piece weight. After this, the process of tare and piece-count is started and repeated as many times as required. The Materials Supervisor will also be required to verify all information stored on the computer to maintain materials accountability.

The user permission level is for the forklift driver and floor worker. This portion of the I/O is designed to accommodate workers with a wide range of cognitive abilities.

Project 2: Hardware
This project is a combination of radio frequency identification (RFID), digital weighing, visual basic code and storage of information in databases. Each of these parts play a crucial role in the functionality of the overall project.
RFID hardware consists mainly of a reader, an antenna, and the FID tags. A Creform stand is designed and built to house the RF antenna, the reader/scanner, and the power supply. To turn on the reader, the user must flip up the switch on the side of the housing and ensure that the indicator light is on. Once the power supply is turned on, the reader is ready to identify any tags brought to within one meter of the antenna. Upon recognition of the tag, the reader is setup to output the number of the tag that was found over an RS232 serial communications port. This tag number is stored on the computer, and is used as the primary key for all data manipulation. All of these components are manufactured by Texas Instruments and are reliable.

The client workplace already has a large floor scale that has a capacity of 5000 pounds. They also have a digital scale connected to the floor scale for tare of containers and piece counting. Like the RFID reader, the digital scale has an RS232 output. The output from the scale will differ depending on the input it receives. For this project, scale weight output is used. Weigh-Tronix is the manufacturer of both the floor scale and the digital weight scale.
Figure 20.5. Block Diagram Representation of the RF Tag Based System.
CHAPTER 21
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ALL TERRAIN TRANSPORTER FOR TWO DOUBLE AMPUTEES

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INTRODUCTION
An all terrain transporter was designed for transporting two children who were born without forearms or lower legs from the knee and with separation between the residual femurs and the hip sockets. The profiles of the children are illustrated in Figure 21.1. Movement is difficult for either boy. Attempts to move are achieved by crawling on the stomach. Lifting the children into and out of a cart is difficult for the caregivers.

SUMMARY OF IMPACT
The design criteria for the all terrain transporter (see photo in Fig. 21.2) were defined by the limited capabilities of the children. Point-to-point mobility in parks, playgrounds and beaches would be impossible by crawling on the stomach. The children have large waist areas, making usual children’s carts impractical. Lifting a total of 115 pounds twice at each stop, and several times in a trip, causes physical difficulties for the caregivers. As a result, the family desired a portable transporter that both the children can safely enter and leave independently. This allows the parents to leave home for parks, swimming and the city circus when they desired.

TECHNICAL DESCRIPTION
After meeting with the parents, the dimensions of the frame were established to be approximately 40 inches long, 18 inches wide and 6 inches high. The frame is constructed welded from 6061-T6 aluminum tube stock with 1/8-inch inner wall thickness. Frame junctures are at 45 degrees. Aluminum was chosen because it is lightweight and has the capability to withstand the load of the two children. This was verified using finite element analysis on the frame.

The transporter is modeled in Pro-E, and a software package called COSMOS Works for Solid Works is used to perform the finite element analysis for the frame. Of particular interest are answers to design questions about structural integrity, deflection, thermal loads, natural frequency, buckling, and safety.

Tests have been conducted with loads above and beyond the intended load for the transporter applied to the frame. The material used is 6061-T6
aluminum with a yield tensile strength of about ~40,000 psi and the ultimate strength about ~45,000 psi. Stress analysis has been performed on the frame, shown in Figure 21.3, at 400 pounds, which is a safety factor of roughly three times the combined weight of the children.

The results (Figure 21.3) show that, during bending, the welded joints are most vulnerable. However, the magnitude of the stress at the highest areas was 1.4e004 psi. The yield strength positively shows that the children may bounce during transportation without forcing the frame to yield. Similar positive results have been obtained with torsion and displacement tests.

The wheels chosen are bicycle wheels for the back and inflatable casters for the front so that they can travel over various terrains, and can be pushed by one parent. Two lightweight fiberglass composite seats were used for their weight and ease of maintenance. With the push column equipped with bicycle type hand brakes, the final product is completed as illustrated in Figure 21.2. Upon completion, the all terrain transporter was presented to the parents.

The cost of parts/material and some labor is approximately $800.
ACUPUNCTURE NEEDLE WARMING AND TEMPERATURE FEEDBACK

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INTRODUCTION
Acupuncture is a practice that consists of inserting extremely fine stainless steel needles into the skin to excite particular anatomic spots in the body for curative objectives. The needles are independently enveloped and utilized only once since they should be sterile before being inserted through the skin. In addition to the customary technique of puncturing the skin, the procedure may include use of heat to warm the needles, pressure, and other methods that help to relieve pain more quickly. This design was focused on the warming process and providing the user with needle temperature feedback. The maximum temperature should be 105 degrees Fahrenheit.

SUMMARY OF IMPACT
Obtaining medicinal herbs for warming the needles is not only far fetched but is unfamiliar to the client. Attempts to use electrical heating without knowing the temperature was not an option since it could produce unwelcoming surprises and pain. The design would allow the client to warm the needle to the desired temperature of 105 degrees Fahrenheit. This will allow the client to use acupuncture more often.

TECHNICAL DESCRIPTION
Two types of acupuncture needles were evaluated for dimensions. Both have a diameter of 12/1000th and 55/1000th of an inch at the tip and base respectively. The common feature was an advantage in designing the rectangular-shaped warming device. The design called for creating multiple chambers for inserting multiple needles for concurrent warming. A rectangular heating structure 3.9" x 2 3/8" x 0.5", illustrated in Figure 21.4, was developed from an aluminum stalk. A photograph of the prototype is shown in Fig. 21.5.
The desired temperature was between 103 and 105 degrees Fahrenheit. In the absence of a temperature controller, the temperature was set by the amount of current (voltage) flowing through the coil. The necessary voltage that permitted the device to warm up to 105oF using the Kapton flexible heater (see Fig. 21.6) had to be determined. At steady state the rectangular warming system should have been at the optimum desired temperature so that the needles were warmed to that desired temperature. As a result, a Kapton flexible heater heating coil, with measured resistance of 75.4 Ω, was used.

A power supply with a maximum current limit of 1A was determined appropriate at a maximum of 28 volts to quickly warm up the heating structure and the needles to the desired temperature. The level of temperature feedback was provided with an RTD version of the DP 371-P2CX temperature digital panel thermometer (see Fig. 21.7).

Tests were conducted to determine the heating characteristics of the rectangular heating structure in terms of duration, voltage and current level. Tests showed that a 15-volt source capable of delivering 0.2 A of current was able to warm the heating structure to the desired temperature in eight minutes. The warming time could be cut drastically with a slightly higher voltage source and current level. In this case a temperature regulator would be necessary.

The cost of the prototype and parts was $363.
ADAPTATION OF HEIGHT-ADJUSTABLE OFFICE CHAIR FOR STIFF KNEE SUPPORT

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INTRODUCTION
A height-adjustable office chair was adapted for a data entry clerk who has an immobile left knee joint due to a diseased state and repeated knee joint surgery. Without leg support while seated at work, pain and discomfort occur. The client quit working because of persistent pain and discomfort after trying compensatory changes in body posture (Figure 21.8). Upon completion, the adapted office chair (Figure 21.9) was presented to the client.

SUMMARY OF IMPACT
The design criteria for the adapted office chair to support the left knee joint were defined by the compensatory methods illustrated in Figure 21.8. With zero flex and extension of the left knee joint, some compensatory methods created poor posturing, pulled the body out of alignment and increased muscle tension resulting in recurrent pain. As a result, the client quit work. The design allowed the client to return to work because the pain was eliminated.

TECHNICAL DESCRIPTION
After meeting with the client, the design team decided on the functional aspects of the adaptation. Existing methods of knee joint support in some wheelchairs was considered more favorable than creating a new device. The technical design concentrated on adapting the mechanism to an office chair and in such a way that the adaptation moved up and down and rotated with the seat base of a height-adjustable office chair. The focus of the design was to adapt an office chair to enable the client to return to work. The goal was for the adapted chair to support the weight of the leg and be comfortable. The adaptation had to be easy to operate and allow for height and rotation movements. The chair also had to be aesthetically pleasing. An Office Depot chair D500P was selected because it has armrests, has adjustable seat height, depth, and back tilt, is durable, and aesthetically pleasing.
The adaptation consisted of the following sections: the hinge joint, telescope rod for length adjustment, knee support, and foot support (Figure 21.10).

Adaptations also included a mounting to the seat base, and the channel cutout to allow the use of large knobs for length adjustment to support the knee (Figure 21.11).

Tests were conducted with the leg of an individual bigger than the client without negative results. There was no misalignment at the pivot joint or bending of the inner rod in the telescoping tube.

The cost of parts/material and labor was about $175.
INTRODUCTION
The control of a height adjustable seat was modified to enable a child born without forearms, without lower legs from the knees, and with separation between the residual femurs and the hip sockets. He is two feet tall and, with limited reach, is unable to control seat height adjustments. Upon completion, the adapted chair was presented to the parents of the client.

SUMMARY OF IMPACT
The client’s short residual hands to the elbow made it difficult for him to use the original adapted quiet actuator to raise and lower the chair in his classroom. Calling the teacher to help undermined the purpose of the quiet actuator that operates without being noticed by nearby classmates. Incorporating adaptive control positioning with mechanical advantage gave the boy the ability to operate the chair independently. The modified control eliminated the need for the client’s teacher to help him raise and lower his chair during class or worry about him falling off the chair.

TECHNICAL DESCRIPTION
From parents’ input and limb anthropometrics it became clear that modifications to improve the client’s reach should drive the design. A height-adjustable office chair from Office Depot was purchased for the project. A DC actuator (ECOMAG 20) by Magnetic Corporation was used to provide the support of the seat and the telescoping functions to achieve required seat height adjustment. The actuator noise was very low, satisfying the noise condition for classroom use.

A hollow interface was designed with an inside diameter to match the end of the DC actuator pillar. The outside diameter was designed to fit inside an oval space at the center of the wheel base structure. The hollow structure was firmly attached to the end of the pillar with a tight press-fit nut. Modification was made to the seat metal bracket to provide an interface between the other end of the actuator and the seat base. This was accomplished through made-to-fit metal gaskets and a tight fitting fastener. With the wheel assembly firmly coupled to one end of the actuator pillar, and the other end of the actuator firmly coupled with the seat base using the modified bracket, mechanical adaptation was completed.

To supply electrical power to the actuator, an 18-volt rechargeable battery was mounted beneath the seat with the necessary electrical circuitry connected to the switch. To engage the switch as purchased required too much effort and dexterity; also, the switch lever arm has limited length and surface area. A special adaptation was made to provide a mechanical advantage to overcome the limited lever arm length. This was accomplished by extending the switch lever arm by one foot, and the switch with the modified lever arm was mounted from a stand off the base of the seat. An L-shaped stand off illustrated in Figure 21.12 was introduced from beneath the chair to ensure improved reach for the child.

The surface area of the original switch lever arm was then increased by a factor of 10 times from a 0.2” diameter to 2” diameter with surround flexible rubber. The mass of the enlarged lever arm (joystick) was increased to require minimum push to activate the implemented double pole-double throw center tap switch type. The final product is as shown in Figure 21.13.

The total project cost was $352.00 for the pillar and parts.
Figure 21.12. L-shaped Standoff to Increase Reach to Control Joystick.

Figure 21.13. Raising and Lowering Control Using Enhanced Lever Arm (Joystick).
NEUROMUSCULAR EXERCISER FOR DIABETIC AMPUTEE

Designers: Tuan Ton
Department of Mechanical Engineering
Supervising Professor: Dr. Bertram N. Ezenwa
College of Health Sciences
College of Engineering and Applied Sciences
University of Wisconsin-Milwaukee,
Milwaukee, WI 53211

INTRODUCTION
The purpose of this design project was to develop a mechanically-induced muscular contraction system for a client with diabetes and lower extremity amputation who has a sedentary lifestyle. With a history of reluctance to exercise and a diabetic condition, the impact of blood pooling in the lower extremity had progressed to below-the-knee amputation. The client is seeking alternative methods of exercise to improve circulation and his general health condition. Alternative methods of induced muscular contraction include functional electrical stimulation, but this causes pain. Compression methods are used to induce venous return but are not very effective and show little improvement in muscle tone. The engineering design aspects of a mechanically-induced muscular contraction system were completed.

SUMMARY OF IMPACT
The design criteria for the mechanically-induced muscular contraction were defined by the sedentary lifestyle of the client, the loss of his lower limb and the safety factors regarding responses of human organs to vibration intensities. With sedentary lifestyle the client’s health worsened. With clinical advice, he was seeking ways to exercise. The design would allow the client to get more venous return, better muscle tone due to contraction and more bone density due to stresses on the bone during exercise.

TECHNICAL DESCRIPTION
After investigating susceptibility of body parts to resonance of types of vibrations, a controlled mixed mode of vibration was implemented. After considering the modes of application, transmission distance and pathways, a two-stage application mode was developed. Technical design concentrated on adapting the mechanism to an office chair in such
The focus of the design was to incorporate the exerciser into an office chair. The adaptation had to be easy to operate. An office chair with armrests, and adjustable seat height was purchased from Office Depot. The seat was used to model the support for the mechanical stimulation system. Some of the subcomponents were designed with steel and aluminum stalks. Typical physical and mechanical properties of aluminum stalk considered were 215-505 MPa yield strength, 230-570 MPa tensile strength, and elastic modulus of 70-79 GPa for density 2600-2800 kg/m3. Similarly for the steel stalk considered were 380-440 MPa, yield strength, 640-2000 MPa tensile strength, and elastic modulus of 190-210 GPa for density 7720-8000 kg/m3 all at room temperature.

Finite element analysis (FEA) was performed on parts of the system to determine if the design could withstand the necessary loads that would be applied. All FEA analysis was conducted in ANSYS. It had to support the weight of the seat assembly, seat support assembly, platform assembly, and the weight of the client. FEA was performed on the cams, platform, frames seat support and shaft at different loading conditions with a safety factor of two. Figures 21.14 and 21.15 are the FEA results of the platform with the cams and drive mechanism, and the weight of the individual.

FEA results were obtained for the cams, frames and shaft. The results under the loading and constraining conditions are shown in the Table 21.1.

The results show stresses under the yield strength. Displacements were small for both aluminum and steel stalks. The unique shapes to satisfy design requirements required detailing the parts for rapid prototyping production.

The cost of Office Depot chair was about $75.00.

<table>
<thead>
<tr>
<th>Part</th>
<th>Load (Lb)</th>
<th>Max. Stress</th>
<th>Max. Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cam: (Maximum distance)</td>
<td>150</td>
<td>609.155</td>
<td>9.68e-09</td>
</tr>
<tr>
<td>Cam: (Minimum distance)</td>
<td>150</td>
<td>691.653</td>
<td>9.64e-09</td>
</tr>
<tr>
<td>Platform</td>
<td>600</td>
<td>196.096</td>
<td>5.80e-09</td>
</tr>
<tr>
<td>Frame</td>
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<td>81971</td>
<td>1.74e-05</td>
</tr>
<tr>
<td>Seat Support</td>
<td>600</td>
<td>1096</td>
<td>9.73e-09</td>
</tr>
<tr>
<td>Shaft</td>
<td>300</td>
<td>8253</td>
<td>2.91e-07</td>
</tr>
</tbody>
</table>

Table 21.1. Load and Constraints for FEA.
CHAPTER 22
WRIGHT STATE UNIVERSITY

College of Engineering and Computer Science
Department of Biomedical and Human Factors Engineering
Dayton, Ohio 45435-0001

Principal Investigators:

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INTRODUCTION
A rehabilitation agency expressed a need for a wheelchair wheel washer (Figure 22.1) that could make the cleaning process less intensive for staff and allow the wheelchair user the opportunity to actively participate in the wheel cleaning process. The nature of this project also required that it meet specifications outlined in The Americans with Disabilities Act regarding safety of usage.

SUMMARY OF IMPACT
After outdoor fieldtrips, wheelchairs track mud and water into the facility, creating hazardous conditions, especially for clients having limited ambulatory abilities. Previously, the staff had to hand-clean every wheelchair entering the building. This was time-consuming and created significant amounts of soiled laundry. It also limited the independence of the user. The wheelchair wheel washer provided a monetary savings in the reduction of labor costs while promoting independence.
TECHNICAL DESCRIPTION

A base unit (Figure 22.2) houses the cleaning mechanism, consisting of water sprayers, air jets, and brushes. As the wheels are rolled in reverse, the sprayers wet the wheels, while brushes scrub the debris away. Air jets dry the wheels when the sprayers shut off and cleaning is complete. All debris is collected in plastic reservoirs under the rollers and removed via a vacuum system consisting of an ordinary shop-vac. Absorbent utility carpeting was placed in the path of the exiting wheelchairs on the exit ramp of the base unit to absorb any moisture remaining on the wheels.

A control unit, constructed primarily of wood (Figure 22.3), supplies water to the base unit from a reservoir where a pump is used to provide clean water for spraying the wheels. The air jets and vacuum system are controlled by a shop-vac inside the control unit. The debris is evacuated from the plastic reservoirs and subsequently deposited inside the shop-vac. The exhaust air from the shop-vac is routed to the air jets and serves to dry the wheels. Dirty water from the shop-vac can be removed via a drain valve located on the external surface of the control unit. A section of hose routes the waste to a suitable drain.

The engineering principles utilized in the design of this project include circuit analysis, material analysis and static force analysis. Circuit analysis (Figure 22.4) is straightforward. Due to the fact that the device is metallic, uses water, and contains electrical devices in the control unit, electrical concerns involved eliminating the risk of electric shock to users. To accomplish this end, GFCI protection is incorporated in the power cord to shield the entire device from the power source.

Materials analysis focused on judicious selection of materials for strength and resistance to corrosion. The base unit is aluminum framework covered in aluminum diamond plate. Wheel rollers are made of stainless steel rods covered with PVC for strength and durability and are fitted with stainless steel bearings.

Static force analysis was performed utilizing Cosmos® (Figure 22.5) and an Instron® stress analyzer. The roller mechanism was shown to tolerate forces in excess of 600 pound/in² and the maximum displacement incurred by the frame under a load of 1000 pounds was determined to be 170 microns. The design can accommodate wheelchair base widths from 31 inches for large wheelchairs to 18.25 inches for smaller chairs. The ADA requirement for ramp inclines is one inch of rise for every 12 inches of ramp length. Ramps on the base unit are therefore made to be three feet long and three inches tall making its overall length approximately nine feet. Dimensions of the control unit are 43 inches by 30 inches by 30 inches. The base unit can be folded and the entire device transported in a small pickup truck.

The total cost was $998.
Figure 22.2. Base Unit.

Figure 22.3. Control Unit.
Figure 22.4. Diagram of Electrical Circuit.

Figure 22.5. Displacement Plot from COSMOSWorks®.
INTRODUCTION
Individuals with sensory integration dysfunction experience deficits in processing tactile signals. This results in improper and sometimes excess tactile sensory feedback. The application of deep pressure at the skin’s surface, which is then transferred into the muscle, has been shown to calm these patients. Ideally, by not being overloaded with sensory feedback, they are able to better process sensory information.

SUMMARY OF IMPACT
If the tactile system is not properly functioning, abnormal signals are sent to the brain, causing tactile defensiveness. The result is that a person is very sensitive to light touch, perceiving it as painful because the nerves in the periphery are sending abnormal signals to the brain about tactile contact. The Deep Pressure Machine (DPM) (Figure 22.6) allows patients to self-treat sensory integration dysfunction.

TECHNICAL DESCRIPTION
Mechanical/structural design and static force analysis were the key engineering principles employed in the design of this project. The framework of the DPM is constructed of two-inch by two-inch by eighth-inch A36 square tubular steel. Two steel rollers, 27 inches in length and 4.41 inches in diameter are positioned in a linear track constructed of one-inch by half-inch by eighth-inch channel steel. The device is fitted with locking casters to keep in place while in use. The rollers that apply the deep pressure are cushioned with foam padding and enclosed with vinyl roller coverings. Deep pressure is supplied with the innovative use of rubber Soloflex® bands stretched between two rollers. Simply adding or changing bands may adjust the amount of deep pressure.

Static force analysis was performed utilizing SolidWorks® (Figure 22.7) coupled with COSMOS WORKS® and focused primarily upon the strength of the rollers against a downward distributed force. Based on the COSMOS WORKS® analysis it was determined that the weak point of the design is located at four bolts holding a mounted bearing to the frame. The spring constant of the Soloflex® bands was determined using a CSD 500 dynamometer. The dynamometer was used to measure the force applied to the Soloflex® bands. By measuring the distance that the bands stretched the equivalent spring constant was calculated for the
five and ten pound bands. Hence, the force applied to the body as a function of band stretch distance was determined.

The DPM was found useful for the self-treatment of patients (Figure 22.8) with tactile defensiveness due to SID. Clients and users reported the DPM provided enough pressure to give the desired calming sensation. The DPM may be cleaned with any type of standard vinyl cleaner. Locking casters allow for movement and safety during usage. When not in use, the dimensions (Figure 22.9) of the device allow for storage in a standard closet.

The total cost was $1,212.
INTRODUCTION
Clients at a rehabilitation agency requested a means by which their patients could vacuum and/or manually sweep floors from a wheelchair. Previous solutions to this problem involved using a corded vacuum in a stop-and-go fashion, or a robotic solution, such as the Roomba®. Users found the manual solution too tedious and the automated solution did nothing to contribute to their rehabilitation. Client supervisors sought a solution which would empower patients with mobility impairments to sweep or vacuum independently.

SUMMARY OF IMPACT
This design allowed users to clean floors (Figure 22.10) in a domestic or institutional setting. Although assistance in attaching the device to a wheelchair is usually required, users still derived feelings of independence and self-sufficiency from performing the simple task of vacuuming floors. The client supervisors hope to utilize this device to secure gainful employment for some of their patients.

TECHNICAL DESCRIPTION
Mechanical and structural design and analysis were the chief engineering principles used in the design of this project. However, electrical circuit design and analysis were also employed.

Initially, design features common to most wheelchairs and most cleaning implements were examined to determine a feasible way to merge the two. It was found that most wheelchairs incorporate tubular footrest supports and most cleaning implements have a (roughly) cylindrical shape. Hence, it was decided to use these common features as attachment points. The device (Figure 22.11.) is constructed of one-inch and three-quarter inch diameter aluminum tubing with an eighth-inch thick wall. A clamp/jaw system was designed and machined to connect the aluminum tubing to the footrest supports. Clamps were designed to fit the two diameters of tubing. This was done to allow telescopic adjustment between footrest supports in order to accommodate footrests from 13 inches to 20 inches apart. A V-shaped trough and strap system...
was then utilized to hold a vacuum or push style broom/dust mop handle. To allow retraction from the floor when not in use, the trough was allowed to pivot on a horizontal bar and a bayonet catch was used to hold the cleaning implement in a position several inches off the floor.

Electrical concerns focused on an adequate power supply and appropriate mode switch. A rechargeable battery powers the cordless vacuum for at least four hours and was mounted to the rear of the wheelchair. This served to counterbalance attachments on the front of the wheelchair in order to avoid any undesired weight distribution problems. A three position double-pole, double-throw switch was mounted on the wheelchair armrest, allowing for carpeting (vacuum and roller brush motors on), flooring (vacuum motor only on) and off modes.

The device was found to be an effective means of attaching most cordless vacuums and push style brooms/mops to most wheelchairs.

The total cost was $660.

Figure 22.11. SolidWorks® Drawing.
AUDITORY AND VISUAL TIMER

Designers: Andrea Horstman, Jaqueline Jones
Supervising Professor: Dr. Ping He
Department of Biomedical, Industrial and Human Factors Engineering
Wright State University
Dayton, Ohio 45435-0001

INTRODUCTION
The purpose of this project is to help children tell time, understand the concept of time, and monitor passage of time during activities.

SUMMARY OF IMPACT
The timer’s use encourages children’s improved concept of time. This, in turn, may lead to greater autonomy and more efficient use of time by these students. The timer (Figure 22.12) also allows for more efficient usage of time available to educators in the supervision of these young learners. The timer may be used for timed activities, such as playtime, time outs and quiet time.

Figure 22.12. Auditory and Visual Timer.
TECHNICAL DESCRIPTION

Engineering principles employed in the design of this project include circuit analysis, mechanical/structural design, and computer programming.

Circuit analysis is involved in the light, sound and motion components of the project. An array of 15 multi-colored LEDs with resistors is located in equal intervals around the face of the timer. Initially all LEDs are on. When the timer is activated LEDs turn off sequentially at the rate of one every 20 seconds. An amplifier circuit with accompanying speaker is utilized to provide the sound requirements and an audible tone is initiated once after the passing of each one-minute interval. A DC step motor and driver circuit (Figure 22.13) is employed for motion and serves to rotate a colored disc through one color segment each minute. A toggle switch located at the top of the timer housing serves to activate/deactivate the mechanism. All electrical components are powered with a single nine-volt battery.

Mechanical and structural design is straightforward and involves construction of the timer face and housing as well as the mounting of electrical circuitry. The housing is constructed primarily of Plexiglas® and has dimensions of 7.5 inches by 7.5 inches by five inches.

PBasic® programming language is utilized to program a BASIC stamp. The stamp (Figure 22.14) is incorporated in the coordination and timing of lights, sound and motion.

The timer is found to exhibit a fair modicum of durability and has been well received by instructors as well as the intended users.

The total cost was $466.
INTRODUCTION
This is a redesign of a typically available range of motion arc used by orthopedic therapists to exercise the shoulders and arms of patients. The physical therapist in an elementary school desired a device that would promote increased range of motion of the shoulder while holding the attention of her clients. The previous product, known as a shoulder arc, did not incorporate a positive feedback mechanism, hence redesign was deemed appropriate.

SUMMARY OF IMPACT
Utilization of the arc promotes greater range of motion of the shoulder and thereby increases motor skills and coordination leading to increased independence. The device is helpful for users who have experienced a degree of reversible motion loss or impairment. The inclusion of positive feedback promotes better pediatric user compliance (Figure 22.16).

TECHNICAL DESCRIPTION
The engineering principles employed in the design of this project include circuit and mechanical/structural design. The circuit (Figure 22.17) design is driven by a standard 555 timer and a 12-volt rechargeable Gel Cell battery. The peripherals such as the lighting display and music chip utilize a five-volt three terminal voltage regulator. A total of 33 high intensity, red LEDs make up the lighting display and are wired in parallel with 1.2 kΩ resistors to allow a current flow of 10 mA to each LED. Both the visual and auditory devices are timed out using the 555 timer. A magnetic ring is integrated into the design to trigger the positive feedback. Six reed switches are wired in parallel and positioned at either end of the arc to facilitate activation of the feedback mechanisms. Recharging of the Gel Cell battery is accomplished with a 12V adapter and current limiting circuit to allow the battery to trickle charge overnight.

The arc itself is constructed of three-quarter inch flexible plastic tubing. Additional lengths of tubing allow for increasing the total range of motion and permit for an arc height of between 15 and 41 inches. A toggle switch is used to set the starting position to either side of the arch base in order to accommodate ambidextrous movement for supination to pronation or vice versa. A case, with inside dimensions of 34 inches by 18 inches by six inches, is fitted with two sheets of eighth-inch white acrylic plastic which houses the electrical components and provides a platform for the tubing arc. Five metal clamps affixed to the platform behind the arc allow for the storage of the additional lengths of arc tubing when not in use. The product is portable for transporting to different classrooms, has adjustable difficulty levels, provides positive feedback to the user with both visual and auditory rewards and is safe and durable.

The total cost was $663.
Figure 22.16. Child Using Range of Motion Arc.

Figure 22.17. Block Diagram of Circuit.
HEAD MOUNTED DISPLAY VISION SCREENER FOR PRESCHOOLERS

Designers: Joseph Cunningham, Adam Lenger, Cayti Zelnio
Supervising Professor: Dr. David Reynolds
Department of Biomedical, Industrial and Human Factors Engineering
Wright State University
Dayton, Ohio 45435-0001

INTRODUCTION
This project essentially automates the process of vision screening in preschoolers. In preschool vision screening, flashcards or posters are used to test for visual acuity, stereo acuity and colorblindness. Currently, screeners in a client program use a measuring tape to fix the appropriate distances between the child and the testing cards. The children are then asked to determine what shapes are being displayed. Often, the children will lean forward to view the images. As a result, the measured distance is not standardized. Based on these shortcomings, vision screening utilizing a head mounted display was deemed appropriate.

SUMMARY OF IMPACT
In addition to standardizing the distances required for vision screenings, the head mounted display (Figures 22.18-22.19.) also regulates effective lighting levels.

The system is compact and easy to carry.
TECHNICAL DESCRIPTION
The engineering principles utilized in the design of this project included optical analysis, static force analysis and computer programming in JAVA®. Optical calculations were the basis for a large portion of the work on this project. Lens powers were calculated to obtain the desired convergence and focal depth from the viewer’s aspect. Calculations were made to determine equivalent image sizes at varying distances. Focal planes were also taken into consideration during the placement of the lenses.

Another principle utilized for this project was the calculation of force balances on both the display mounted on the head, as well as, the display resting on a stand. It was important to see exactly what forces were being compensated for and how different parts of the body (i.e. head, neck, and back) would be affected when the display is worn on the user’s head. Some flexibility for the children was obtained by creating a stand (Figure 22.20) to support the display if a child chooses not to wear it (Figure 22.21) on their head. When used in conjunction with the stand, it was important to provide, for the safety of people and of the display itself, a support for the potential problem of the apparatus tipping over. The stand, which is likely to be used on the floor, can be adjusted from 18 to 48 inches fully accommodating a preschool child sitting in a chair or in the standing position.

A flow chart was made to sketch out the proper ordering of the testing cards. This involved outlining what to do and where to proceed when certain series of tests were passed or failed by the subject. In some cases, a failed testing series meant more tests needed to be conducted to guard against a false negative being obtained from the screening test. Once the outline was finalized, the JAVA program had to be written to accommodate the testing procedure. The program had to take into account image sizes and be tailored to the display.

The total cost was $995.
LIGHTWEIGHT GRIPPER

Designers: Allison Gadd, Kelly Barrett
Supervising Professor: Dr. Chandler Phillips
Department of Biomedical, Industrial and Human Factors Engineering
Wright State University
Dayton, Ohio 45435-0001

INTRODUCTION
This project involved redesigning a commercially available gripper for an eight year old child with arthrogryposis multiplex congenital, which causes the fusion of the patient’s joints, resulting in severe movement restrictions. The user is unable to lift a large amount of weight or bend elbows or wrists to assist in getting objects within reach. The gripper will be used in a physical education setting to facilitate the retrieval of objects, such as balls and beanbags, and to aid in the grasping of a plastic hockey stick.

SUMMARY OF IMPACT
The primary effect resulting in the use of this device is the improvements experienced in the self-sufficiency of the child in physical education class. In time, psychological and sociological improvements may be derived as a result of the child’s enhanced interactions with others. Continued use may show therapeutic improvements resulting from increased muscle mass and some decrease in muscle atrophy.

TECHNICAL DESCRIPTION
Primary engineering principles employed in the design of this project included mechanical, ergonomic and materials analysis. Mechanical analysis involved computation of the precise gear size and ratio needed for the interface of the gear key and finger assemblies (Figure 22.22). It was also necessary to incorporate a dual locking mechanism at either end of the gripper to facilitate retrieval of objects to the child’s lap and provide for their subsequent release. This was accomplished with dual three-position bayonet catches (Figure 22.23) on both the handle and gripper ends of the device. Positions of the bayonet catches allowed for grasping, holding and release of small, medium and larger objects less than six inches in diameter.

Ergonomic analysis was employed in the design and size of the handle and several prototypes were tested on the user for comfort and ease of use. The handle was made of PVC tubing covered in moleskin at the location most likely gripped by the user’s hand.

Materials analysis involved research of suitable materials for their lightweight characteristics and durability. The product needed to withstand being hit lightly on the ground while the user gets the gripper fingers around the object to be retrieved. Delrin® was utilized for the construction of the finger assembly, lever handles and an inner rod connected to the gear key as it fulfilled the aforementioned materials requirements.

The final product weighed approximately one pound and is nearly three feet long. The gripper proved capable of grasping, holding and releasing three specified objects (Figures 22.24-22.26). The gripper was capable of grasping objects having average diameters ranging from two inches to six inches.

The total cost was $798.
Figure 22.22. Key and Finger Assembly.

Figure 22.23. Handle and Bayonet Catch.

Figure 22.24. Large Ball.

Figure 22.25. Small Ball.

Figure 22.26. Bean Bag.
INTRODUCTION
Instructors at a middle school desired a voice-activated system incorporating lights, sound and motion for the sensory stimulation of their students with cognitive and physical disabilities, ranging in age from 10 to 13 years.

SUMMARY OF IMPACT
The Voice Activated Sensory System (Figure 22.27) serves to empower users by giving them a sense of comfort and control. Providing these children with various types of sensory stimulation is known to have a calming effect and affords them a sense of independence and individuality. Enabling these educators to supply their students with sources of stimulation allows for more efficient use of their limited time.

Figure 22.27. Voice Activated Sensory System (VASS).
TECHNICAL DESCRIPTION

Three commercially available toys mounted at the top of the unit were employed to provide the sound and motion components of the design while back lighted pictures fulfilled the lighting specification. Circuit and structural design, as well as computer programming, were the primary engineering principles exploited in the conception of this project.

Circuit design (Figure 22.28) focused primarily on the control of the system and was centered about a voice-activated relay (VOX) powered with a 12-volt AC to DC converter. Reed relays and diodes were used to facilitate the control signal for activation of the toys. The power source for the toys was supplied with rechargeable batteries. Flashlight bulbs were utilized to deliver back lighting of the pictures on the front of the unit. A three-position rocker switch allowed for the selection of voice activated, manual and off modes.

Structural design skills were employed in the fabrication of the project’s housing and mounting the electrical components and toys in and upon the enclosure. Disposable, aluminum roasting pans were used as reflectors for back lighting of the pictures. The project enclosure was fabricated of quarter-inch thick plywood and clear Plexiglas®. Dimensions of the enclosure are 30 inches by 30 inches by five inches.

P.Basic® programming language was used in conjunction with the BASIC stamp in providing the signals to sequentially activate the three toys. The BASIC stamp’s power supply was provided by a nine-volt AC to DC power converter.

The total cost was $527.

Figure 22.28. Circuit Design for the Voice Activated Sensory System.
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