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ENGINEERING SENIOR DESIGN PROJECTS TO AID PERSONS WITH DISABILITIES

Edited By
John D. Enderle
Brooke Hallowell
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## CONTENTS

<table>
<thead>
<tr>
<th>Publication Policy</th>
<th>iii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contents</td>
<td>iv</td>
</tr>
<tr>
<td>Contributing Authors</td>
<td>viii</td>
</tr>
<tr>
<td>Foreword</td>
<td>x</td>
</tr>
<tr>
<td>Chapter 1 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Chapter 2 Best Practices in Senior Design</td>
<td>7</td>
</tr>
<tr>
<td>Chapter 3 Meaningful Assessment of Design Experiences</td>
<td>19</td>
</tr>
<tr>
<td>Chapter 4 Using NSF-Sponsored Projects to Enrich Students’ Written Communication Skills</td>
<td>25</td>
</tr>
<tr>
<td>Chapter 5 Connecting Students with Persons Who Have Disabilities</td>
<td>33</td>
</tr>
<tr>
<td>Chapter 6 Arizona State University</td>
<td>41</td>
</tr>
<tr>
<td>Orthopedic Driving Simulator</td>
<td>42</td>
</tr>
<tr>
<td>Manually Controlled Hip Orthosis</td>
<td>44</td>
</tr>
<tr>
<td>Neuro-Rehab Game</td>
<td>46</td>
</tr>
<tr>
<td>Tremor Control Arm Brace</td>
<td>48</td>
</tr>
<tr>
<td>Arm Rehabilitation Game</td>
<td>50</td>
</tr>
<tr>
<td>Magnetic Resonance (MR) Compatible Hand Diagnostic Device</td>
<td>52</td>
</tr>
<tr>
<td>Transferring Wheelchair</td>
<td>54</td>
</tr>
<tr>
<td>Hip-Knee Mentor</td>
<td>56</td>
</tr>
<tr>
<td>Chapter 7 Duke University</td>
<td>59</td>
</tr>
<tr>
<td>Outdoor Play Activity Center</td>
<td>60</td>
</tr>
<tr>
<td>Foot-Action Guitar Strummer</td>
<td>62</td>
</tr>
<tr>
<td>Personal Play Canopy</td>
<td>64</td>
</tr>
<tr>
<td>Steady Stepper</td>
<td>66</td>
</tr>
<tr>
<td>Power Soccer Bumper Attachments</td>
<td>68</td>
</tr>
<tr>
<td>Biomimetic Reaching Assist Device</td>
<td>70</td>
</tr>
<tr>
<td>Improved Bee-Poll</td>
<td>72</td>
</tr>
<tr>
<td>Falls Recovery Lifting Device</td>
<td>74</td>
</tr>
<tr>
<td>Pandaroo: Personalized Stuffed Animal Companion</td>
<td>76</td>
</tr>
<tr>
<td>Thigh-Controlled Piano Pedal</td>
<td>78</td>
</tr>
<tr>
<td>Walking Motivator</td>
<td>80</td>
</tr>
<tr>
<td>Speedy Recovery Vehicle</td>
<td>82</td>
</tr>
<tr>
<td>Chapter 8 North Dakota State University</td>
<td>85</td>
</tr>
<tr>
<td>Automated Medicine Dispenser</td>
<td>86</td>
</tr>
<tr>
<td>Musical Rainbow</td>
<td>88</td>
</tr>
<tr>
<td>Modified Patient Lift</td>
<td>90</td>
</tr>
<tr>
<td>Automated Patio Door System</td>
<td>92</td>
</tr>
<tr>
<td>Voice Activated Thermostat</td>
<td>94</td>
</tr>
<tr>
<td>Interactive Animal Sounds System</td>
<td>96</td>
</tr>
<tr>
<td>Brain-Computer Interface Hyper-Trainer</td>
<td>98</td>
</tr>
<tr>
<td>Mailbox-Computer Alert System</td>
<td>100</td>
</tr>
</tbody>
</table>
CHAPTER 9    ROCHESTER INSTITUTE OF TECHNOLOGY .................................................. 103

MODIFIED HOME ENTRY ................................................................. 104
ADAPTED COMPUTER KEYBOARD .................................................. 106
PRESSURE SORE ALLEVIATION DEVICE ......................................... 108
STANDING TABLE ........................................................................ 110
CUSTOM WHEELCHAIR TRAY ......................................................... 112
DROP-SHIPMENT AREA MODIFICATION FOR PEOPLE WHO ARE BLIND OR VISUALLY IMPAIRED ................................................................. 114
ARCWORKS SPORTS BOTTLE CLOSURE TUBE ASSEMBLY WORKPLACE ADAPTATION ............................... 116
SENSORY AWARENESS TRAIL ......................................................... 118
SEIZURE MONITOR ...................................................................... 120
THERAPY POOL LIFT .................................................................... 122

CHAPTER 10    STATE UNIVERSITY OF NEW YORK AT BUFFALO ......................................... 125

CHAIN-DRIVEN SEVEN-SPEED WHEELCHAIR ................................. 126
WHEELCHAIR POUCH ....................................................................... 130
WHEELCHAIR ACCESSIBLE EXERCISE STATION ............................ 132
COLLAPSIBLE WHEELCHAIR LIFTING SEAT .................................... 134
SHOULDER STEERABLE TRICYCLE .................................................. 136
ONE-HANDED X-BOX CONTROL JOYSTICK ...................................... 138
LIGHT EMITTING SLIPPER TO ASSIST PEOPLE WITH VISION IMPAIRMENT ............................................ 140
LIFT-UP OVEN RACK ...................................................................... 142
REDESIGN OF A PORTABLE, COLLAPSIBLE WHEELCHAIR-TO-VEHICLE TRANSFER SYSTEM ................. 144
TREADMILL GUARDIAN ANGEL ....................................................... 146
CARPET CLEANER ATTACHMENT FOR A WHEELCHAIR .................... 148
SIMULTANEOUS MULTIPLE KEYSTROKE SUPPLEMENT FOR KEYBOARDS .................................................. 150
MANUAL WHEELCHAIR WITH PNEUMATIC HEIGHT ADJUSTABLE SEAT ....................................................... 152
ADJUSTABLE SEAT HEIGHT ATTACHMENT FOR WHEELCHAIRS .................................................................. 154
HUMAN POWERED OFF-ROAD WHEELCHAIR ................................... 156
ACTIVELY ADJUSTABLE CANE TO ASSIST STANDING FROM A SITTING POSITION ......................................... 158
WHEELCHAIR EXERCISE STATION .................................................... 160
STAIR TO RAMPS CONVERSION KIT ................................................. 162
AUTOMATIC TELESCOPING REACH EXTENDER .............................. 164
RADIO CONTROLLED BRACELET FOR OPENING DOORS ................ 166
MULTI-STORY WINDOW FIRE ESCAPE ........................................... 168
PORTABLE AUTOMATED MULTI-PILL DISTRIBUTOR AND MEDICAL NEEDS KIT ........................................ 170
WHEELCHAIR DIP STAND .................................................................. 172
THERAPEUTIC INJURY MASSAGE ................................................... 174
DEVICE FOR DETERMINING DIRECTIONALITY OF SOUND .......... 176

CHAPTER 11    STATE UNIVERSITY OF NEW YORK AT STONY BROOK ..................................... 179

CHAIRCYCLE .................................................................................. 180
ASSISTIVE TREADMILL ................................................................. 182
STAIR-CLIMBING WHEELCHAIR ELEVATING DEVICE .................... 184
MULTIFUNCTIONAL QUADRICYCLE ................................................ 186
ACCESSIBLE MEDICATION DISPENSING DEVICE .......................... 188
TRANSPORTER ................................................................................ 190
ARTICULATING THERAPEUTIC WHEELCHAIR ................................ 192
EASY TOILET ACCESS WHEELCHAIR .............................................. 194
BEACH MOBILITY DEVICE: BANDIT ................................................. 196
PATIENT TRANSFERRING AND POSITIONING AID (PTP) ............. 198

CHAPTER 12    TULANE UNIVERSITY ........................................................................ 201
CHAPTER 16 UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL .......................................................... 301
SUPINE LEG EXERCISER .......................................................... 302
MOTIVATIONAL SYSTEM TO BUILD UPPER BODY STRENGTH IN CHILDREN ........................................... 304
COMFORT READER 2K6 .......................................................... 306
EMOD: ELECTRONIC MEDICATION ORGANIZER AND DISPENSER ......................................................... 308
SWITCH RELAY .......................................................... 310
ACCESSIBLE GARDEN BED AND ADJUSTABLE HANGING BASKET ..................................................... 312

CHAPTER 17 UNIVERSITY OF TOLEDO .......................................................... 315
TRANSFER LIFT SYSTEM .......................................................... 316
PORTABLE MOUNT TO ACCESS CRUTCHES .......................................................... 322
ADAPTIVE HAND TOOL TO PROMOTE INDEPENDENT LIVING ................................................................. 324
POKER CHIP DISPENSER .......................................................... 326
ALL TERRAIN WHEELCHAIR FOR METROPARKS – SECOND GENERATION .................................................. 328

CHAPTER 18 UNIVERSITY OF WYOMING .......................................................... 331
LEG POWERED QUAD-CYCLE .......................................................... 332
CHESS AUTOMATION BOARD (CAB) .......................................................... 336
SPEECH-RECOGNITION TELEPHONE .......................................................... 338
MECHANICAL LIFT FOR A DISABLED TEENAGER .......................................................... 340
CRANIAL CONTROL (WHEEL) CHAIR .......................................................... 342
MOBILE WHEELCHAIR LIFT .......................................................... 344
VOICE MACHINE .......................................................... 346
“CYCLOPS II”: MOBILITY AID DEVICE FOR THE BLIND .......................................................... 348
“LIFE’S A SWITCH”: PROJECT UPDATE .......................................................... 350

CHAPTER 19 WAYNE STATE UNIVERSITY .......................................................... 351
PACKAGING AND ASSEMBLY FIXTURES AND SHIPPING KIT DESIGN .................................................... 352
FACILITIES ANALYSIS AND WORKSTATION DESIGN .......................................................... 354
MATCHING CORRESPONDENCE COUNTER: COUNTING AND PACKAGING .................................................. 356
MATCHING CORRESPONDENCE COUNTER: MATHORAMA MATH GAME .................................................. 358
ACCUCUT MANUAL DIE MACHINE CONVERSION TO SWITCH OPERATED .................................................. 360

CHAPTER 20 WRIGHT STATE UNIVERSITY .......................................................... 363
INTERACTIVE OBJECT MOBILE WITH LIGHT AND SOUND .......................................................... 364
ADAPTATION OF THE 7-LEVEL COMMUNICATION BUILDER .......................................................... 368
SENSORY VEST .......................................................... 370
CANDY SORTER .......................................................... 372
TACTILE BOARD .......................................................... 374
SOUND AND LIGHT DOME .......................................................... 376
ACCESSIBLE WHEELCHAIR TRAY .......................................................... 378
TOUCH SCREEN FOR COMPUTER AND INTERACTIVE DISPLAY .......................................................... 380

CHAPTER 21 INDEX .......................................................... 383
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FOREWORD

Welcome to the eighteenth 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.


1 This program is now in the Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET).
presenting 154 projects carried out by students at 16 universities during the 2004-2005 academic year.

This book, funded by the NSF, describes and documents the NSF-supported senior design projects during the eighteenth year of this effort, 2005-2006. 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 desiring more information on a particular design should contact the designated supervising principal investigator. An index is provided so that projects may be easily identified by topic. Chapters on best practices in design experiences, outcomes assessment, and writing about and working with individuals who have disabilities are also included in this book.

Hopefully this book will enhance the overall quality of future senior design projects directed toward persons with disabilities by providing examples of previous projects, and 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 have been completed and are in use. A number of different technologies were incorporated in the design projects to maximize the impact of each device on the individual for whom it was developed. A two-page project description format is generally used in this text. Each project is introduced with a nontechnical description, followed by a summary of impact that illustrates the effect of the project on an individual's life. A detailed technical description then follows. Photographs and drawings of the devices and other important components are incorporated throughout the manuscript.

Sincere thanks are extended to Dr. Allen Zelman, a former Program Director of the NSF BRAD program, for being the prime enthusiast behind this initiative. Additionally, thanks are extended to Drs. Peter G. Katona, Karen M. Mudry, Fred Bowman, Carol Lucas, Semahat Demir, Robert Jaeger 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 Samuel Enderle for technical illustrations, and Alexandra Enderle, Laurie Turner, Meggan Moore, Nicholas Linn, and Rachel Poling for editorial assistance. We also acknowledge and thank Ms. Shari Valenta for the cover illustration and the artwork throughout the book, drawn from her observations at the Children's Hospital Accessibility Resource Center in Denver, Colorado.

The information in this publication is not restricted in any way. Individuals are encouraged to use the project descriptions in the creation of future design projects for persons with disabilities. The NSF and editors make no representations or warranties of any kind with respect to these design projects, and specifically disclaim any liability for any incidental or consequential damages arising from the use of this publication. Faculty members using the book as a guide should exercise good judgment when advising students.

Readers familiar with previous editions of this book will note that John Enderle moved from North Dakota State University to the University of Connecticut in 1995. With that move, annual publications also moved from NDSU Press to Creative Learning Press Inc. in 1997. During 1994, Enderle also served as NSF Program Director for the Biomedical Engineering and 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 Director of 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 many of the persons who need them.

In 1988, the National Science Foundation (NSF), through its Emerging Engineering Technologies Division, initiated a program to support student engineers at universities throughout the United States in designing and building devices for persons with disabilities. Since its inception, this NSF program (originally called Bioengineering and Research to Aid the Disabled) 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. 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 2005-2006. The purpose of this publication is threefold. First, it
is to serve as a reference or handbook for future senior design projects. Students are exposed to this unique body of applied information on current technology in this and previous editions of this book. This provides an even broader education than typically experienced in an undergraduate curriculum, especially in the area of rehabilitation design. Many technological advances originate from work in the space, defense, entertainment, and communications industry. Few of these advances have been applied to the rehabilitation field, making the contributions of this NSF program all the more important.

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

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

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

After the five introductory chapters, 15 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 analysis, critique and evaluation. Design is an

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iterative decision-making process in which the student optimally applies previously learned material to meet a stated objective.

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

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

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

- Selects the device or system to design,
- Writes specifications,
- Creates a paper design,
- Analyzes the paper design,
- Constructs the device,
- Evaluates the device,
- Documents the design project, and
- Presents the project to a client.

Project Selection
In a typical NSF design project, the student meets with the client (a person with a disability and/or a client coordinator) to assess needs and 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 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 evaluated periodically for performance and usefulness after the project is complete. Evaluation typically occurs, however, when the device no longer performs adequately for the client, and 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; they are summaries of the final reports. A typical final report for a design project is approximately 30 pages in length, and includes extensive analysis supporting the operation of the design project. Photographs of the device may be included in the final report but mechanical and electrical diagrams are often more useful in documenting the device.
CHAPTER 2
BEST PRACTICES IN SENIOR DESIGN

John Enderle and Brooke Hallowell

This chapter presents different approaches to the design course experience. For example, at Texas A&M University, the students 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 grants from the National Science Foundation, and is offered each fall. The course is limited to 12 students and four to six projects to provide a team atmosphere and to ensure quality results.

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

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

Course lectures are focused on basic principles of engineering design, oral and written communication, and ethics. In addition, guest lectures cover topics such as an overview of assistive technology, universal design, ergonomics and patent issues. Field trips to a local assistive technology lending library, and to an annual exposition 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 or her employees and the teams are thus formed. Each team is expected to do the following:

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

- Demonstrate understanding of the cost of insurance and meet with insurance agents to discuss health and life insurance for employees and liability insurance costs for the company, and
- Explore OSHA requirements relative to setting up development laboratories.

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

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

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

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

Early in the course, potential capstone projects are presented; students are required to review current and past projects. In some semesters, potential clients address the class. Representatives from agencies have presented their desires and individuals in wheelchairs have presented their requests to the class. Students are required to begin the process of choosing a project by meeting with potential clients and 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 to be used to accomplish the project?
- How much time is necessary?
- How much will the project cost?

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

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

**Texas A&M University**

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

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

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

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

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

Throughout each phase of the project, a faculty member supervises the work, as do the 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 questionnaire form as well as personal discussion. The objective of the reviews is to obtain students’ assessment of the educational value of the rehabilitation design program, the adequacy of the resources and supervision, and any suggestions for improving the process.

North Dakota State University

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

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

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

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

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

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

The second laboratory contains computers for analysis, desktop publishing and microprocessor testing. The computers all have analysis, CAD and desktop publishing capabilities so that students may easily bring their design projects from the idea to the implementation stage. Analysis software supported includes Microsoft EXCEL and Lotus 123 spreadsheets, PSspice, 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 of work.

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

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

**University of Connecticut**

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

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

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

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Senior design consists of two required courses, Design I and II. Design I is a three-credit hour course in which students are introduced to a variety of subjects. These include: working in teams, design process, planning and scheduling (timelines), technical report writing, proposal writing, oral presentations, ethics in design, safety, liability, impact of economic constraints, environmental considerations, manufacturing, and marketing. Each student in Design I:
- Selects a project to aid an individual after interviewing a person with disabilities,
- Drafts specifications,
- Prepares a project proposal,
- Selects an optimal solution and carries out a feasibility study,
- Specifies components, conducts a cost analysis and creates a time-line, and
- Creates a paper design with extensive modeling and computer analysis.

Design II is a three-credit-hour course following Design I. This course requires students to implement a design by completing a working model of the final product. Prototype testing of the paper design typically requires modification to meet specifications. These modifications undergo proof of design using commercial software programs commonly used in industry. Each student in Design II:
- Constructs and tests a prototype using modular components as appropriate,
- Conducts system integration and testing,
- Assembles a final product and field-tests the device,
- Writes a final project report,
- Presents an oral report using PowerPoint on Senior Design Day, and
- Gives the device to the client after a waiver is signed.

Course descriptions, student project homepages and additional resources are located at http://design.bme.uconn.edu/.

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

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

Each student then selects a project from a client that he or she has visited, or from the Project Notebook. If the project selected was from the Project Notebook, the student visits the client to further refine the project. Because some projects do not require a full academic year to complete, some students work on multiple projects. Students submit a project statement that describes the problem, including a statement of need, basic preliminary requirements, basic limitations, other data accumulated, and important unresolved questions.
Specific projects at Ohio University are established via distance communication with the co-principal investigator, who consults with a wide array of service providers and potential clients in the Athens, Ohio region.

The stages of specification, project proposal, paper design and analysis, construction and evaluation, and documentation are carried out as described earlier in the overview of engineering design.

To facilitate working with sponsors, a web-based approach is used for reporting the progress on projects. Students are responsible for creating their own Internet sites that support both html and pdf formats with the following elements:
- Introduction for the layperson,
- Resume,
- Weekly reports,
- Project statement,
- Specifications,
- Proposal, and
- Final Report.

**Teamwork**

Student learning styles differ among team members. Gender, cultural factors, personality type, intelligence, previous educational background, academic achievement, and previous experience in teams may influence the strengths and weaknesses that individuals bring to team membership. Research pertaining to differences in cognitive style characterized by field dependence versus independence helps to shed light on individual differences among team members and how those differences may affect team interactions. 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

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also that every team member has an equal learning opportunity and hands-on experience.

Because students are motivated to work and learn according the way they expect to be assessed, grading of specific teamwork skills of teams and of individual students inspires teams’ and individuals’ investment in targeted learning outcomes associated with teamwork. Teamwork assessment instruments have been developed in numerous academic disciplines and can be readily adapted for use in engineering design projects.

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

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

**History of Teams in Senior Design at UConn**

**Projects Before the NSF Program**

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

Procrastination, a lack of enthusiasm and poor planning were common themes among the students. Most teams encountered significant difficulties in completing projects on time. Conflict among team members was more frequent than desired, and in some extreme encounters, physical violence was threatened during lab sessions. Many students complained that the projects were too difficult, scheduling of team meetings was too challenging, their backgrounds were insufficient, they had difficulty communicating ideas and plans among team members, and they did not have enough time with outside activities and courses. A peer evaluation was used without success.

**NSF Projects Year 1**

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

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

Overall, students were enthusiastic about the working environment and the approach. Although students seemed content with being concerned only with their individual accomplishments, and completing a project according to specifications and on time, this approach lacked the important and enriching multidisciplinary team experience that is desired in industry.
NSF Projects Year 2
During the second year of the NSF senior design program, seven students worked on two- and three-person team projects, and the remaining students in the class worked in teams oriented around a client; that is, a single client had three students working on individual projects. These projects required integration in the same way a music system requires integration of speakers, a receiver, an amplifier, a CD player, etc. In general, when teams were formed, the instructor would facilitate the teams’ multidisciplinary nature. Two teams involved mechanical engineering students and electrical engineering students. The others were confined by the homogeneity of the remaining students. All of the students met each week at a team meeting with the same expectations as previously described, including oral and written reports. Dynamic teaming occurred often throughout the semester.

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

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

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

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

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

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

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

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

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

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

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

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

Tasks are first listed in major groups. Major groupings are anything that is convenient to the project. Major groups consist of the design and/or manufacture of major components, design type (EE, ME or programming), departmental tasks, or any number of related tasks. After the major groups are listed, they are broken down into sub-tasks. If the major group is a certain type of component, say an electro-mechanical device, then related electrical or mechanical engineering tasks required to design or build the item in the major group are listed as sub-groups. In the sub-groups the singular tasks themselves are delineated. All of the aforementioned groups, sub-groups, and tasks are listed on the left side of the timeline without regard to start, completion, or duration times. It is in this exercise where the project planner lists all of the steps required to complete a project. This task list should be detailed as highly as possible to enable the project manager to follow the plan with ease.
The desired detail is determined by the requirements of the project. Some projects require week-by-week detail; other projects require that all resource movements be planned. It is also useful to schedule design reviews and re-engineering time if a design or component does not meet initial specifications as set out at project inception. Testing of designs or component parts should also be scheduled.

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

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

**Weekly Schedule**

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

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

**Other Engineering Design Experiences**

Experiences at other universities participating in this NSF program combine many of the design program elements presented here. Still, each university's program is unique. In addition to the design process elements already described, the program at the State University of New York at Buffalo, under the direction of Dr. Joseph Mollendorf, requires that each student go through the preliminary stages of a patent application. Naturally, projects worthy of a patent application are actually submitted. Thus far, a patent has been issued for a “Four-Limb Exercising Attachment for Wheelchairs” and another patent has been allowed for a “Cervical Orthosis.”
CHAPTER 3
MEANINGFUL ASSESSMENT OF DESIGN EXPERIENCES

Brooke Hallowell

The Accrediting Board for Engineering and Technology (ABET)\textsuperscript{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: (1) improvements in the learning of engineering students, especially those engaged in design projects to aid persons with disabilities, and consequently, (2) improved knowledge, design and technology to benefit individuals in need.

Brief History
As part of a movement for greater accountability in higher education, U.S. colleges and universities are experiencing an intensified focus on the assessment of students' educational outcomes. The impetus for outcomes assessment has come most recently from accrediting agencies. All regional accrediting agencies receive their authority by approval from the Council for Higher Education Accreditation (CHEA), which assumed this function from the Council on Recognition of Postsecondary Accreditation (CORPA) in 1996. The inclusion of outcomes assessment standards as part of accreditation by any of these bodies, such as North Central, Middle States, or Southern Associations of Colleges and Schools, and professional accrediting bodies, including ABET, is mandated by CHEA, and thus is a requirement for all regional as well as professional accreditation. Consequently, candidates for accreditation are required to demonstrate plans for assessing educational outcomes, and evidence that assessment results have led to improved teaching and learning and, ultimately, better preparation for beginning professional careers. Accrediting bodies have thus revised criteria standards for accreditation with greater focus on the "output" that students can demonstrate and less on the "input" they are said to receive.\textsuperscript{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

\textsuperscript{13} Accrediting Board for Engineering and Technology (2006). Criteria for Accrediting Engineering Programs. ABET: Baltimore, MD.

\textsuperscript{14} Hallowell, B. & Lund, N. (1998). Fostering program improvements through a focus on educational outcomes. In Council of Graduate Programs in Communication Sciences and Disorders, Proceedings of the nineteenth annual conference on graduate education, 32-56.
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, college divisions, or even whole institutions by using assessments intended to capture information about the final products of our programs. Examples are student exit surveys, surveys of graduates inquiring about salaries, employment, and job satisfaction, and surveys of employers of our graduates.

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

Cognitive/Affective/Performative Outcome Distinctions

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


personal qualities and values that students ideally gain from their experiences during a particular educational/training program. Examples are appreciation of various racial, ethnic, or linguistic backgrounds of individuals, awareness of biasing factors in the design process, and sensitivity to ethical issues and potential conflicts of interest in professional engineering contexts.

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

**Faculty Motivation**

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

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

- Consideration of outcomes assessment work as part of annual merit reviews,
- Provision of materials, such as sample instruments, or resources, such as internet sites to simplify the assessment instrument design process
- Demonstration of the means by which certain assessments, such as student exit or employer surveys, may be used to make strategic program changes.

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

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

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

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

ABET's requirements for the engineering design experiences 17 provide direction in areas that are essential to assess in order to monitor the value of engineering design project experiences. For example, the following are considered "fundamental elements" of the design process: "the establishment of objectives and criteria, synthesis, analysis,

Furthermore, according to ABET, specific targeted outcomes associated with engineering design projects should include:

- Development of student creativity,
- Use of open-ended problems,
- Development and use of modern design theory and methodology,
- Formulation of design problem statements and specifications,
- Consideration of alternative solutions, feasibility considerations,
- Production processes, concurrent engineering design, and
- Detailed system descriptions.

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

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

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

Basic terminology related to pertinent assessment issues was presented earlier in this chapter. Brief descriptions of cognitive, performative, and affective types of outcomes are provided here, along with lists of example types of assessments that might be shared among those involved in engineering design projects.

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

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

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

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

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

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

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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College of Health and Human Services
W218 Grover Center

Ohio University
Athens, OH 45701

E-mail: hallowel@ohio.edu
APPENDIX: Desired Educational Outcomes as Articulated in ABET's "Engineering Criteria for the 2006-2007 Academic Year" (Criterion 3, Program Outcomes and Assessment)\(^{18}\)

Engineering programs must demonstrate that their graduates have:

(a) An ability to apply knowledge of mathematics, science, and engineering

(b) An ability to design and conduct experiments, as well as to analyze and interpret data

(c) An ability to design a system, component, or process to meet desired needs

(d) An ability to function on multi-disciplinary teams

(e) An ability to identify, formulate, and solve applied science problems

(f) An understanding of professional and ethical responsibility

(g) An ability to communicate effectively

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

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

(j) A knowledge of contemporary issues

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

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\(^\text{19}\). Given that most students in the NSF-sponsored Senior Design Projects to Aid Persons with Disabilities programs are already in their fourth year of college-level study, it is critical to recognize that previous formative writing instruction is essential to their continued development of writing skills during the senior year. Model strategies for improving writing presented here in light of senior design projects may also be implemented at earlier stages of undergraduate learning.

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

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

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

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

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

Areas of overall content evaluation for senior design reports include aspects of writing that are often among the most problematic for undergraduate engineers. One such area is that of using appropriate language when referring to individuals with disabilities. Reports submitted for NSF publications often include terms and descriptions that may be considered offensive by many, such that the editors of this annual publication often engage in extensive rewriting of sections including client descriptions. It is most likely that students engaged in projects for persons with disabilities are wholeheartedly supportive of their clients, and use such terms out of naiveté rather than any ill intent. Still, the words we use to communicate about other people powerfully influences readers’ perceptions of them, especially in cases in which readers may be unfamiliar with the types of conditions those people are experiencing. Using appropriate language is of paramount importance to our joint mission of enabling individuals to live fully and with maximum independence. It is thus critical that instructors provide clear instruction and modeling for appropriate language use in writing about disabilities. In cases where instructors may have outdated training concerning language use in this arena, it is critical that they seek training regarding sensitivity in language use.

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

Evaluation of content within specific sections of senior design project reports will help students focus on drafting 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\(^{20}\). 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 to such flaws as grammatical errors, misspellings, misuse of punctuation, and specific formatting rules for the assignment. Finding patterns of errors and providing constructive feedback about those patterns may help individuals or teams of students learn efficient strategies for improving their written work.

**Structured Critical Peer Evaluation**

Many instructors require several forms of written assignments within project design courses, including the final reports required for submission to the NSF-sponsored annual publication. Consequently, it is impractical or impossible for many instructors to provide evaluation and feedback at three levels of revision for each written assignment. One means of promoting students’ experience with critical reflection on writing is to implement assignments of structured critical evaluation of writing using reader-response strategies, with students as editors for other students’ work. Students (as individuals or on teams) may be given a basic or detailed rubric for evaluating other students’ written work, and explicit guidelines for providing structured constructive comments following critical evaluation.

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\(^{20}\) Ohio University Center for Writing Excellence Teaching Handouts [on-line] (2007). Available at: http://www.ohio.edu/writing/tr1.cfm

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

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

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

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

### D. Overall content

<table>
<thead>
<tr>
<th>Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excludes extensive tutorials on specific disabilities</td>
<td>2</td>
</tr>
<tr>
<td>Demonstrates appropriate language regarding individuals with disabilities</td>
<td>3</td>
</tr>
<tr>
<td>Avoids redundancy of content among sections</td>
<td>3</td>
</tr>
<tr>
<td>Demonstrates clear and logical flow of ideas</td>
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<tr>
<td>Excludes use of proper names of clients</td>
<td>3</td>
</tr>
<tr>
<td>Citation and reference provided for any direct quote from published material</td>
<td>1</td>
</tr>
</tbody>
</table>

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

### Introduction

- Includes a brief description of the project in laypersons’ terms /4
- Includes problem addressed, approach taken, motivation for the approach, a summary of usual or existing solutions, and problems with these solutions /4

### Summary of impact

- Includes a brief description of how this project has improved the quality of life of a person with a disability /5
- Includes a quoted statement from an educational or health care specialist who supervises the client, or from a significant other /2
- Includes a description of the project’s usefulness and overall design evaluation /5

### Technical description

- Clear, concise technical description of the device or device modification such that others would be able to replicate the design /10
- Detailed parts lists included only if parts are of such a special nature that the project could not be fabricated without the exact identity of the part /2
- Text refers to circuit and/or mechanical drawing of the device /3
- Includes analysis of design effectiveness /5
- Concludes with approximate cost of the project, including parts and supplies (not just the NSF’s contribution) and excluding personnel costs /5

### Total points for section content /45

### Evaluation Summary

| A. Total points for form and formatting | /15 |
| B. Total points for images | /10 |
| C. Total points for grammar, spelling, punctuation, style | /15 |
| D. Total points for overall content | /15 |
| E. Total points for section content | /45 |
| TOTAL POINTS | /100 |
APPENDIX B: A Summary of Guidelines for Writing about Persons with Disabilities

The World Health Organization (WHO) has launched world-wide efforts to modify the ways in which we refer to persons with disabilities. The WHO emphasizes that disablement is not considered an attribute of an individual, but rather the complex interactions of conditions involving a person in the context of his or her social environment. An early classification scheme proposed by the WHO, the International Classification of Impairments, Disabilities and Handicaps (ICIDH) employs the general terms “impairment”, “disability”, and “handicap”; a more recent scheme, the ICIDH-2, employs the terms “impairment”, “activity”, and “participation”; the most recent version, the International Classification of Functioning, Disability and Health (ICF), refers to body functions and structures, activities and participation to refer to the various contextual aspects of disabling conditions one might experience.21 Healthcare professionals and researchers throughout the world are following suit by de-emphasizing the reference to individuals according to medically-based diagnostic categories, focusing instead on their holistic functional concerns and what might be done to address them. Readers of this book are encouraged to join in this important movement. General guidelines are presented here.

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

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

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Refer to “disabilities”

Although the very term “disability” may be considered offensive to some (with its inherent focus on a lack of ability), it is currently preferred over the term “handicap” in reference to persons with physical, cognitive, and/or psychological challenges or “disabilities”.

**Use person-first language**

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

**Avoid using condition labels as nouns**

Many words conveying information about specific disabilities exist in both noun and adjectival forms, yet should primarily be used only as adjectives, or even better, modified into nouns corresponding to conditions, as in the person-first language examples given above. For example, it is not appropriate to call an individual with aphasia “an aphasic.” Although the term “an aphasic individual” would be preferred to the use of “an aphasic” as a noun, such labeling may convey a lack of respect for, and sensitivity toward, individuals who have aphasia.22 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

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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 disabilities and related issues. Only when students are able to combine their scientific knowledge with an understanding of other related humanistic factors will they be able to make significant contributions to the field. Therefore, it is imperative for engineering programs participating in the NSF projects to ensure that students have the opportunity to gain the necessary awareness and social competencies needed. Specifically, students need to have a basic understanding of philosophical attitudes toward disability as well as an understanding of assistive technology and how to communicate effectively with persons with disabilities. This awareness and understanding will not only enable students to have a more meaningful experience, but also ensure a more meaningful experience for the individuals with whom they will be working.

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

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

Models of Disability
There are three predominant social constructs of disability. These models define the source or problem of disability and determine the ways to best address the related issues. The oldest model is the moral model, which posits that disability is caused by moral lapse or sin. It explains disability as a supernatural 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 or family carries the blame for causing the disability. In a tenuously more auspicious interpretation of the moral model, disability is perceived as a test of faith (i.e. “God only gives us what we can bear”) or as a mystical experience in which one sense may be impaired but others are heightened and the adversity of the disability provides increased emotional and spiritual strength often recognized by the belief that “with the grace of God” the disability can be overcome.

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

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

While it is beyond the scope of this chapter to view these constructs in detail, an awareness of these models enables one to examine one’s own beliefs and attitudes toward disability. It also helps students understand that they will encounter both professionals and persons with disabilities whose beliefs are rooted in any one (or combination of) these identified constructs. Although it may not be readily evident, these beliefs will impact how students approach their projects, their ability to see beyond the disability and consider other related factors, and their ability to establish meaningful relationships with the individuals they are trying to assist. Therefore, it is highly recommended that all engineering programs establish collaborative partnerships with other disability professionals in order to provide students with an awareness of disability issues. Potential partners include other programs within the university, especially those with disability studies programs, state assistive technology projects, and independent living centers.

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

In regard to disability, the use of person first language (i.e. always putting the person before the disability) recognizes the person first and foremost as a unique individual. In contrast, referring to someone by his or her disability defines them by a single attribute and limits the ability to distinguish who they are as a person from the disability, which in fact they may consider to be a very minute characteristic. For example, the statement “The stroke victim’s name is Joe” conjures up a very different image from “Joe is a great musician who had a stroke last year”, or “she can’t ski; she is paralyzed and confined to a wheelchair” versus “she loves to ski and uses a sit ski device because she has paraplegia and is a wheelchair user.” Putting the person before the disability demonstrates respect and acknowledges the person for who he or she is, not for what he or she does or does not have. Although it may seem awkward when one first begins to use person first language, it will become natural over time, it will demonstrate respect, and it will have a positive societal impact. For guidelines on person-first language, a keyword internet search will reveal many resources. For detailed guidelines on writing, see Chapter 4.

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

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

Universal Design (UD) refers to a concept or philosophy for designing and delivering products and services that are usable by people with the widest possible range of functional capabilities. This includes products and services that are directly usable (without requiring assistive technology) and products and services that are made usable with assistive technology.

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

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

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

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

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

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

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

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

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

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

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

The WYNOT project director and the engineering PI met on a regular basis to evaluate the suitability of the submitted projects. Specifically, each requested project was reviewed to ensure it was sufficiently challenging for a year-long senior design project. Also, the required engineering expertise was scoped for each project. Once a project was determined to be of suitable scope for an undergraduate design project, the PI coordinated with the appropriate engineering department(s) to publicize the project in the senior design course. This process is illustrated in Fig. 5.1. Overall, an individual with a disability was linked with a student engineering team, which was to provide a prototype custom designed assistive device specific to his or her needs.

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

At the individual project level, students must:

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

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

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

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

**Expected Benefits**

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

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

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

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

**Resources**

**Resources on Disability:**
The Family Village is a website maintained by the Waisman Center at the University of Wisconsin-Madison, http://www.familyvillage.wisc.edu/index.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/

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

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

page, one can locate all of the state assistive technology projects and obtain contact information for his or her particular state or territory.

For specific product information, http://www.assistivetech.net/ as well as http://www.abledata.com/Site_2/welcome.htm are excellent resources.

**Resources on Universal Design:**


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

**References**


CHAPTER 6
ARIZONA STATE UNIVERSITY

College of Engineering and Applied Sciences
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INTRODUCTION
An orthopedic driving simulator was designed to aid in evaluating the driving ability of individuals who have undergone orthopedic surgery of the hip or knee.

SUMMARY OF IMPACT
The orthopedic driving simulator replicates driving environments to assess functional recovery for driving after orthopedic surgery, such as total hip or total knee replacements. It provides physicians and researchers a realistic method of evaluating a person’s driving ability. This is important in making an informed decision about the driving safety of a given individual before he or she is permitted to drive.

TECHNICAL DESCRIPTION
The concept design for this device is shown in Figure 6.1. The system, shown in Figure 6.2, consists of a chair, a pedal with force transducer and a computer. Upon an event (red light), the patient is to brake as soon as possible with a force he or she judges to be necessary. The braking time and force are recorded and displayed.
Fig. 6.2 (a) Prototype Design. (b) Details of the Foot Pedal.
MANUALLY CONTROLLED HIP ORTHOSIS

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Supervising Professors: Ed Koeneman and Mark Werner
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INTRODUCTION
Hip Orthosis is used extensively in physical therapy, orthopedics, and in the orthotics industry to provide support of the hip joint on one or both sides of the patient’s body. Hip orthosis is used by patients with normal hip flexors, who have the capability of flexing their hips manually when the gait cycle is initiated. If a patient has weak hip flexors, his or her only option is to have very limited gait or to be confined to a wheelchair. The current technology for hip orthosis involves very limited assistance in gait such as the Reciprocating Gait Orthoses, the general Hip Orthosis, and the Standing-Walking and Sitting Hip Orthosis (S.W.A.S.H) used primarily by infants and children. There is a need to develop a manually controlled hip orthotics for patients with weak hip flexors.

SUMMARY OF IMPACT
The aim of this project was to provide a manually controlled hip orthosis that will manually flex the hip when a lever is pulled to initiate the gait cycle. This information will be directed toward patients who have had a stroke and have paralysis on one side of the body along with mild cases of muscular dystrophy and multiple sclerosis. Future iterations of this device will include the ability to provide manually controlled hip orthoses for patients with weakness in both hips. The design is versatile, flexible and low-cost. Materials chosen are common and the technology is easily attainable. Quality and customer satisfaction were important in the design of this product.

TECHNICAL DESCRIPTION
Specifications were based on customer suggestions and needs. Important design considerations were the location of the lever, the required force needed to pull the lever and flex the hip, and the configuration of the spring around the total hip replacement joint. It was decided that the force required to push the button to release the gear tooth and manually flex the hip should be under 1 pound, the required force to flex the hip being 60 pounds, and the configuration of the spring being a flat spring in the cantilever spring/beam configuration with point load at extreme end. Based on customer and manufacturing needs, it was decided that offering a flat spring in cantilever beam formation would be the most flexible and effective option. The prototype is shown in Figure 6.3.
Fig. 6.3. Prototype.
INTRODUCTION
Repetitive exercises have been shown to help rewire damaged nerves. According to personal interviews with occupational therapists (OTs) and physical therapists (PTs), supination and pronation movements are critical to recovery. However, most exercise equipment designed to focus on such movements does not provide feedback to motivate users. Some computerized devices do provide feedback but are too expensive for many clinics and individual users.

SUMMARY OF IMPACT
The neuro-rehab game, shown in Figures 6.6 and 6.7, was designed to provide motivation for stroke survivors during exercise. The designer may turn this idea into a useable device that will meet FDA standards for a class I medical device 5370.

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Fig. 6.4 [a and b]. Design and Display of System for Practicing Grasping and Wrist Rotation.
TECHNICAL DESCRIPTION
The designer assessed customer needs and created metrics based on those needs that could be measured and evaluated for the product. Next, concepts were generated and taken through a selection process to select the best design for the neuro-rehab game. This process was followed by surveys to derive opinions from potential buyers. The results helped to select one design over the others. The designer continued with the selected concept and began selecting materials with the use of an analytical model. Also, a business plan was completed to summarize the efforts to date and propose future work. The testing of the prototype focused on functionality of the test and proved adequate in satisfying user expectations.

Fig. 6.5. Device in Use to Practice Wrist Rotation. Amount of Rotation Displayed on Screen.
INTRODUCTION
The goal was to design a low-cost, mechanical, Tremor Control Arm Brace that can be used by tremor patients when trying to perform certain activities. The client has a hereditary essential tremor.

DESCRIPTION OF IMPACT
This project represents a temporary means of reducing arm tremor. Other options are costly and invasive procedures such as deep brain stimulation, neurosurgery or medication. Rather than addressing neurological problems, this project focuses on a mechanical solution for use during short periods of time.

TECHNICAL DESCRIPTION
Design requirements were based on one client’s needs but are compatible with the needs of most patients with tremor.

The major design requirements were that the product effectively reduce tremor, allow for wrist rotation, have universal sizes, be lightweight, be simple to position around the arm (by the patient alone), and not be very noticeable. The most viable option, given time and budget constraints, was a hinged joint arm brace. The brace has a clamping mechanism in both the upper arm and lower arm.

Fig. 6.6. Final SolidWorks Model (Upper View).
with variable pressure settings. These clamps are connected to a stiff bar that includes a lockable joint at the level of the elbow. This joint will allow for movement in flexion and extension while offering the possibility to lock at a certain angle for specific activities such as lifting or pushing. The combination of the arm bar and the arm clamps will offer the necessary resistance to control the tremor. The device is illustrated in Figures 6.6 and 6.7.

Testing was performed on a 3D modeling system called ViconPeak in order to model tremor. An analytical prototype of the Tremor Control Arm Brace has been created and tested in SolidWorks. This design has resisted a pressure of 15 N and passed all stress and displacement tests to effectively reduce tremor. A physical prototype is currently under construction. Future work will include testing this prototype with the ViconPeak system to compare past tremor data with conditions under the effect of the Tremor Control Arm Brace.

Fig. 6.7. Final SolidWorks Design [Lower View].
INTRODUCTION
A goal of this project was to design a fun and interactive rehabilitation system that incorporates repetitive exercise to enhance arm mobility.

SUMMARY OF IMPACT
This fun and interactive tabletop game, shown in Figure 6.8, incorporates useful arm movements for rehabilitation of patients with limited mobility due to stroke. It reduces the monotony of repetitive exercise. It is the hope of the designer that the arm

Fig. 6.8. Arm Rehabilitation Tabletop Game.
rehabilitation game will reduce the cost of therapy and reduce the monotony of the repetitive movements in neurological stroke rehabilitation.

**TECHNICAL DESCRIPTION**

A House of Quality was constructed, detailing the vital design information, including customer needs, product metrics and product specifications. Mathematical models were also created to ensure the technical merit of the product design. The Arm Rehabilitation Tabletop (ART) Game, shown in Fig. 6.8, incorporates three main movements for the patient: reaching straight ahead, reaching up and away from the body, and rotating. The device is adjustable according to patient ability, amount of spasticity or tightness of the limbs. Each movement corresponds to a movement for which multiple repetitions have been shown to stimulate brain plasticity. The game provides timing feedback and a scoring system to keep the patient motivated and to provide a sense of competition. The ART Game is classified as an exempt Class 1 device according to the FDA Center for Devices and Radiological Health. No pre-market notification will be required. A cost model was created by determining the necessary components for the game and the cost of manufacturing. The 1-3-9 rule was modified to 1-4-5 and applied to the device. The designer will continue to work on ways to reduce the cost of the device by searching for less expensive components and manufacturing methods.

The estimate of the total retail cost of the device is $507.

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Fig. 6.9. Illustration how the game will be used for rehabilitation
MAGNETIC RESONANCE (MR) COMPATIBLE HAND DIAGNOSTIC DEVICE

Designer: Katie Bray
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INTRODUCTION
The Magnetic Resonance (MR) Compatible Hand Diagnostic Device is a diagnostic research tool for use on patients who have had a stroke affecting mobility in the left or right hand. The device is designed to be used during a functional magnetic resonance image (fMRI) to allow the motion of the affected hand to be mapped to the brain. The device is non-magnetic and uses a pneumatic air-muscle and angle sensor to measure the range of motion and force produced by the hand and wrist during flexion and extension. The device will allow variable resistance to be applied to resist hand flexion and therefore provide more information about the ability of the hand. The motion of the hand is monitored on...
a computer outside the MRI room. The device also provides a method for immobilizing the arm during the MRI to allow for minimal image artifact. Through research using the MR Compatible Hand Diagnostic Device, the changes in the brain over a rehabilitation period can be mapped to the increasing mobility of the hand. Advancement in this area of neurological rehabilitation research has the potential to reach the millions of people living with the effects of stroke.

SUMMARY OF IMPACT
The design goal was to make a diagnostic tool for the hand that is fMRI compatible and universal to all stroke patients. The design process followed the Food and Drug Administration’s (FDA) Quality System Requirements (QSR) by developing design inputs and outputs and validating that the design outputs adequately met the design requirements. The primary market for this device is neurological research institutions and research hospitals.

TECHNICAL DESCRIPTION
Customer surveys were used to gather design input. An extensive concept testing and selection process was used to select the design of this device. The product was designed, prototyped and tested. It is shown in Figures 6.10 and 6.11.

To optimize the device for manufacture, a cost model was generated which includes estimates for standard and custom components, processing, assembly, and overhead – yielding an approximate unit cost of $177. Based on the manufacturing cost of this device, the retail price is expected to be $1,400, which is reasonable for the market consumers at research hospitals and universities and other research institutions.

Fig. 6.11. MR Compatible Hand Diagnostic Device.
TRANSFERRING WHEELCHAIR

Designer: Darron Anglin
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INTRODUCTION
The objective of this biomedical device was to assist with the transfer of people from a wheelchair to a stationary object such as a bed. This device is based on the design of the basic wheelchair and includes variations of that design in order to accomplish the purpose of the device.

SUMMARY OF IMPACT
For many, the wheelchair transfer process is difficult and cumbersome, as well as painful. It affects those using a wheelchair and those assisting with this process. This new wheelchair design includes new features that will aid with the transfer process. These include: 1) reclining seatback of chair; 2) extra supports for stability in the reclined position; and 3) sliding seat and seatback to facilitate moving from chair to object.

TECHNICAL DESCRIPTION
This is a medical device design and thus would be under the jurisdiction of the Food and Drug Administration. Design and manufacture must meet quality standards of viability, safety, and effective design. The design controls consist of such areas as: design input, design output, design transfer, design verification, and validation, and the manufacturing processes. From these procedures the final product specifications have been established, and the final prototype has been created and tested. It is shown in Figure 6.12.
Fig. 6.12. Wheelchair in Transferring Position.
INTRODUCTION
Many stroke survivors have a loss of some degree of motor control. If the lower extremities are affected, gait may be limited and the ability to perform routine tasks may be reduced. There is a need for a device to help rehabilitate hip and knee movement.

SUMMARY OF IMPACT
The device in development for this need is dubbed the Hip-Knee Mentor. The purpose is to retrain the brain, through repetitive motion, to potentially establish new neural pathways in order to recover lost motor control in both the hip and knee.

TECHNICAL DESCRIPTION
The Hip-Knee Mentor, shown in Figures 6.12 and 6.13, was designed to help patients regain hip and knee motion. Once the mentor is put around the waist, it uses force to move the patient's hip and knee. The patient is expected to focus on the hip and knee movement, thus forcing the brain to associate the function with the movement of the hip and knee. Such a device will be used for years on a daily basis for several hours a day. In certain cases, the brain will not be able to relearn the motion, depending on the age of the patient, and the extent of brain damage.

In the long term, the brain is expected to rewire neural pathways, thus creating new hip and knee flexion and extension functions. It is not reasonable to assume that the patient will have the same hip and knee control that he or she had before the accident, but it is reasonable to expect that the patient will be able to move his or her hip and knee, which is more beneficial than not being able to move them at all.

Fig. 6.13. The Hip-Knee Mentor Fully Extended.
Fig. 6.14. Hip-Knee Mentor Helps a Person Flex the Knee and Hip Joints.
CHAPTER 7
DUKE UNIVERSITY

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OUTDOOR PLAY ACTIVITY CENTER

Designers: Jacqueline L. Anderson, Jialing Kim Png, Ying Min Wang
Client Coordinator: Diane Scoggins, Hilltop Home
Supervising Professor: Larry Bohs
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INTRODUCTION
A play activity center was designed to stimulate the senses of children with limited physical and cognitive abilities in an outdoor setting. The device consists of a frame structure with five activity stations and nine different activities. The frame structure is weatherproof and height-adjustable. It can be easily dismantled for storage. The activities stimulate the visual, auditory and tactile senses and reinforce the sense of cause and effect. The components are interchangeable and removable for cleaning or storage. The device is inexpensive and easy to modify and clean.

SUMMARY OF IMPACT
This device will enable the residents a private, nonprofit residential center that serves children with profound developmental disabilities to engage in outdoor play activities. The device can be modified easily to include other activities in the future. The client coordinator commented, “We have looked for many years for playground equipment that would address the needs of our children. Our new play station has opened up a whole world of fun for our children. It is appealing and accessible. The variety of activities stimulates all the senses, which helps our children to learn to explore and to interact with their environment. The play station opens up a whole world of outdoor recreational activities for our children... and will definitely allow (the) children to play more independently.”

TECHNICAL DESCRIPTION
The Outdoor Play Activity Center (Fig. 7.1) consists of five activity stations, allowing five children in wheelchairs to play simultaneously. Nine interchangeable activities are provided.

The frame is constructed from 1 ¼" red furniture-grade PVC. To provide stability but also allow the device to be removed if necessary, the 5’ long vertical posts of the frame are inserted into 12” long stainless steel sleeves, 2” in diameter, which are submerged into holes in the ground, made with a garden auger and drill. The six vertical pipes are connected via L- or T-joints to similar PVC beams, 32.5” long, parallel to the ground. The resulting height of the PVC beams is 4’. Five green powder-coated clothesline hooks are evenly spaced on the vertical posts, 26” to 44” above ground. Each hook extends 6” in front of the vertical post, so that the wheelchairs can remain on the flat concrete patio, away from the adjacent grass slope.

For each activity station, a 36” long, ½” PVC pipe is supported at each end by the clothesline hooks. Two of the nine stations are directly connected to these horizontal activity bars. The remaining stations are connected to the activity bars via custom attachments with three components. A nylon strap loops around the PVC bar and extends 5” to a plastic buckle. This buckle allows length adjustment of the nylon strap. The other end of the nylon strap loops through the terminal link of an 8” segment of garden-grade plastic chain. The other terminal link of this chain attaches to a connecting device, either a
metal key ring or a plastic latch, which attaches to the activity.

A variety of activities were designed to meet the needs of the client. The designs were inspired by toys currently on the market. All the activities are visually stimulating as they are brightly colored. Three of the activities stimulate the tactile sense. Activity A consists of strings of plastic beads hung vertically from a dowel rod. Activity B is a series of three rubber balls of varying textures. Activity C uses a commercially available children’s toy that vibrates and talks when activated. This toy was switch adapted with a standard 1/8” phone jack so that vibration and sound occur only upon pressing the switch.

Five other activities also reinforce the learning of cause and effect. Activity D is a commercially available bubble maker that was switch adapted to produce bubbles when the switch is pressed. Activity E consists of painted wooden balls within a clear plastic container. The container is attached directly to the horizontal activity bar and has three large knobs around the perimeter. When the user pushes the knobs, the container rotates and balls roll around within. Activities F through I also reinforce the concept of cause and effect and stimulate the auditory sense. Activity F is a “rain-stick.” A clear plastic tube containing beads and obstructions to the beads is attached directly to the horizontal activity bar. When the user rotates the tube about the horizontal bar, beads fall from one end to the other, creating a sound similar to rain. Activity G consists of seven hand bells, each producing a different note when hit. Activity H is constructed from four plastic Christmas ornaments, each containing small beads that rattle when the ornaments are swung. Activity I consists of a large colorful wooden butterfly attached to a commercially available wind chime. Figure 7.2 shows two clients using the center.

Cost of parts was approximately $600.
FOOT-ACTION GUITAR STRUMMER

Designers: Jonathan Lee, Jason Leung, and Matthew Topel
Client Coordinator: Shiela Tayrose, Occupational Therapist
Supervising Professor: Larry Bohs
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INTRODUCTION
The client is a 17-year-old boy who had a left hemispheric stroke at the age of three that affected the right side of his body. Because of the stroke, he does not have the dexterity and fine motor control necessary in his right arm to strum a guitar. A device was built to allow him to strum the guitar using his left foot. The strumming mechanism is composed of a pick rod, which holds six individual guitar picks, and two complementary-action solenoids that move the rod across the strings. This mechanism is mounted to the guitar face and controlled by a momentary switch within a foot pedal. The system is powered by an AC/DC converter that plugs into a wall socket. The device is portable, produces good sound quality, and requires minimal user effort.

SUMMARY OF IMPACT
This device has enabled the client to start taking guitar lessons. The client’s mother commented, “I had to make him put down the guitar and leave for school this morning, so I would say the project has been a success. (He) is progressing in his lessons and last night he was practicing the chords for new songs. He says it's pretty hard but he is confident he'll learn. This whole experience has been good for his self-esteem, and has given him a hobby.”

TECHNICAL DESCRIPTION
The Foot-Actuated Guitar Strummer (Fig. 7.3) consists of a pick rod, two solenoids, a guitar mount, and a foot pedal. When the user pushes on the pedal with his foot, the device strums downward, and when he releases the pedal, the device strums upward.

The pick rod is constructed from a ½” square Delrin rod. Six slits, cut 1/8” into the bottom of the rod, hold six standard guitar flat picks so that the separation between picks equals that between the guitar strings.
track mounted on the guitar. Ball detents on the track allow for easy and consistent positioning, and a wing screw secures the strumming components to the sliding track.

The foot pedal uses commercial footswitch housing. The commercially supplied switch was replaced with a SPDT momentary switch connected to the power supply such that one solenoid is activated at all times. Pressing the pedal activates one solenoid while releasing the pedal activates the other. This method of control allows for a playing speed comparable to hand strumming. A standard ¼" stereo guitar cable connects between the SPDT switch in the pedal and the solenoids on the guitar. Each connection in the system uses a different sized plug and jack to ensure correct connection of components.

The device was tested to determine the maximum strumming rate and the temperature escalation over time. The maximum strumming rate was 17 strums per second corresponding to 9 pedal presses and 8 releases per second. This high frequency should prevent strumming rate from being a limiting factor in any musical composition. The surface temperature of the solenoids rose sharply to a temperature of 140°F. However, the enclosure attained a maximum temperature of 89.6°F, low enough to protect the user from potential injury. Figure 7.4 shows the client using the Foot-Action Guitar Strummer.

Cost of parts for the device was approximately $525.

Fig. 7.4. Client Using Guitar Strummer.
PERSONAL PLAY CANOPY

Designers: Kelvin Ho, Jenna Olson, Rivai Tan
Client Coordinator: Nancy Hoopingarner, Physical Therapist, Durham Schools
Supervising Professor: Larry Bohs
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INTRODUCTION
A play system was developed for a nine-year-old child with severe cognitive and physical disabilities. It consists of a wheelchair canopy with activities that produce sounds when struck, two head-operated levers that strike the activities, and a textured panel on a wheelchair tray. The system promotes mental, physical, and social development of the child through play.

SUMMARY OF IMPACT
This Personal Play Canopy will allow the client to be engaged both independently and with other children on the playground and in the classroom. The canopy will allow her to spend more time on the playground despite her sensitivity to light. Her physical therapist hopes that the device will help her develop her understanding of cause and effect, as well as her ability to actuate switches using head control.

TECHNICAL DESCRIPTION
The Personal Play Canopy (Fig. 7.5) consists of three main components: a headset, a canopy with musical attachments, and wheelchair tray with a touch panel. The headset contains two independent levers, one for each side of the client’s head. An ABS plastic box houses each lever mechanism. Each lever is actuated by pushing on a 4.5” diameter padded button, which is connected to the lever with a ½” diameter nylon guide rod. Exterior to the housing box, the guide rod extends through a 2” long 1.77 lbs/in compression spring. The spring pushes against the side of the housing box and button recovering the position of the lever. A 2.5” x 1.5” x 0.5” Delrin sleeve, attached to the side of the housing box, ensures that the guide rod moves perpendicular to the box wall and in the plane of the lever swing. The lever is 15.7” long, with 10.7” protruding from the front end of the housing box through a 3” x ¾” slot that allows the lever to swing.

The lever is made from a commercial drumstick. It is attached to the housing box with a pivot screw near the large end of the lever. The guide rod attaches to the stick with a freely rotating screw, 2.5” forward of the pivot screw. When the button is pushed, the lever pivots on the pin and moves laterally outward to strike an object. The levers are mounted onto the wheelchair handlebars using a system made from PVC tubing.

The canopy is modified from a commercial wheelchair canopy (WeatherBreaker, Deistco, Chico, CA), which attaches to two aluminum tubes fastened vertically onto the wheelchair frame. Eyebolts are attached at intervals along the upper canopy frame, through grommets in the canopy.

Fig. 7.5. Personal Play Canopy.
Musical activities are attached to the eyebolts using lengths of nylon rope with plastic hooks on either end.

The 16” x 12” wheelchair tray is constructed from clear Plexiglas, with rounded edges and a semicircular cutout to accommodate the user’s body. The tray is attached to two hollow red PVC pipes, which slide over the wheelchair armrests for easy mounting.

The textured panel consists of a variety of soft textures glued onto a 12” x 12” plywood square covered with white felt. A Lazy Susan bearing is attached to the bottom of the plywood square, allowing the textured panel to rotate while on the tray. Non-slip Dycem pads are attached to the base of the textured panel to prevent it from sliding on the tray surface. Figure 7.6 shows the client using the device.

Cost of parts was $520.
**STEADY STEPPER**

*Designers: Christian Agudelo, Dorothy Lowell and Troy Swimmer*

*Client Coordinator: Annette Lauber, North Carolina Assistive Technology Project*

*Supervising Professor: Larry Bohs*

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**INTRODUCTION**

Our client is an energetic and active adult who has cerebral palsy (CP) and uses a wheelchair. We designed the Steady Stepper to address her request for a safe and effective weight-bearing home workout. This device utilizes a stair-stepper coupled with a custom railing system to aid in transitioning from the wheelchair to the stair-stepper, and to provide stability while stepping. Interchangeable wooden pegs mounted to the bottom of each step allow for a varying range of motion. Weight distribution over each step, and variable foot position, provide variable workout intensity.

**SUMMARY OF IMPACT**

The Steady Stepper gives the client the opportunity to exercise independently in the comfort of her home. She commented, “I am so pleased about the stepper and especially the versatility that was built into it which went beyond my expectation. My maximum time of using it in a single session is seven minutes, which is great. It really helps to relax my leg muscles. The stepper fits so easily into my regular routine and I anticipate years of use to help me maintain good health.”

**TECHNICAL DESCRIPTION**

The Steady Stepper (Fig. 7.7) uses a commercial portable stepper attached to a custom railing system. The railing system consists of four side handrails: two top handrails and two bottom handrails, which attach to a wooden base. Each handrail is made of U-shaped pieces of 1” diameter aluminum piping. The front rail attaches diagonally across the four side rails and serves as a truss to prevent parallelogram failure. Caps on the extruding aluminum pipe prevent injury. Each handrail is covered in a foam grip. The aluminum railing is attached to a wooden base with shotgun clamps, which are welded to four 4”x2” aluminum plates, bolted to the base.

The wooden base extends 10” past the railing so that the client’s wheelchair can be rolled onto the base and secured by locking the wheels. The leading edge of the base is angled 45º to ease the transition. Two wooden placement strips are bolted to the base-plate to prevent the stair-stepper from moving horizontally. Since the stepper is not permanently attached to the base-plate, it can be easily removed if desired. The exercise monitor of the stepper is attached to the middle of the front handrail with a Velcro strap, allowing the user to adjust the angle of the display.

Five pairs of color-coded stoppers allow the client to vary her workout intensity by screwing a different pair into the bottom of each step, thereby altering the maximum step travel. The stopper lengths are 1” (black), 2” (red), 2.5” (green), 3” (yellow), and 3.5” (blue).

Cost of parts for the Steady Stepper was approximately $510.
Fig. 7.7. Client Using the Steady Stepper.
INTRODUCTION
Bumpers are required in power soccer to protect the player and provide a flat striking surface. The commercial bumpers used by the team were difficult to attach and detach, and unstable during game play. Two new attachment mechanisms were developed to be compatible with commercial bumpers. One attaches to the footrest supports, and the other attaches to the stable sidebars of the wheelchair. Bumpers can now attach more quickly than before, using hardware that makes them more durable during game play.

SUMMARY OF IMPACT
The power soccer team coach commented, “Thanks to the (device), our team can play a whole tournament without repairs... In the past, individual guards would have to be fixed and readjusted any time a player made contact with another chair. This would leave very little time for playing or coaching. Now we can focus on playing.”

TECHNICAL DESCRIPTION
After examining the wheelchairs and commercial bumpers of the team, two attachment approaches were determined to be necessary: one to the lower horizontal bars of the wheelchair frame (Fig. 7.8), and the other to the footrest support bars (Fig. 7.9).

For both types of wheelchairs, the bumpers themselves were first made to be more durable. As wheelchairs collided during game play, the two bolts on the front of the bumper would slide together, causing adjacent sides of the bumper to collapse. To address this problem, a 2x8” retainer bar of 1/16” steel was added behind these bolts, thereby preventing them from moving together.

The original hardware of the bumpers was also replaced. Instead of the six hex-head bolts, combo-head machine screws were added so they could be tightened with either a Philips- or flat-head screwdriver. Split lock washers and nylon-insert locknuts were used to prevent loosening of the hardware after repeated impact.

To attach the stabilized bumpers to wheelchairs with usable footrests, circular hose clamps were mounted to permanent locations on the bumpers. Two clamps were used on each side, such that the open ends of the clamps faced inward from the bumper sides. A nut was welded to one side of each clamp, so that when the bumpers were inserted over the footrest supports, a machine screw with a large phenolic knob could be used to tighten the clamps over the footrest supports.

For the wheelchairs with unusable footrests, the bumper was attached to the lowest horizontal side members on the wheelchair base, using custom clamps made from stainless steel plates and commercial pipe joints. On each wheelchair side member, two plates were bolted together so as to sandwich the member. A 1.5” rotating pipe-to-plate joint was bolted to the outer of these plates, and fixed in rotational position with a screw. Attached to the bumper was a matching joint with a free angle to absorb the impact of a collision. A 1.5” aluminum pipe connected these two joints. The aluminum bars were permanently connected to the joints on the bumper, so they could be inserted into the joints on the wheelchair and secured with an Allen screw before games.

Cost of parts for the Power Soccer Bumper Attachments was about $690.
Fig. 7.8. Bumper Attachment for Wheelchair Frame.

Fig. 7.9. Bumper Attachment for Footrest Supports.
INTRODUCTION
The client is an active seven-year-old boy with TAR syndrome, which causes him to have very short arms. A biomimetic reaching assist device (BRAD) was developed to enable him to acquire, manipulate, and transport objects out of reach. Special features of BRAD include: a TIG-welded aircraft aluminum harness, a horizontally folding tubular arm with a 40” reach, plastic rubber-tipped pincers controlled by a bike brake, an acrylic tray to allow access to retrieved objects, foam padding on the shoulder straps and chest plate, a nylon cord to enable the client to control arm extension and folding, and a furniture-grade PVC docking station for device storage. With this device, the client can extend and retract the arm, perform fine-motor skills such as opening a cabinet, and retrieve a variety of objects including cups and snacks.

SUMMARY OF IMPACT
The client’s mother commented, “The reacher greatly increases (his) ability to get things off of higher shelves. More importantly, it helps him use a creative way of thinking about solutions to problems he faces. It is much more than just a piece of equipment for him. It helps him think of ways he can have more independence.”

TECHNICAL DESCRIPTION
The BRAD (Fig. 7.10) consists of a modified drum harness (CSCI Competitor Snare Drum Carrier, Pearl Corporation) with a hinged two-segment arm and fixed support member. Both are made of 1” square aluminum tubing, attached to the chest plate. The base arm segment and support member are TIG-welded to the aluminum chest plate and to each other. A butterfly hinge, attached with rivets, connects the two arm segments.

A pair of rubber-tipped pincers, from a commercial reacher (PikStik, Reid Industries), was modified for control by a bike brake/cable system. It was then attached to the end of the arm.

The bike brake lever is attached to the chest plate so the client can operate the pincer with his right hand. A nylon cord with three wooden balls is attached through guiding rings to the outer arm. The client pulls on the cord with his left hand to extend the outer arm, and releases the cord while tilting his torso to fold the arm inward using gravity. An acrylic tray, lined with black felt, is mounted to the support member. When the outer arm is folded inward, the pincers can drop an object on the tray, allowing the client to retrieve it.
A docking station, made from black and blue furniture-grade PVC, allows the client to suspend the BRAD by two wings attached to the shoulder straps of the harness. This enables him to mount and remove the device without assistance. The commercial shoulder harness padding did not provide a stable operating platform or comfortable fit. Open cell foam was contoured to our client’s upper body and attached to the shoulder straps with Velcro, which will enable replacement as he grows. Figure 7.11 shows the client using the Biomimetic Reaching Assist.

Cost of parts was approximately $680.

Fig. 7.11. Client Using BRAD.
IMPROVED BEEPBALL

Designers: Emily M. Mugler, Steven E. Reich, and Margaret M. White
Client Coordinator: Kim Lyons
Supervising Professors: Richard Goldberg, Kevin Caves
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INTRODUCTION
Beepball is a sport similar to softball, designed for individuals who are visually impaired. A beeping transmitter inside a 16-inch softball informs players of the ball's location. The beeping transmitter in current commercial beepballs sometimes fails after a hard hit, and is often difficult for players to hear. The goal was to create a new, more durable Beepball. This ball has two speakers to provide louder sound if the ball lands on one speaker. In addition, the ball charges faster and lasts longer on a charge than commercial models.

SUMMARY OF IMPACT
In initial testing, the new beepball was well liked. The coach of one Beepball team said, “It’s a great ball. I could really tell the difference in the way the players tracked the ball in the field.” Several of the players had positive reactions to the ball, especially the two-speaker design and the slightly higher pitch of the beeping. After one player made a play on the ball, a teammate shouted, “Great play!” to which he responded “Great ball! I really like the way it sounds!”

TECHNICAL DESCRIPTION
The Improved Beepball (Fig. 7.12) comprises a large softball (16” circumference), which houses a battery, on/off switch, beeping circuit, and speakers.

The beepball uses a 7.4 V rechargeable lithium ion battery, which is compact (2x1x0.6”) and has no “memory,” providing longer battery life. The battery is connected to a 1/8” audio jack, mounted flush to the surface of the ball, allowing the external battery charger to connect to the battery. The battery charges using a commercial wall-outlet-mounted unit (Universal Smart Charger, Batteryspace.com), which produces 8.4V DC. A switch on the charger allows the user to change the charging voltage, but we fixed this switch in place using epoxy. A red LED on the charger indicates that the battery is charging, and a green LED indicates when charging is complete.

The beeping circuit uses a 556 timer, which functions as two 555 timers in series. The first creates a tone at 1480 Hz. The second turns the tone on and off at 4Hz. The circuit resides on a 2”x1.3” custom circuit board, designed using ExpressPCB.

To protect the circuitry from large forces, the battery pack and circuit board are encased in a cylinder of polydimethylsiloxane (PDMS), a silicone-based elastomer, which solidifies into a polymer gel after the base and curing agent are mixed together. A metal support for the charger jack, coated in PlastiDip® to eliminate electrical shorting, was inserted halfway into the PDMS before it set to help stabilize the jack. Sound permeable fabric is sewn beneath 1” holes in the leather covering of the ball, so that no potentially damaging materials can enter the speaker chambers.

The circuit board is connected to two separate speaker chambers, 1” in diameter. The chambers consist of a piezoelectric tweeter (Taiyo Yuden, MODEL #MLS20070), sandwiched between a 1/2” PVC tube and a 1/4” PVC tube, sealed with a 1/4” solid cap at the bottom. The chambers are sealed with epoxy. Cylindrical foam pieces fit around the speaker chamber, and extend the diameter of the chamber to 1 3/8 inches, allowing it to fit snugly inside one core of the ball.

Before the cylinder could be placed in the ball, a cylindrical portion of cotton had to be removed from the inside the ball. It is easier to cut this cotton by compression force rather than by pulling, so tools were created out of 6” sections of steel pipe, sharpened on one end for cutting. A hole drilled through the diameter on the other end allowed a screwdriver to be used as a handle. Creating cores in the ball was quick, precise and easy using these tools.
To prevent the transmitting device from flying out of the ball after it is hit with a bat, the model has a cross-member design, with two perpendicular cores of differing diameters through the center of the ball. The battery pack, circuit board and audio jack fit into the larger cylinder. The two speaker chambers are attached together, in tension, by an elastic cord in the other core. This tension keeps the two speaker chambers together, centered inside the ball.

The charger jack is connected to the oscillator circuit such that when a pin is in the audio jack, the ball does not beep. In this way, the battery charge can be reserved by silencing the ball while it is charging. The Improved Beepball achieves a sound pressure level of 95 decibels at 3 inches, equivalent to commercial models. The battery lasts over 14 hours or at least seven times that of other beepballs, and charges in only five minutes.

Cost of parts was about $100.

Fig. 7.12. Improved Beepball.
INTRODUCTION
The client is an adult with Friedrich’s Ataxia, who has great difficulty getting back into his wheelchair whenever he falls out. The Falls Recovery Lifting Device uses a hydraulic jack that lifts a chair 22” vertically from near floor level. When the chair is pumped to the desired height, the client can easily perform a sliding or standing transfer from the device back into his wheelchair.

SUMMARY OF IMPACT
The device provides the client with a safe and reliable means to return to his wheelchair after a fall. Although such events are infrequent, the recovery process previously had been time-consuming and hazardous, since he had relied on his wife to help him. A typical recovery would take them one hour or more. Now, after a fall, the client’s wife may retrieve the device, using the attached wheels to roll it over to the location of the fall. Once the device is in position, recovery takes approximately two to three minutes. The client’s wife remarked, “This will work well; two or three minutes is nothing compared to the hour or more that this used to take.”

TECHNICAL DESCRIPTION
The Falls Recovery Lifting Device (Fig. 7.13) consists of a hydraulic jack, an aluminum base, and a stand with attached seat. The jack is a three-ton long-ram bottle jack, normally used in cranes and engine hoists, which travels vertically by manually pumping a one-piece handle. One hundred and twenty pumps cause the ram to travel its full length. Releasing a valve on the side of the base and pushing down on the ram manually returns the jack.

The base is constructed from 2”x2” square aluminum tubing and ½” thick solid aluminum plate. The jack is secured to the top portion of the base with a 5/8” machine bolt. The bottom portion of the base consists of a 30”x12” plate, bolted to two 30” long square tubes. Two 2” radius non-rotating wheels are attached to the ends of the tubes making the device easy to move. The device can be picked up by the legs and moved around like a wheelbarrow.

The seat from a commercial heavy plastic chair is attached to two sections of 1” diameter steel conduit. The conduit is bent to support the seat of the chair and also bent over the back of the chair to form overhead hand grips. The grips are for the client to use for support when sliding from the ground onto the seat, and during the lift. The seat is connected to the bottle jack via a piece of 2” square tubing. The square tubing has a 1” clearance hole that fits the top
of the lift piston, which allows the seat apparatus to be detached at any time.

A track, constructed from two ¾”x¾” aluminum square tubes and mounted behind the chair, prevents the seat from rotating during use. A 2” radius non-rotating wheel is attached to the back of the chair to slide on the column of the jack while being guided by the track. The track is secured to L-brackets on the bottom and top of the jack.

Cost of parts for the device was about $615.

Fig. 7.14. Client and Wife Using Device.
PANDAROO: PERSONALIZED STUFFED ANIMAL COMPANION

Designers: Ling Bei, Courtney Olmsted, Yao Quan Xie
Client Coordinator: Diane Felton, Duke Hospital
Supervising Professors: Richard Goldberg Kevin Caves
Department of Biomedical Engineering
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Durham, NC 27708

INTRODUCTION
Children can face considerable psychosocial anxieties during hospital stays, especially when parents or guardians are absent. The PandaRoo comfort toy was designed to help alleviate these anxieties, through audio and visual components that can be customized to suit individual needs. The audio component consists of an MP3 player housed in a miniature backpack, which can be easily attached to and removed from stuffed animals of various sizes. This allows the child to use his or her favorite stuffed animal, while the hospital can own the costly electronics and use them on multiple patients. This eliminates the need to sterilize stuffed animals before reuse. The MP3 player features four user-selected playback modes. Additionally, playback buttons are situated along the edges of a picture pocket that spans across the backpack straps, thus creating a unified user interface on the front of the stuffed animal. The user presses one of four buttons on the backpack to play one of the MP3 recordings. These could be a parent reading a story, singing a lullaby, or a recording of a favorite song.

SUMMARY OF IMPACT
By reducing pediatric patients’ anxieties during their hospital stays, PandaRoo will provide comfort and entertainment, particularly when children are not with their primary caretakers. The hospital supervisor and other therapists expressed excitement about the possibility of using PandaRoo in the clinic for their own patients. The supervisor stated, “I think this is definitely something we can use that will be a source of comfort for those kids who are here without their parents.”

TECHNICAL DESCRIPTION
The PandaRoo (Fig. 7.15) consists of a custom miniature backpack with an embedded MP3 player and user controls. Because the electronics are housed in the backpack, a stuffed animal of the child’s choice can “carry” the backpack, and the device can be used by multiple patients. In addition, the backpack provides a way for the unit to be sanitized: the electronics are removed, and the backpack itself is then washed.

The audio component of PandaRoo uses a Rogue Robotics MP3 Playback Module that is controlled by a PIC 16F876 microcontroller. Although the current MP3 module has no direct recording capabilities, Rogue Robotics is currently developing a newer version with recording capabilities that can be used for a future model. In the meantime, any MP3 recording can be easily downloaded to PandaRoo using a personal computer and a flash memory card reader. The electronics are powered by a standard 9V battery, and the voltage is reduced to 5V using a regulator. The regulator has a shutdown pin so that the PIC can shutoff its own power supply to conserve battery power. The audio component is housed in an ABS plastic enclosure.
The visual component of PandaRoo involves a picture pocket, located on the front of the stuffed animal. The picture pocket is attached to the backpack straps on only one edge, allowing the backpack to easily mount to the stuffed animal. Four brightly colored, waterproof buttons are located along the edges of the pocket. Each button selects playback of a different pre-recorded message. Wires from the buttons to the electronics housing run through one of the backpack straps, and contain connectors so the electronics can be easily detached before washing the backpack.

The audio interface provides four different playback modes, controlled by two independent slider switches located on the electronics enclosure. These switches are designed for access by the patient’s caretakers. The first pair of playback modes selects either Custom or Default. Some children’s anxieties are worsened when they only hear their parents’ or guardians’ voices and do not see them physically. For these users, the MP3 player can be set to play default lullabies and stories featuring neutral voices. For children who are comfortable with listening to their parents’ or guardians’ voices, the MP3 player can be switched to playback of custom clips instead. The second set of playback modes selects between Single Play and All Play modes. In Single Play, the MP3 module only plays one clip (custom or default, depending on the first setting) when a playback button is pressed. This helps to engage the child since he or she has to actively and frequently interact with the toy in order to elicit audio responses. However, some patients do better with accessing all clips on the push of a single button, hence, the existence of the All Play mode.

Finally, the device powers down automatically after five minutes of consecutive inactivity, so as to conserve battery power. In this case, it can be turned back on using an on-off switch located on the front of the backpack.

Cost of parts for the PandaRoo was about $300.
THIGH-CONTROLLED PIANO PEDAL

Designers: Devin Odom, Krishana Wooding, and Jesse Longoria
Client Coordinator: Bill Dowe
Supervising Professors: Kevin Caves, Richard Goldberg
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INTRODUCTION
The client is a man with double below-knee amputation who plays the piano, but cannot actuate the sustain pedal reliably with his prosthetic legs. The Thigh-Controlled Piano Pedal allows him to use his thigh to push and release the pedal. The design uses a mechanical lever that is pushed horizontally to actuate the sustain pedal. It also has a mechanism to pre-load the pedal, which reduces the force needed to actuate the pedal, and a wedge system to anchor the device to the piano. The device allows him to reliably use the sustain pedal, thereby improving his playing quality and enjoyment.

SUMMARY OF IMPACT
The device, which anchors solidly to any piano, allows the client to use the lateral motion of his thigh to depress a pre-loaded piano pedal. The device is portable yet solid and durable enough to aid the client’s playing of music for years to come. The client commented, “Life has been a lot different to me in the past 16 months, since my second amputation. I’ve had more obstacles than I’ve ever had but one by one I’ve conquered each negative and turned it into a positive and now I’ve got my music back. I will be forever grateful and thankful.”

TECHNICAL DESCRIPTION
The Thigh-Controlled Piano Pedal (Fig. 7.17) involves a pedal assist device, a wedge anchoring system, and a lever. The pedal assist device consists of an aluminum frame and an adjustable, spring-loaded cylinder. Once the device is placed over the sustain pedal, the cylinder is tightened against the pedal until the played notes are sustained. It deactivates by loosening slightly. The spring inside of the cylinder is compressed against the pedal, substantially reducing the additional force required. The process lowers the pedal enough so that minimal motion is needed to engage the pedal and sustain the notes played on the piano.

The wedge anchoring system uses the piano pedal casing as an anchor, and can be slid underneath most pianos directly in front of the pedals. A Quick-Grip™ clamp, typically used for woodworking, is anchored to the top of the pedal assist device. When the clamp is squeezed, it pulls on a wedge that presses against the base of the piano pedal housing and the floor. This holds the device in place during use. The handle of the Quick-Grip™ clamp and the adjustment knob for the pedal assist device are both set at heights accessible by the client.

A right-angle lever is utilized to depress the sustain pedal. The short end of the lever rests on the pedal when the device is being used. The vertex of the...
lever is anchored with a pin joint at the top of the pedal assist device. The 24” long arm of the lever makes contact with the outer right knee and thigh of the client. To depress the pedal, the client shifts his leg laterally outward, and to release the pedal, he moves his leg back to the resting position. Varying pedal heights (initial heights and depressed heights) are accommodated by foam pads of varying diameter. These pads can be placed around the lever arm at the contact point with the client’s thigh, and can improve device comfort.

Cost of the device was approximately $205.
INTRODUCTION
The client is an eight-year-old boy with cerebral palsy and autism. Due to a recent leg surgery, he spends little time voluntarily walking. The aim of this project is to build a device that would use music to stimulate the client to walk on his own. The Walking Motivator includes a pedometer to detect motion, a microprocessor, an MP3 music player, and headphones. Other than the headphones, the entire device fits inside a small pouch that straps onto the client’s hip. As long as the client walks, the music plays; when he stops, he receives a message to motivate him to keep walking. The device is very effective for stimulating the client to walk.

SUMMARY OF IMPACT
During testing of the device at the client’s school, the client’s actions showed he was affected by the starting and stopping of the music. After several minutes of successful testing with the client, his teacher stated that the device would encourage him to focus more on walking. The client seemed upset when the device was taken away from him, a good sign. Finally, his therapist was pleased that the Walking Motivator’s most efficient operation was when steady steps were continuously taken, as steady walking was one of her goals for the client. With help from his teachers and therapists to successfully integrate its use into his classroom activities, and perhaps eventually his parents for use at home, the client will build leg strength, gain more comfort in walking, and be more self-reliant for traversing longer distances.

TECHNICAL DESCRIPTION
The Walking Motivator (Fig. 7.19) is a motion-activated music player, containing a pedometer, a PIC microcontroller and an MP3 player. A commercial pedometer (Digiwalker SW 701, Yamax Corp, Tokyo) contains a switch, which closes and opens each time the user takes a step. The pedometer was modified to disable all features other than this switch. Wires from the switch are connected to a PIC microprocessor (16F876, Microchip Corp, Chandler, AZ) in such a way that each step produces a low pulse (5V to zero). Software in the processor continuously monitors this signal, interpreting each low pulse as a step. When the software first detects a step, it triggers an MP3 player (Rouge Robotics, Toronto) to start playing music as a reward.

When the PIC detects walking motion, the music is played continually until no walking motion is detected for six seconds. After six seconds, the music is stopped and a motivational cue is played, which explains that music will start again if the user starts to walk again. The PIC program contains a filter to guard against false positive detections of walking. This filter determines the frequency of steps, and if it is too high, triggers a different message that informs the user that the device will not play music unless normal walking is resumed. Additionally, if the PIC detects no walking motion for six seconds, it powers itself down to a sleep mode to conserve battery power.
Music was collected from the client’s teacher and uploaded to a Flash memory card, which plugs into the MP3 player. Ninety-one songs are stored on the card.

The pedometer, PIC, and MP3 player are packaged in a 3-1/4"W x 4-1/2"D x 1-1/2"H ABS plastic project box, which contains an easily accessible 9V battery holder. A voltage regulator drops the voltage to 5V for the microprocessor. Headphone wires exit the box and connect to standard audio headphones.

The device is worn on the hip of the client to allow for maximum efficiency of walking detection. The project box must be oriented properly for the pedometer to work reliably. This is ensured by attaching the device inside a camera case, which has been connected to a luggage strap, and strapping this ensemble around the waist of the client.

Cost of parts for the device was approximately $390.

Fig. 7.20. Walking Motivator with Client and Designers.
SPEEDY RECOVERY VEHICLE

Designers: Melissa Latorre, David Semko and Jen Wei
Client Coordinator: Jennifer Edelshick, Duke Hospital
Supervising Professors: Kevin Caves, Richard Goldberg
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INTRODUCTION
Children in hospital settings can experience feelings of fear and anxiety when faced with the task of getting into wheelchairs. The purpose of this project was to design and assemble a wheelchair that is fun and visually appealing to children. The Speedy Recovery Vehicle combines the functionality of traditional wheelchairs with the visually appealing design of racing dune buggies. The vehicle includes a custom welded frame, a reclining seat, and a colorful interactive steering wheel. Its small size makes it easy to store, and ideal for children in the two to six-year-old age group.

SUMMARY OF IMPACT
The Speedy Recovery Vehicle has the potential to help children who are scared of riding on traditional wheelchairs become cooperating patients. The supervisor remarked, “The speedy recovery vehicle is a kid-friendly means of transportation for sick kids. I think as physical therapists we will use it to motivate kids to get out of bed and sit up in a chair. It will also be a helpful way of getting them to want to go to the gym. This will allow kids to get the therapy that they need, without as much trauma.”

TECHNICAL DESCRIPTION
The Speedy Recovery Vehicle (Fig. 7.21) includes a custom welded frame, smooth rolling wheels, a reclining seat, footrests, a steering wheel, arm rests, a safety belt, an IV pole, and a storage area for an oxygen tank. The frame is constructed from 1” diameter aluminum tubing, making it lightweight and non-porous. Contoured handles make it easy for hospital staff to push the vehicle, and they can clean and sterilize it with traditional disinfectants made for non-porous equipment. The front caster wheels are solid polyurethane and 2” in diameter, while the rear pneumatic wheels have an 8” diameter. Custom welding of the frame was performed by KBC Machine Shop (Sterling Heights, Michigan).

The seat of the vehicle, like a wheelchair, can be reclined 30 degrees back from upright, in 5-degree increments by moving a retaining pin. The seat is made out of plywood and covered with high-quality foam and non-porous vinyl fabric. It easily supports the weight of a child in the 2-6 age group. The back support of the seat is 18” tall. The seat is 14” x 14” inches, and is 12” from the base of the vehicle.

The frame is painted red, and racing stripes and a decorative logo are stitched into the seat fabric. The vehicle is 42” long and 16” wide, allowing it to be stored more easily than other devices available for children in the hospital.

Two pairs of footrests are provided, both constructed from the same materials as the seat. One pair resides on the floor of the vehicle; 12” lower than the seat, and can support the child’s legs at a 90-degree angle. The other pair resides on the front of the vehicle, supporting a child’s extended legs. Either pair can be topped with an appropriate pillow to provide for different sized children.

The steering wheel is mounted on a pivoting arm, so it can be rotated out of the way when placing a child inside the vehicle. It contains a cartoon of the highway that moves as the wheel is rotated and bright buttons with pictures of different animals that make sounds when pushed.

An oxygen tank can be stored either in an upright position on a 4.5” wide metal platform at the rear of the vehicle, or at a 45-degree angle under the seat. A metal chain attached to the back of the seat prevents the oxygen tank from toppling when stored upright. A holding device is built underneath the seat for the 45-degree angle storage, and the footrest serves as a ledge for the bottom of the tank.

An IV pole, constructed from 1/2” aluminum tubing, extends 29 inches from the top of the seat of the vehicle. It contains a hook at the top that can support the IV. Aluminum armrests on each side of
the seat prevent the child from falling out sideways. One end of each armrest is attached to the seat frame with a pin that can easily be removed by the hospital staff to move the armrest out of the way when placing a child inside. A safety belt is attached to the bottom seat cushion to secure the child firmly in the seat.

Cost of the Speedy Recovery Vehicle was about $610.

Fig. 7.21. Speedy Recovery Vehicle.
CHAPTER 8
NORTH DAKOTA STATE UNIVERSITY

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AUTOMATED MEDICINE DISPENSER

Designers: Patrick Beaver, Daniel Bowen, Rachel Dorry
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INTRODUCTION
The client for this project is an assisted living facility that provides care for individuals with cognitive disabilities. Some of these residents lack the ability to take timely or precise dosages of vital medications. Thus, the home has requested a medicine dispenser that can dispense up to eight large-size pills three times per day for an entire week.

Automated medicine dispensers are used to assist in the accurate administration of medicines to individuals with memory or cognitive disabilities. Medicine dispensers typically alert and dispense medications to a resident at predetermined times of the day. Along with these capabilities, this system offers features such as a detachable keypad, which decreases the risk of tampering, and nametag and picture slots for unit personalization. Figure 8.1 displays the complete system.

SUMMARY OF IMPACT
This device offers advantages for the resident as well as the caregiver. When properly used, this system ensures accurate and timely delivery of medication, allows a more independent lifestyle for the resident, and reduces the time required for caregivers to administer medications. This device enables the caregiver to ensure dosage times and amounts by setting dosage amounts and times of day. Using this device reduces the amount of supervision required by the caregiver.

In addition to these advantages, caregivers are enthusiastic about the personalization features of the device. Residents are able to personalize their dispenser by putting their name in the name space and placing pictures into slots located on the side of the device.

TECHNICAL DESCRIPTION
As shown in Fig. 8.2, there are five major components to the dispenser: 1) the base unit; 2) the dispenser body; 3) the medicine compartment body-insert; 4) the detachable keypad; and 5) the unit lid.

The base unit contains the essential electronic components of the system. A standard AC-to-DC wall adapter provides the required 5-volt power supply. A battery backup is included to provide system power in the event of a power failure. A Microchip PIC 16F876 microcontroller coordinates and controls all activities. The microcontroller obtains time-of-day information by communicating with an integrated real-time clock chip. The microprocessor also controls the stepper motor through a motor controller board, obtains dosage time and day information by a detachable keypad that is interfaced through a keypad matrix encoder, and displays user information on an LCD that is mounted on the unit lid. A dose is dispensed when the programmed dose time matches the time on the real-time clock.
The housing body is made from one 6” PVC coupler, one 4” PVC cap, two sheets of plexiglass, one 1” 45-degree PVC fitting, and miscellaneous hardware. The unit body includes a 5-volt 7.5-degree stepper motor that is used to advance the medicine compartment body-insert. The unit body also includes a dispensing tray and a series of LEDs that illuminate whenever a dosage is administered. The stepper motor is mounted to a plexiglass platform that also supports the medicine compartment body-insert.

The medicine compartment body-insert is a cylinder that is 6 inches in diameter 2.5 inches in height. The cylinder is constructed of a polyethylene material that is non-reactive with most medicines. Through custom machining, the cylinder insert includes a set of 24 equally-spaced compartments used to house the individual medicine doses. The caregiver loads pills into the compartments located around the circumference of the cylinder insert.

Once loaded, the caregiver uses the detachable keypad to enter dose time and day information. The handheld keypad has 12 buttons consisting of the numbers zero through nine, enter button, and a star key. Of the 12 buttons, there are four dual function buttons. Button one is also a.m., and two corresponds to p.m. Button number five is also a “yes” command, and six is “no”.

The LCD mounted in the unit lid provides the caregiver with instructions on how to enter time and day information. Using a small padlock, the lid secures the insert in the body housing so that residents cannot improperly access the medicine.

The unit weighs approximately ten pounds. The total cost for the dispenser is $778.
MUSICAL RAINBOW

Designers: Brittany Johnson, William Long, and Kary Martin
Client Coordinator: Connie Lillegard, Anne Carlsen Center for Children
Supervising Professor: Roger Green, Ph.D.
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INTRODUCTION
This project is for a center that provides many services for children with a wide range of disabilities. They offer medical, residential, and education services for children with disabilities up to age 21. The center has a room that contains a variety of interactive devices for the children, and continually seeks novel additions to the room.

The musical rainbow is a device that provides entertainment as well as stimulation. By playing an “invisible” keyboard, the musical rainbow responds with musical sounds and colorful lights. Multiple tones can be played at once, just like a real keyboard. The device supports a full musical scale and outputs pleasing flute-like tones. The complete system is shown in Fig. 8.3.

SUMMARY OF IMPACT
In recent years, caregivers at the center have achieved positive results from stimulating children with sounds and light. The musical rainbow builds on this success and improves the quality of life of children at the center by providing interactive and entertaining stimulation. This device is fun for all ages and abilities. The caregivers are very pleased with the device, saying that both they and the children love it.

TECHNICAL DESCRIPTION
As shown in Fig. 8.4, the musical rainbow consists of five main blocks: 1) user interface comprised of IR emitter and photodiode pairs; 2) light emitting diodes (LEDs); 3) digital signal processor; 4) audio amplifier and speakers; and 5) power.

The device is activated by placing a hand or object in the “invisible” keyboard. This causes a corresponding light to illuminate and a tone to play. The keyboard consists of eight infrared emitters and eight photodiodes. When a non-transparent object is placed between the emitter and the photodiode, the photodiode sends a logic high signal to the gate of a MOSFET. The LEDs are connected to ground through the MOSFET. When the gate is high, current flows through the MOSFET and illuminates the LEDs, providing a colorful display to the user.

There are eight colors in the rainbow that correspond with the eight IR emitter/photodiode pairs that comprise the keyboard. Each emitter/photodiode pair has four LEDs grouped by color: red, orange, yellow, green, aqua, ultraviolet, blue, and violet. At the same time that a group of LEDs light, a flute-like note is also synthesized.

To create the notes, a mathematical analysis software package (MATLAB) was used to determine a flute’s frequency components. These frequencies are scaled to produce the eight notes of the keyboard, ending with middle C. An envelope is also applied to the note to produce a more realistic sound. The digital audio samples are mathematically constructed by a digital signal processing chip.

The Microchip dsPIC 30F4013 is sufficiently powerful to synthesize the notes in real-time at the

Fig. 8.3. The Musical Rainbow.
required quality. The MOSFETs that allow the LEDs to light also signal the dsPIC to produce a sound. When a current conducts through the MOSFET, the input pin on the dsPIC is grounded. It then signals the processor to output the proper note. The audio output samples from the dsPIC are converted to an analog signal using a digital to analog converter (DAC). The current output from the DAC is then converted to voltage using the LM741 operational amplifier, which allows subsequent amplification.

The audio amplifier boosts the output from the DAC to an audible level. A good quality amplifier is needed to minimize distortion and keep the tone pleasing. The tone is sent from the processor to a potentiometer for volume control and then to the audio amplifier. The amplifier removes the DC offset and then increases the output power. The audio amplifier sends the amplified signal to the two 4-inch speakers.

All the blocks are powered by the power block. The power block consists of an AC to DC converter, that supplies ±12 volts at 800 mA each, 5 volts at 3 A, and ground. Power is supplied to the main board and branches off the main board to power the auxiliary boards.

The development cost of the musical rainbow system is approximately $330.

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Fig. 8.4. System Block Diagram.
MODIFIED PATIENT LIFT

Designers: Nabi Abolfathi, Andrew Locken, Merideth Midgarden, and Betty Wey
Client: “JT”
Supervising Professor: Dr. Roger Green
Department of Electrical and Computer Engineering
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INTRODUCTION
The client is an adult male with quadriplegia who has limited right arm mobility. He requires assistance in moving between his wheelchair, bed, bath, and other locations. A variety of lifts are available to assist in such patient transfers, and they help minimize the risk of injury to patients as well as caregivers. Older lifts typically operate using manual hydraulic pumps while newer lifts tend to operate electronically. Electrical units are generally preferred and considered safer. On the other hand, hydraulic systems do not require electric power and operate reliably in wet and other adverse conditions.

When traveling by commercial aircraft, the client encounters the additional difficulty of packaging his equipment, including his patient lift, in a manner that is efficient, secure, and that conforms to airline regulations. Although he owns a newer electric lift, it is not easy to disassemble or pack for air travel. His request was for a lift that fit the requirements for travel.

The modified patient lift, shown fully assembled in Fig. 8.5, allows the original manual hydraulic pump to be interchanged with an electromechanical actuator that is powered from an electric wheelchair and controlled by a convenient handheld switch.

SUMMARY OF IMPACT
The client learned that he had the opportunity to fly to Alaska and participate in a summer sporting event. He requested help in upgrading his older hydraulic lift with an electromechanical actuator. The modified patient lift provides the client with the advantages of an electric lift while retaining the required disassembly and packaging features required for air travel. The new electromechanical actuator is interchangeable with the existing hydraulic cylinder, providing the client the option to use the most appropriate actuator for the conditions at hand. The freedom of travel and participation in recreational and sporting activities offer quality-of-life improvements for all people. The improved lift allows participation in these types of activities.

TECHNICAL DESCRIPTION
The original hydraulic actuator, shown in Fig. 8.6, provides a guide for the replacement system, which requires an appropriately sized electromechanical actuator, a mechanism to power the actuator, and a mechanism to control the actuator. Based on the client’s request, his electric wheelchair serves as a power source for the actuator. This wheelchair, which utilizes marine batteries, provides a 24 volt dc supply with ample current. To support an individual up to 300 pounds, the actuator must
deliver in excess of 1400 pounds of pushing force. This is due primarily to the 4:1 ratio between the load and actuator mounts on the lever arm, but also due to the varying angles between load, lever arm, and actuator that occur during the lifting operation (see Fig. 8.5).

McMaster-Carr offers a suitable 24-volt dc electromechanical actuator (part number 9005K22) that delivers 1798 pounds of push force and 1349 pounds of pull force. This particular part has a 12-inch stroke that matches the stroke length of the original hydraulic part. Unfortunately, the actuator’s retracted length (20.3 inches) is several inches too short to be interchangeable with the existing actuator, and the clevises are not compatible with the existing lift mounts. Two custom-machined pieces, which include recessed set screws to prevent slippage, provide the necessary length extensions and also serve as clevis-to-mount adaptors.

Actuator control is accomplished using a double-pole double throw break-before-make switch that is wired to reverse voltage polarity between the two momentary-on positions of the switch. Pressing the rocker switch in one direction raises the lift, and pressing the rocker switch in the other direction lowers the lift. These components, including the power connector to the wheelchair batteries, are shown in Fig. 8.7.

The cost for modified patient lift, excluding the original lift, is approximately $700.
AUTOMATED PATIO DOOR SYSTEM

Designers: Justin Strong, Matt Brummer, Ben Christenson, Greg Rise
Client Coordinator: Kary Jones (Friendship, Inc.)
Supervising Professor: V. V. Bapeswara Rao
Department of Electrical and Computer Engineering
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INTRODUCTION

A patio door system was designed for a man with special needs to allow him to open and close his door without assistance. The system is activated by a wall mounted pushbutton as well as a wireless pushbutton. By implementing a wireless system, the need for a pushbutton outside his apartment is eliminated, therefore reducing security risks. The system operates the same way whether started by the wireless or the wall-mounted pushbutton. With the door in the closed position, it begins to open once a button is pushed. It takes the system about nine seconds to open the door completely. The door remains in the open position until a button is again pushed. If at any time during the opening or closing of the door a proximity sensor indicates an obstruction, the door automatically moves toward the open position; this is a safety feature to protect the client from becoming caught in the door.

Although similar systems are available commercially, these products are more permanent and do not allow the user to preserve the integrity of the door. Comparable commercial systems have base prices of $300 and higher depending on features.

SUMMARY OF IMPACT

The patio door system offers the client an opportunity to enjoy the patio and the outdoors when it is convenient for him, instead of waiting for someone’s help. The simple and attractive design allows for easy operation, which promotes use of the device. The ability for the system to be disassembled and easily moved facilitates long-term usage and will promote a higher quality of life for the client for years to come.

TECHNICAL DESCRIPTION

The automated patio door has three primary design requirements: 1) the system must be able to open a typical patio door; 2) the system must be portable in case the client moves to a different apartment; and 3) no major modification can be made to the door.

The system consists of:

- One control box, which houses custom circuit boards, a motor, gears, bearings, axle drive, battery and battery charger;
- Two proximity sensors located in the door jams, which report when the door is open or closed and also sense obstructions;
- One drive rail, with suction cup attachments, to actuate the door; and
- Two pushbutton controllers, one wall-mounted and one wireless, to activate the system.

Fig. 8.8 shows the installed system and Fig. 8.9 shows the system block diagram.

The system is powered by a 12V battery, which is maintained by a trickle charger that connects to a standard household outlet. Regulators provide 5V for the control circuitry and 3V for the wireless control circuitry in the box. The wireless pushbutton and transceiver are powered by a single 9V battery.
The system can still be used if there is a power outage because the 12V battery is sufficient to perform over 100 cycles before it needs to be charged again.

The system is controlled by a PIC microprocessor, as illustrated in Fig. 8.9. The PIC in the control circuit monitors the various inputs and controls the motor through an H-bridge. The H-bridge, which is comprised of MOSFETs and BJTs, is powered by the +12V DC battery. Depending upon desired direction of the door, the PIC sends either a +5V DC or -5V DC control signal to the H-bridge circuitry. As designed, the system is non intrusive, practical, and easy to use.

As it is constructed now, the cost is $400. Should the design be mass produced, it would cost less.

Fig. 8.9. Block Diagram.
VOICE ACTIVATED THERMOSTAT

Designers: Craig Harper, Jesse Holtan, and Sasha Pross
Client: Friendship, Inc.
Supervising Professor: Dr. Roger Green
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INTRODUCTION
The voice activated thermostat, shown in Fig. 8.10, allows the client, a person with learning disabilities who is legally blind, to control the temperature of his apartment without assistance from the apartment staff. Following a simple training process, the thermostat is controlled completely by voice commands.

One function of the thermostat is to keep the apartment at a certain temperature, or “setpoint”, much like the existing thermostat. A temperature sensor monitors the temperature of the room, and turns the heater on or off as needed to keep the room within a couple degrees of the setpoint. The other function of the unit is a simple interface, which allows the client to adjust this setpoint according to his preference. In order to do this, the client stands near the unit and says the trigger word “thermostat.” The unit then asks “hotter or colder?” After a reply is spoken, the unit confirms the choice and adjusts the setpoint accordingly.

SUMMARY OF IMPACT
Previously, in order to adjust the temperature, the client needed to contact an on-site caretaker. Consequently, when a caretaker was not available, the client was forced to deal with an uncomfortable environment for durations beyond his control. This device allows him to independently adjust the temperature of the apartment, which decreases his reliance on the caretakers and improves his quality of life.

TECHNICAL DESCRIPTION
A system block diagram is shown in Fig. 8.11. The heart of the system is a custom microcontroller, the Voice Extreme Module (VE-Module) from Sensory, Inc., which is designed for speaker dependent voice recognition applications. Upon power-up, the system defaults to a setpoint of 72 degrees Fahrenheit until the unit is trained. A button is pushed to start the training process, and the unit asks the user to say the first word that is being trained, “thermostat”. The user says the word, and the pattern is stored in a buffer. The user is then told to repeat the word, and that word is compared with the buffer. If they are similar enough, the word is accepted and the two patterns are averaged and saved to memory. If the word is not similar enough, the unit will ask the user to repeat the word again until a sufficient match is found. This process is repeated for the words “colder” and “hotter” to complete the training process.

The system then switches to “continuous listening mode”, a feature available on the VE-Module. Each time a sound is heard, the unit first checks the sound to see if it was the same length as the trigger word. If not, it goes back into listening mode. If it is the correct length, the system tries to recognize the word by comparing it to the stored pattern which is in the memory. If the word is recognized, the unit asks the user whether to make the room hotter or colder, and the same recognition technique is used to try to recognize which of the two words is being said. If it doesn’t match the pattern to either...
“hotter” or “colder,” the system beeps and asks again. This process is repeated up to four times and if a word is never recognized, the system beeps several times and returns to continuous listening mode.

The system contains a temperature sensor IC that monitors the temperature of the room. The system continuously communicates with the temperature chip through a three-wire SPI communication. The heater is turned on once the temperature of the room falls 1.8 degrees Fahrenheit below the setpoint and stays on until the room is .9 degrees above, an economically efficient range recommended by Honeywell.

When a command to increase or decrease the setpoint has been recognized, the setpoint is raised or lowered with reference to the current room temperature. This is desirable to prevent any accidental large changes in the temperature of the room. If an impatient user repeatedly requests a hotter temperature, the setpoint will still stay at a reasonable level rather than increasing to a high value. When the system is commanded hotter, the setpoint is changed to the current temperature plus 2.7 degrees. This ensures that the heater will turn on, as it would be confusing to say “hotter” and have nothing happen. It also ensures that the temperature of the room will stay warmer than the current temperature. When the system is commanded “colder”, the setpoint is changed to the current temperature minus 1.8 degrees, for similar reasons.

The values of a resistor and a capacitor can be altered to adjust the distance at which the microphone will pick up sound. In this application, an arms length distance is appropriate. The Voice Extreme module contains drive circuitry for a speaker. However, separate drive circuitry is used to allow the client to control the volume of the device. The drive circuitry for the speaker is an op amp circuit that includes two variable resistors that control the volume of the output.

The unit is powered by 120V AC from a nearby wall outlet. This voltage has been stepped down, rectified, and regulated to 3.3V, which provides power for the majority of the unit’s circuitry. The apartment’s thermostat uses a mercury switch that acts as a single pole, single throw switch. The switch closes when the heat is to be turned on, and opens when the heat is off. The interface to the existing thermostat bypasses the current mercury switch with an electromechanical relay. This allows us to control the apartment’s temperature without altering the existing thermostat as per the design requirements. In the unlikely event that the device fails, the original thermostat will still operate.

The cost of the voice activated thermostat is approximately $100.

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Fig. 8.11. System Block Diagram.
INTERACTIVE ANIMAL SOUNDS SYSTEM

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Client Coordinator: Connie Lillejord, Anne Carlsen Center for Children
Supervising Professor: Roger Green, Ph.D.
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INTRODUCTION

The project is for a center that offers residential, therapeutic and educational services for children. Individualized services at the center include care for children and young adults with: cerebral palsy; orthopedic, vision and hearing impairments; autism, pervasive and other behavior disorders; and many other medical challenges. They use creative combinations of special education, training and therapy. Sensory integration is especially important for children with special needs. Located in the center’s jungle-themed sensory playground, the interactive animal sounds system produces different types of animal sounds. It is triggered by children lifting pre-installed carpet panels located on the playground walls. Fig. 8.12 shows the jungle-themed sensory playground.

The center has many different types of sensory stimulation devices already in use on their campus. The interactive animal sounds system is another tool that can be used to entertain children using auditory stimulation.

SUMMARY OF IMPACT

This system is designed to provide children at the...
their environment and provide visual and auditory stimulation, which helps to improve their quality of life. The children at the center experience stimulation when exposed to bright flashing lights and different types of enjoyable sounds.

**TECHNICAL DESCRIPTION**

The interactive animal sounds system consists of a main aluminum enclosure, input triggers, and speakers to output the appropriate sounds. Fig. 8.13 shows the block diagram of the animal sounds system.

The main enclosure consists of five parts: 1) power supply; 2) digital signal processor; 3) digital-to-analog converter; 4) audio amplifier; and 5) a volume control knob. A Meanwell T-40C power supply is used to convert 120V AC to three DC voltages: +5V, +15V, and -15V. The digital signal processor monitors the input signals from the external triggers. When one of the external triggers is activated, the DSP locates a digitized animal sound from its internal memory and sends it to a digital-to-analog converter. The digital-to-analog converter transforms the digital audio signal into an analog waveform, which is then sent to the audio amplifier. The audio amplifier, which is constructed using a National Semiconductor LM3876 overture chip, amplifies the analog waveform and sends it to the speakers. Volume is controlled by a knob that is connected to a 1 turn 100kΩ potentiometer attached to the outside of the main enclosure. The speakers consist of two 5 ¼ inch Pioneer 130 watt 2-way speakers. The external triggers are Cherry Switch MP2018 magnetic proximity switches. A magnetic proximity switch is a switch that uses a magnet for activation. To activate the switch, you simply remove the actuator from the switch. The interactive animal sounds system also includes a master power switch that can be used to disconnect power when the system is not in use. Fig. 8.14 shows the main enclosure and three external triggers.

Items with significant cost for the system include the power supply at $59.95 and the digital-to-analog converters, which are about $20 each. Using only one converter and building a power supply could reduce the production costs for this device. The model of the interactive animal sound system costs around $375 to produce.

Fig. 8.14. Main Enclosure with Three External Triggers.
INTRODUCTION

Hyper-training allows a user to customize a program to improve productivity. Through customizable menus, the brain-computer interface (BCI) hyper-trainer allows persons with physical disabilities to control an object on a computer screen in two dimensions by thought. A set of electrodes monitors the user’s brain (EEG) signals. The program then records these signals and calculates four different parameters based on the signals. Using these parameters to identify what the user is thinking, the program allows the user to choose how they want to move a target object. This emphasis on interface and interaction is unlike most BCI projects, which focus on feature extraction from EEG signals. The BCI hyper-trainer is programmed using LabVIEW, and MATLAB is utilized to verify the mathematical results from the program.

SUMMARY OF IMPACT

With the aid of the BCI hyper-trainer program, the user can control a cursor on a screen using only...
thought. This approach allows individuals with motor disabilities to better use a computer. With the simple and convenient program interface, users are able to train quickly and efficiently. The program is shown to be effective in moving a cursor without motor functions.

TECHNICAL DESCRIPTION
The BCI hyper-trainer is a software program that consists of the following main components: 1) data acquisition; 2) pre-training; and 3) hyper-training. Fig. 8.15 shows one of the training preparation pages where the user is shown the different regions of the brain that control bodily functions. This information assists with proper placement of the electrodes. The user can also modify the customizable thoughts at this time. The other pages of the BCI hyper-training program have a similar style.

To begin, four electrodes are strapped on the head of the individual to measure EEG data. The four channels are input into hardware amplifiers, gained, and then low-pass filtered to 100Hz. These filtered and gained signals are then processed with a data acquisition (DAQ) card and input into the LabVIEW program. The program applies 40 Hz digital low-pass filters to the signals to remove 60 Hz noise. Additional user-customizable band-pass filters are also available. At this point, the EEG signals are ready for analysis.

During the pre-training process, 12 thoughts chosen by the user are flashed in series on the screen. While the user is thinking these various thoughts, the computer calculates the average root-mean-squared (RMS) power, skewness, kurtosis, and form factor for each of the four channels of the filtered EEG data. RMS power and form factor calculate the overall size and complexity of the EEG signal, respectively. The skewness and kurtosis are both measured using the frequency distribution of the signal, with skewness being the symmetry and kurtosis being the peakedness. The program utilizes these parameters for a combination of reasons including: frequency of use in EEG analysis, ability of the parameter to discriminate different thoughts, ease of implementation, and user understanding. After performing these parameter calculations, the computer then ranks each thought based on its difference from a resting-state control value. The pre-training process takes less than two minutes.

After pre-training, the user views the calculated data in the BIODATA page. Based on these results, the user chooses a different thought for each of the cardinal directions for the hyper-trainer compass challenge, a demonstration of which is shown in Fig. 8.16. The user also selects from various targets and timing options before beginning the hyper-training process. As in pre-training, parameters are continually calculated for the incoming EEG. These data are then compared to the thresholds defined in pre-training. If a parameter exceeds the selected thought’s threshold, the cursor is moved in the corresponding direction. The compass challenge tends to be difficult to master at first, but continued user practice normally results in improvement. To date, all users have successfully learned to control the cursor, although with varying degrees of proficiency.

The user can also choose what parameters to display on a waveform graph as well as view their filtered EEG waveforms. The graph displays the most recent 30 seconds so the user can see the effect of changing thoughts with time.

PC, LabVIEW license, amplifiers, and electrodes were the most costly items. The total cost approximates $8,300.
MAILBOX ALERT SYSTEM

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INTRODUCTION
The mailbox alert system allows persons with physical limitations to check by telephone when their mail has been delivered. A thin rectangular box containing infrared sensors to detect the mail is placed at the bottom of the mailbox, with the sensors pointing straight up. A separate device containing the system’s microprocessors and circuitry connects to the mailbox insert, connecting the system to both standard wall power and telephone outlets. The user dials in to the system using a telephone and receives voice prompts from an audio chip. He or she keys in the mailbox number through the telephone touchpad, and the system audibly tells him or her whether or not there is mail in the mailbox, along with the day and time the mail was detected.

There are several commercial products that detect when mail has been placed in a mailbox. Many of them use motion detectors placed on the mailbox door, triggered as soon as the door is opened. However, this causes the detector to indicate mail every time the mailbox door is opened, regardless of whether mail is present or not. The mailbox alert system uses infrared beams, which are reflected back only if mail is actually present in the mailbox, so false indications are eliminated.

Most commercial mail detection products use a proprietary device with an LED or audible tone to alert the user. These devices are fixed to one location in the user’s home, and are only accessible from that location. The mailbox alert system, on the other hand, requires no installation in the user’s home and operates with any telephone, allowing the user to check mail from any telephone.

Fig. 8.17 shows how the sensors are placed in the mailbox. The LEDs send a beam of infrared light straight into the mailbox; any mail present in the mailbox will reflect the infrared beam back down into one of the photo detectors, which allows the system to detect the mail.

SUMMARY OF IMPACT
The mailbox alert system provides the user a simple, user-friendly way of checking their mail. For a
TECHNICAL DESCRIPTION

A block diagram of the system is given in Fig. 8.18. The system consists of four PIC 16F876 microcontrollers, several specialized integrated circuit chips, and the sensors used to detect the mail. Not shown on the block diagram are the power connections; a power converter plugs into a standard 120V AC wall outlet and provides +5V to each of the microcontrollers and integrated circuits.

The master microcontroller is the “brains” of the system; it sends commands and receives data from the other microcontrollers in the system. The master microcontroller connects directly to a Xecom XE0068DT Data Access Arrangement chip, which connects directly to the phone line through an RJ-11 connector. The XE0068DT safely isolates the mailbox alert system from the high-voltage telephone system, and is also certified through FCC Part 68 to allow the system to legally connect to the telephone system.

When the user calls in to the phone line connected to the system, the ringing generates an interrupt on the XE0068DT phone chip. The master microcontroller detects this interrupt and instructs the phone chip to pick up the phone line. It sends a command to the voice chip to play an introductory audio message over the phone line (“Please enter your three-digit mailbox number, followed by the pound sign.”). The master microcontroller then waits for the user to key their mailbox number into their telephone keypad; the phone chip decodes the DTMF tones into binary digits for the microcontroller.

Once the user has keyed in their mailbox number, the master microcontroller sends a command to the microcontroller connected to the real-time clock chip to retrieve the status of their mailbox. The real-time clock chip, a Dallas Semiconductor DS1305, provides timekeeping functions, two programmable alarms, and 96 bytes of memory backed up by a rechargeable super-capacitor in case of temporary power loss. The DS1305 stores the status of up to 32 mailboxes in its memory. Once the master microcontroller receives the status for the user’s mailbox, it forwards the status on to the microcontroller that controls the voice chip (a Winbond ISD4005). The voice-chip microcontroller decodes this message and plays the appropriate audio over the phone line. The master microcontroller then instructs the phone chip to hang up the phone line.

The real-time clock generates an alarm every 15 minutes; this alarm is detected by the microcontroller connected to the real-time clock chip. The microcontroller raises an interrupt which is detected by the master microcontroller, which then instructs the microcontroller connected to the sensors to check for mail in each of the mailboxes. The status of each mailbox is sent to the real-time clock microcontroller, which stores them in its memory.

In full production, the prototype cost of several hundred dollars could be reduced to below one hundred dollars.
CHAPTER 9
ROCHESTER INSTITUTE OF
TECHNOLOGY

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INTRODUCTION
Two residents of an assisted living residence were unable to enter their home without assistance. These individuals use wheelchairs and could not unlock and open their front door. The goal of this project was to create a modified home entry system that would allow them to enter and exit their home independently. A key project requirement was that the front door should still function normally for other residents and employees entering and exiting the home, as everyone there is encouraged to do as much for themselves as possible.

SUMMARY OF IMPACT
The final design provides two individuals increased independence without affecting the way the front door opens for other residents and employees. The system is activated by garage door opener-style remotes that allow the two individuals to operate

![Fig. 9.1. Schematic of the Modified Home Entry System.](image-url)
the entry. Part of the door’s strike plate around the latch was replaced with a lock bypass that moves out of the way, allowing the door to swing freely without having the doorknob turned. Depressing the remote causes the lock bypass to slide clear of the door latch, and it also activates the motor that swings the door open and closed. The door is equipped with sensors that detect objects or people in its path. Fig. 9.1 shows a system schematic. The individuals using the new system say they “love the door and love showing it off.”

**TECHNICAL DESCRIPTION**

The home entry system is composed of four subsystems: 1) electronic control; 2) door motion; 3) lock bypass; and 4) sensors. The key physical structure modifications are shown in Fig. 9.2.

For the electronic control, a garage door transmitter and receiver were used for the user input to the system. In order to coordinate the individual components of the system, an electronic logic controller is needed. A Parallax BASIC Stamp™ microcontroller was selected. The controller is used in conjunction with relays, a transformer, a voltage regulator, and other electronic components. A program was written for the microcontroller to control the operation of the door, allowing for easy programming changes and incorporating adjustability into the system.

A 90 VDC motor that provides 250 in-lbf of torque and moves at 3.2 RPM was used to move the door. In order to preserve the manual operation of the door, an electromagnetic slip clutch is used so that the motor can be disengaged when not in use. This clutch serves two purposes. First, it produces negligible friction when disengaged. Second, it slips when 250 in-lbf of torque is applied. This slipping allows the system to be manually stopped or moved during operation. It was found that a large amount of force was needed to overcome the weather seal of the door being used. This force only needs to be overcome for the initial motion of the door from the closed position, so a linear push solenoid is used in conjunction with the motor to overcome the seal.

The lock bypass is the mechanism that allows the door to swing open without requiring the doorknob to be turned. A portion of the strike plate has been replaced with a sliding steel gate, actuated by a linear pull solenoid. When the system is activated, the slide is lifted by the solenoid, allowing the door to open without handle rotation. This system allows the door to lock and unlock as it always has, while also bypassing the lock when the remote control button is pressed.

Infrared ranging sensors were selected for object detection. They are easy to use, are designed for operation within a large temperature range, and are very cost effective. Five sensors are used in conjunction with analog-to-digital converters. The sensors are mounted approximately 2 ft off the ground with even spacing. They will detect any object appearing in the door’s path. When a sensor is activated, the door stops moving and returns to its prior position.

The total cost of the project was approximately $1500.
INTRODUCTION
A consumer wishes to use a computer to send e-mail and write letters. This individual has experience typing, but has not used a computer, and has several disabilities that prevent use of a standard keyboard. This particular individual is legally blind, is unable to isolate one finger to type with, and does not have sufficient reflexes to depress and release a key quickly enough to type only one letter at a time. In addition, there were some ergonomic concerns that would require the keyboard to be elevated higher than a normal keyboard.

SUMMARY OF IMPACT
The team performed two visual and two motor skills tests to determine the individual’s abilities so the keyboard would meet all specified needs. The final design included keys that were large enough and spaced so that the consumer would be able to identify and depress only one key at a time. The size of the lettering on the keys was also increased to accommodate the consumer’s visual impairment. The total number of keys was reduced to 49 from the standard 104: the numbers 0-9, letters A-Z, six punctuation keys, Return, Space, Backspace, Shift, Caps-lock, a key to start the e-mail application, and a key to start an internet browser. The consumer requested that the keys be arranged in alphabetical order.

TECHNICAL DESCRIPTION
The final design is shown in Fig. 9.3. Key size, spacing, and layout were determined based on tests of the consumer’s mobility and reach, ability to depress keys of certain sizes and spacing, and ability to read letters of different sizes, stroke widths, and color patterns. The team also determined that the consumer typically depresses a key for approximately three seconds for a keystroke and requires a concave key surface to prevent fingers
from sliding off the keys. The curvature of the keyboard was modified to match the consumer’s reach patterns.

The switching mechanism used in the keyboard design is a flexible printed circuit board (PCB). This mechanism uses three Mylar or Kapton sheets. The bottom sheet is connected to the short slot in the encoder, and the top sheet is connected to the long slot in the encoder. The middle sheet is used as a spacer sheet with strategically placed holes. When a key is depressed it pushes down a rubber dome, which then makes contact with a particular node on the first sheet, and finally makes contact with another node through the spacer sheet, thus closing the circuit. The flexible PCB design was done in AutoCAD to ensure the nodes lined up exactly with the locations of the centers of each key. The PCB layouts for the top and bottom sheets are shown in Fig. 9.4. An existing fully-functional keyboard encoder was used and the new keyboard layout was programmed using Microsoft’s Keyboard Layout Creator.

The keys and keyboard frame were manufactured from delrin, chosen for its high strength to resist frame deflection and its low coefficient of friction to resist key binding. The keyboard frame was made with extra internal supports to stiffen the structure in case the consumer hits the frame instead of the keys. The keys were made using a CNC machine, and were designed with a flat surface to prevent them from spinning in place. The keyboard frame and keys are shown in Fig. 9.5.

The user has been given a detailed user’s manual that includes installation instructions as well as key identification for keys with non-alphanumeric symbols.

The total cost of the project was approximately $550.
INTRODUCTION
Pressure sores are common in individuals who are required to remain seated or lying down for long periods of time without being able to shift their weight. Constant contact on pressure points causes restricted blood flow and may eventually lead to sores that can penetrate into the bone and cause systemic infection. Therefore, it is important to

Fig. 9.6. Air Bladders, Non-Inflatable Firm Foam Cylinders, and Bedding Grade Foam that Forms a Full-Sized Frame around the Twin-Sized Air Bladders.
provide a means to vary pressure points for individuals who are not able to move independently. The focus of this project was to develop a bed that will automatically vary pressure points during the night for a consumer who has pressure sores. Typically, aides would come in several times during the night and manually move the individual. This was causing severe sleep disturbances, so a key goal was to provide a system that would allow the individual to sleep undisturbed while still varying pressure points.

**SUMMARY OF IMPACT**

The final product is an air bladder system with three different cycles of support that can be set to change in 30-, 45-, or 60-minute intervals. The design also has a “full inflate” option that provides a uniformly inflated surface. All controls are located outside the consumer’s room, so aides do not need to enter during the night to vary cycle times. The consumer is now sleeping through the night regularly, and is relaxed enough to move her own legs slightly while sleeping.

**TECHNICAL DESCRIPTION**

The pressure sore alleviation system is a device that fits on top of the consumer’s existing full-sized bed. The system consists of a series of air bladders and firm foam cylinders enclosed in a bedding-grade foam frame. Since the individual only moves minimally during the night, a twin-sized air bladder system is used, and bedding grade foam surrounds the bladders and makes the system fit a full-sized bed. A pump is located near the bed and a control box, that allows aides to control the inflation cycles, is located outside the consumer’s room.

The cycle variation over the ten air bladders is:

1. Inflate bladders 1-3-5-7-9; weight is supported on these bladders only.
2. Inflate bladders 2-4-6-8-10; weight is supported on these bladders only.
3. Deflate all bladders; weight is supported on firm foam cylinders.
4. Inflate all bladders; weight is supported on all bladders.

The pump is controlled using a BASIC stamp microcontroller connected to a four-button user control box. The four switches on the control box are linked into I/O ports 10, 11, 12, and 13. Port 10 is set up for 30 minute cycles, port 11 for 45 minute cycles, port 12 for 60 minute cycles, and port 13 for full inflate. The initial control is to determine when one of the switches is turned to the “ON” position, which creates a voltage to the port to signal the controller to switch that port to high. Once that port is set to high (>1.5 V), the program switches to the proper subroutine to begin the alleviation cycle. If no switch is selected, the program is set up to automatically fully inflate the mattress until a cycle switch is chosen, and if multiple switches are chosen, the program will only use the first switch selected. A pressure sensor monitors each set of air bladders (1-3-5-7-9 and 2-4-6-8-10).

Once in the switch subroutine, the program cycles continuously through the routine until either the switch is turned off or the power to the controller is lost. While in the individual switch subroutine, the ports that the pressure sensors are connected to (0 and 1) are continuously checked to see if they are switched to high due to the voltage reading from the pressure sensors. Since the ports only switch from low to high at 1.5 volts, a resistor was necessary to make the appropriate pressure switch to high to signal the sensors to activate the valves. The resistor was chosen to be 18 ohms after testing was completed for comfort. When the pressure sensor port is switched to high, the valve ports, either 3 or 4, depending on which pressure sensor is switched, also switch to high. This high signal opens the valve for five seconds to release some of the pressure in the air cells, and this entire routine is looped continuously for either 30-, 45-, or 60-minute cycles based on counters in the program. The first cycle leaves the one valve on high for the entire routine and only controls the other valve. The second cycle does the opposite of the first and the third cycle leaves both valves open to utilize the foam layer of alleviation. A 3-cycle rotation takes approximately 90, 135, or 180 minutes to complete depending on the whether the 30, 45, or 60 minute interval is chosen.

The total cost of the project was approximately $840.
STANDING TABLE

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Industrial Engineering Designer: Jeffrey Matusik
Electrical Engineering Designer: Aditya Srinivas
Client Coordinator: Kristen Quinlan, Arc of Monroe County
Supervising Professor: Dr. Elizabeth DeBartolo
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INTRODUCTION
The goal for this project was to design and build a standing table, a device used to lift individuals with disabilities out of a wheelchair and support them in an upright standing position. Ideally, the table would be able to lift and support a person weighing up to 275 pounds in a standing position, while providing a stable work surface.

SUMMARY OF IMPACT
The final product is a collapsible, rolling standing table that can support users of varying heights and weights up to 300 pounds. The table legs extend out to allow the table to fit around an easy chair and back in to allow the table to fit through doorways. The lifting mechanism is controlled by a corded remote, and the actuator is sized so that it would not be able to lift individuals who are too heavy for the table’s structure to support. The adjustable-height work surface is transparent, allowing the consumer using it to see the ground ahead of him or her when the table is being moved. The standing table is shown in Fig. 9.7.

TECHNICAL DESCRIPTION
Design of the standing table was divided into three areas: 1) power and lifting, 2) frame, and 3) ergonomics. Individual components are identified in Fig. 9.8.

Lifting is driven by an actuator with a 1000-pound limit, 12 inches of travel, a 15 percent duty cycle, a ball screw for quiet operation, and a clutch to prevent overloading. The actuator is mounted so that it will be perpendicular to the lifting arms at the start of lifting, when the most force is required. It is nearly parallel to the lifting arms near the standing phase, when the least force is required. The actuator is powered by a 12V 24A sealed and rechargeable medical battery. A power switch on the frame controls power to the system, and a second power switch on the corded remote controls power to the remote only.

The standing table frame is primarily made from steel with welded construction and was painted to reduce rust. All static and fatigue factors of safety meet or exceed the required 1.5, and static analysis was done to demonstrate that the table will not tip, even with unusual loads applied. The base is made from 8020 aluminum that slides over UHMWPE linear bearings. The base width can be adjusted.
through the use of two water cylinders, one for expanding the width and one for compressing.

Ergonomic analysis ensured that the table would be suitable for all body sizes from the 5th percentile female to the 95th percentile male. Chest and kneepad locations were determined accordingly, as were attachment points for the lifting harness. An anti-fatigue mat is included on the footplate.

The new owners have been provided with a user’s manual that includes maintenance and troubleshooting guides.

The total cost of the project was $1292.

Fig. 9.8. Standing Table Key Components.
CUSTOM WHEELCHAIR TRAY

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INTRODUCTION
The object of this project was to design and fabricate a custom quick-release wheelchair tray for the Quickie S-626 Power Wheelchair with Power Tilt. Prototypes were made for two consumers who desired a tray that could be used not only as an eating area, but also as a workstation. The consumers also requested a storage compartment and cup holder. Existing trays are not rigidly attached to the wheelchairs, causing the individuals some distress if the tray slides back and hits either of them in the abdomen.

SUMMARY OF IMPACT
The final products are two transparent wheelchair trays with several unique features. Each prototype includes an under-tray compartment that can be used for storing writing utensils or eyeglasses, a collapsible cup holder, and a protected space for each consumer to display a photograph. The rigidly attached trays have a rimmed edge to prevent liquid spills from rolling off the surface, and they can be attached and removed quickly. Unfortunately, due to an unforeseen modification in the supplemental support devices required by the consumers, the trays no longer fit on the wheelchairs; however, they are available if other individuals would like to use them.

TECHNICAL DESCRIPTION
The tray surface (Fig. 9.9) is made out of ¼-inch Lexan MR10, which is a polycarbonate material that provides sufficient clarity, allowing the consumer to see through it to the floor in front of his or her wheelchair. The Lexan has an abrasion and ultra violet (UV) resistant coating on both sides. The high mar-resistant surface prevents paint, adhesives, and other materials from adhering to its surface. These characteristics aid in preserving the clarity of the tray surface. An ANSYS model was run to ensure that a typical load (textbooks, notebook, weight of individual leaning, etc.) would not cause dangerous deflection or failure. Both trays also feature a 3” x 7” storage compartment with a closable lid. The storage compartment is removable and can slide on and off by way of channels mounted on the underside of the tray surface. These channels are secured using polycarbonate silicon sealant and four screws. The compartment lid is attached to the tray by means of a rod that runs through the length of the lid.

The trays are attached to the wheelchairs through a system of 304 stainless steel rods and cast iron pipe.
clamps (Fig. 9.10). These are rigidly attached to the wheelchairs, and a roller catch clip allows the tray to rapidly attach and detach from the rods and clamps.

An additional feature that was designed into the system, but later eliminated by the client coordinator, was the ability to automatically adjust the tray’s position. The design consisted of three motor-driven lead screws: one would slide the tray in and out, and the other two would raise and lower the front and rear of the tray separately, providing both height and tilt adjustment (Fig. 9.11).

The total cost of the project was $764.

Fig. 9.11. Original Design Showing Motor-Driven Fully Adjustable Tray.
DROP-SHIPMENT AREA MODIFICATION FOR PEOPLE WHO ARE BLIND OR VISUALLY IMPAIRED

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INTRODUCTION

The client for this project works in an agency that employs individuals who are blind or have visual impairments in various light manufacturing jobs. A drop shipment area, where orders for reusable sticky notes are collected and labeled for shipping, required modification. The products being stored and shipped include pastel and neon pads, and range in size from 1.5” x 2” to easel-sized pads. Most of these are packaged into corrugated cardboard boxes of similar sizes, so that distinguishing one product from another is difficult even for sighted employees. Additionally, the process previously used was taxing for the individual working in the area, and was resulting in incorrectly filled orders. The project goals were to reduce the number of shipping errors and make the job easier for employees with visual impairments.

SUMMARY OF IMPACT

The design team redesigned the drop shipment layout and established a standard operating procedure that allowed a visually impaired employee to work more efficiently. Improvements yielded a 28 percent reduction in walking distance and a 13 percent reduction in time spent to complete an order. Employee feedback has been positive and order filling errors have been minimized.

TECHNICAL DESCRIPTION

The team’s work was focused on two areas: layout redesign and operating procedure development. The benefits of the new layout (Fig. 9.12) in comparison to the old (Fig. 9.13) are described below.

1. Reduced Walking Distance: The worker’s desk was moved into the inventory area, effectively reducing the distance walked to collect an order. The most frequently ordered products were moved closer to the worker’s desk, while less frequently ordered products were moved away from the desk, reducing walking distance even further.

2. Standardized Layout Orientation: Large signs were put in place in addition to standardized product inventory floor spaces to ensure pallets would always be placed in the correct spot. The standardized floor spaces are the numbers 1 through...
22 of inventory labeled in Fig. 9.12. Also, all products were grouped functionally allowing the worker to have familiarity of where products are each time an order is picked.

3. Standardized Pick Order: The team worked with Order Entry personnel to develop order slips to allow the worker to pick orders in a standardized path (Fig. 9.12).

4. Decreased Floor Space: The design team implemented a flow-through rack to decrease the floor space within the Drop Shipment Area. The slowest moving products were placed in this flow-through rack, creating additional floor space that allowed the design team to add new products within the layout.

The new operating procedure includes barcode scanning to generate a packing list and to confirm that the picked order is correct. The benefits of new operating procedure are described below.

1. Reduced time to input order number: It is difficult for the visually impaired worker to type in the ten-digit order number because it is in small print and hard to see on the order slip and on the UPS Software Entry Screen. Scanning the order number makes it easier for the worker, and more accurate.

2. Reduced number of order-picking errors: The pick and scan system allows the worker to verify that the correct notepads were picked. This increases accuracy, and effectively improves customer satisfaction.

3. Reduced time to input weight of packaging: The worker had to enter the weight of each package into the computer manually. Now, these weights will be electronically entered into the computer when the worker scans the boxes picked. Again, this saves time entering this information and reduces the potential for mistakes.

The total cost of the project was $1500.

Fig. 9.13. Old Layout of Drop Shipment Area; New Layout Now Situated within One Side of Old Layout.
ARCWORKS SPORTS BOTTLE CLOSURE TUBE ASSEMBLY WORKPLACE ADAPTATION

Industrial Engineering Designers: George Gooch (team leader), Michael Hayden
Mechanical Engineering Designers: Jeffrey Coppola, Christopher Donati, Hui Kim, Michael Levis, William Lucas, Drew Stone-Briggs,
Client Coordinator: John Syrkin, ArcWorks
Supervising Professors: Dr. Matthew Marshall, Dr. Elizabeth DeBartolo
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INTRODUCTION
An agency employs individuals with developmental disabilities to perform light manufacturing work subcontracted from local companies. Employees are paid based on the number of pieces they produce. One of the products assembled by employees is a closure tube assembly for squeeze-style sports bottles (Fig. 9.14). Existing equipment required individuals to manually fit together the cap and adapter using a press. The subassembly was boxed, and later a different individual attached the straw to the adapter. The design team was asked to help the organization with inventory management and raw material order points.

SUMMARY OF IMPACT
The new design includes a number of improvements. First, the entire closure tube assembly is now done on a single pneumatically driven machine, with automatic counters included to record the number of caps, adapters, and straws each employee assembles. Next, the device is automated, reducing ergonomic strains on the individuals performing the assembly. The new device is also robust enough to work with a range of different sizes of caps and straws, so employees do not need assistance to modify the machine when different-sized units are being assembled. Finally, the warehousing and ordering procedures have been modified so the correct amount of raw materials are always on hand in easily identifiable locations. The completed system is shown in Fig. 9.15.

TECHNICAL DESCRIPTION
The system is based around two pneumatic presses that are operated with an anti tie-down switch. The left side of the system (Fig. 9.15) presses an adapter into a cap and the right side presses a straw onto an adapter. A switch on the base allows the user to run both sides simultaneously or each side individually, and a counter on each side tracks the number of components assembled. The new automated system limits the user’s motions to those required to press the anti tie-down buttons and eliminates the gross

Fig. 9.14. Closure Tube Assembly: Cap (Left), Adapter (Center), and Straw (Right).

Fig. 9.15. New Closure Tube Assembly System.
motion required to operate the existing manual presses.

Fig. 9.16 shows some comparisons between the existing and newly designed assembly devices. It is clear that the new designs reduce the manual aspect of assembly as well as the number of parts required for the device to be able to handle all of the products. This increases the independence of the user, who will now be able to assemble any product without requiring assistance to modify the equipment.

The total cost of the project was $1658.

Fig. 9.16. Top (a and b): Old (Left) and New (Right) Equipment for Pressing Adapter into Cap. Bottom (c and d): Old (Left) and New (Right) Equipment Required for Assembling Straws of Varying Lengths.
SENSORY AWARENESS TRAIL

Mechanical Engineering Designers: Richard Adams (team leader), Brian Luke Hogan, Choi Wong
Electrical Engineering Designers: Chiedu Monu, Timothy Mugwanya
Client Coordinator: Susan Epstein, Everybody Rides
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INTRODUCTION
The object of this project was to create a sensory awareness trail at a therapeutic horseback riding facility that serves individuals with developmental disabilities. Users may be on horseback or on foot. Each station created stimulates one or more of the senses, educates participants on the natural elements surrounding them, and blends in with the natural surroundings as much as possible, all while requiring only renewable energy sources.

SUMMARY OF IMPACT
The team’s final designs consisted of a set of bamboo chimes, a solar powered floating fountain, a pinecone bucket game, wooden animal silhouettes, and a series of audio boxes that play informational messages about particular natural features.

TECHNICAL DESCRIPTION
The bamboo chime station (Fig. 9.17) reaches 8 feet above the ground and is 53 inches wide. Trail users on horseback and on foot will take a stick from the basket shown and strike the chimes. The chimes will then project melodic sounds. This station stimulates the user's motor skills, sense of touch, and sense of hearing.

Audio boxes stationed around the trail play pre-recorded 20-second sound clips. These boxes are used in the animal silhouette station and in various parts of the trail. They provide informative clips about different aspects of the trail and in the silhouette station. A 9V rechargeable NiMH Energizer battery is used in each. The circuit draws 58mA from the battery; therefore, the lifecycle of the battery will provide approximately 460 operations.

Silhouettes of deer, squirrel, rabbit, and coyote were constructed (Fig. 9.18). These silhouettes are stationed throughout a clearing alongside the trail. Immediately off the trail, mounted to the top of a post, is a wooden box with a speaker inside. When the black button on the speaker encasement is pushed an audio clip plays. This clip educates the user about the animals that are represented by the silhouettes. Therefore, the user’s sense of hearing and sight are stimulated.

A pinecone bucket game was devised to challenge motor skills and aid practice for a similar game in the Special Olympics (Fig. 9.19). The buckets are mounted to trees roughly 30 yards apart along the trail. The user takes a pinecone from one bucket, carries it to the next bucket, and drops the pinecone in that bucket.
Finally, a realistic lily pad fountain was placed in a pond bordering the sensory trail. The fountain contains three heads built into a resin leaf shape. The pump is powered completely by a solar panel and shoots water 18" high. This solar fountain creates a soothing sound and it is visually appealing.

The total cost of the project was $709.
SEIZURE MONITOR

Electrical Engineering Designers: Alexey Chernyakov (team leader), Piyanan Siridej
Mechanical Engineering Designers: Zachary Levine, Eric Smith
Client Coordinator: Dr. Michael Berg, Strong Epilepsy Center
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INTRODUCTION
The mother of a teen who has generalized tonic-clonic (GTC), or grand mal, seizures requested a device to detect her teen’s seizures during sleeping periods. The mother requested an easy-to-use device that could be attached to her teen during sleeping periods. The device audibly alerts a person located somewhere within the same household to the occurrence of a seizure.

SUMMARY OF IMPACT
Though a device might be developed to detect only GTC seizures, the medical coordinator requested a system that could be used to detect multiple types of seizures, since such a device would be useful in the treatment and care of other patients with seizure disorders. Other seizure types exhibit a combination of movements in the limbs, head, and/or torso and may not involve rhythmic shaking. Therefore, the system designed for this project is capable of collecting data from several different sources attached to different parts of the body. The system consists of wearable motion-monitoring devices, a base unit to collect the motion data, and data analysis software that will determine whether or not a seizure event is occurring.

TECHNICAL DESCRIPTION
After researching the different products that were commercially available, the decision was made to use the M5282ZIGBEE ColdFire MCF5282 ZigBee ready demo kit. The kit, technology used, and design modifications are specified below.

The motion monitoring system:

1. Communicates with the base device using ZigBee protocol based on the IEEE 802.15.4 wireless communication standard;
2. Has a communication range of approximately 50 m from the motion monitoring device to the base device;
3. Has a maximum data transfer rate from the motion monitoring devices to the base of 250 kbps;
4. Uses data transfer rate of 2.197 kbps, based on a six monitoring device design, a 100 Hz sampling rate, 10 bit microcontroller, and a 3 axis accelerometer; and
5. Transmits the motion data to a personal computer or laptop via an Ethernet (UDP) connection.

The motion monitoring device:

1. Is padded using PORON, a medical grade cushioning material;
2. Employs a selectable (1.5, 2, 4, 6)-g tri-axial accelerometer;
3. Has a usable bandwidth of 350 Hz for XY motion and 150 Hz for Z axis motion;
4. Is capable of being dropped onto concrete from 1.8 meters onto any axis;
5. Is powered by two AAA batteries, which will provide continuous operation for nine hours; and
6. Has an overall mass of 151.7 grams.

The base device:

1. Can communicate simultaneously with up to 16 motion-monitoring devices; and
2. Can send the data from the motion monitoring devices to a computer via UDP.

The software:
1. Is able to process and write the 16-channels of data streams to a computer via UDP; and

2. Is able to perform FFT, cross-correlation, and signal energy analysis techniques to identify seizure events.

The current design is functional but can still be improved. A key aspect of plans for future work is installing extra safety measures, such as a periodic self-test mode that will warn if the system is not working, a low battery warning, and extended usage time (beyond 9 hours). A modified base unit might store data on a flash memory drive, which would eliminate the need for a laptop as part of the base unit. Finally, data analysis will be improved and geared more specifically at identifying specific types of seizure events.

The total cost of the project was $1109.

Fig. 9.20. A wireless motion monitoring device worn on the wrist of a user.
INTRODUCTION
Many of the individuals using the pool at an agency for people who have physical disabilities are unable to walk unassisted down the steps into the pool. They use a pool lift that lowers them into and raises them out of the pool. The lift previously used was unreliable, unsteady, and did not meet ADA/ABA regulations. This project was aimed at designing and constructing a new lift to improve the safety and comfort of consumers using the therapy pool.

SUMMARY OF IMPACT
The new pool lift meets all ADA/ABA regulations, in addition to providing a safer and more comfortable seat for the consumers using it. Consumers and therapists can now be a safe distance from the edge of the pool deck when individuals are helped into and out of the seat. Also, motion from the deck to the pool is smooth. Critical surfaces are padded, and all pinch points have been eliminated. The lift can be completely operated by one person, although it has been designed so that two people can assist the consumer, one on each...
side of the seat.

**TECHNICAL DESCRIPTION**

The final design is shown in Fig. 9.21. This is the submerged position of the lift, where the consumer could exit the seat in the water. The armrests are shown in the lowered position, but they can also be raised to facilitate a person entering or leaving the seat. A linear actuator with a wired remote powers the lift; a therapist can lift an individual out of the pool using the “Raise” button on the actuator remote. The actuator itself is splash resistant, and the actuator control box is waterproof. Power for the actuator comes from a GFCI outlet located below the pool deck, so the power supply is out of splash-range and there are no exposed power cords to pose tripping hazards.

The raised pool lift position is shown in Fig. 9.22. The lift can rotate 360°, but will typically only be rotated 180°, from the submerged position over the pool to the loading position over the pool deck. The horizontal bar at the top of the device is used to rotate the lift. In the loading position, the seat centerline is 36” from the edge of the pool deck, and the seat is accessible by therapists from both sides.

The base of this new pool lift is designed to fit into the hole used for the existing lift with few modifications. The base consists of a stainless steel plate with a thrust bearing set on it. The main post that rotates the consumer in the lift will ride on this thrust bearing. An oil-impregnated bronze bushing is set into place around the main post to provide an additional bearing surface. The bushing is encased in PVC pipe to protect it from the surrounding concrete, and a waterproof gasket under an aluminum top plate protects the entire base assembly.

The structural elements of the pool lift are all made from 6061-T6 aluminum, coated with industrial corrosion resistant paint. Static and fatigue analysis on load bearing components indicate that the lift should operate for at least 20 years. The new owners have been provided with a user’s manual that includes maintenance and troubleshooting guides.

The total cost of the project was $1479, with an additional actuator donation valued at approximately $1000.

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Fig. 9.22. Pool Lift in Raised Position.
CHAPTER 10
STATE UNIVERSITY OF NEW YORK AT BUFFALO

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INTRODUCTION
The goal of the Chain-Driven Seven-Speed Wheelchair, shown in Fig. 10.1, was to provide its user with greater mobility than a traditional wheelchair. Traditional wheelchairs, although intended to increase mobility, often create restrictions. Their speed is limited by the user’s arm strength and range of motion. The range of inclines that users are able to navigate is similarly restricted. This device addresses both of these issues. It adds an adjustable amount of mechanical advantage to the user’s input (arm motion), thus allowing him or her to travel at a faster rate of speed, or with greater output torque, than would be possible in a typical wheelchair. The mechanics of the device are such that they can be controlled by the user as they are traveling. Different “gears” can be chosen depending on the ground characteristics or the user’s desire (see Fig. 10.2).

SUMMARY OF IMPACT
This device can expand the range of recreational activities in which a person who uses a wheelchair can participate. By enabling people who use wheelchairs to move at a faster pace, they can more easily accompany others while they participate in activities requiring such movement. The increased ability to take part in activities and keep up with those not using wheelchairs can provide greater independence and confidence.

The gearing system in place on this new device allows a range of different outputs for the same input, thus making a more efficient use of the energy input. Brakes on a traditional wheelchair are generally four-bar locking mechanisms. They are either ‘on’ or ‘off’. While this is good for keeping a wheelchair stationary once it is in a desired position, it does not work well for slowing the wheelchair to a gradual stop. This new device makes use of pressure sensitive brakes, which are actuated from a convenient location for the user. In addition to allowing the user to decrease speed safely, these also can be helpful while navigating steep inclines. By squeezing the brake controls a user may pause on an incline. To continue he or she needs only to release these controls.

While the prototype only retains a small amount of the wheelchair’s collapsibility (due to fabrication limitations), in actual production the modified wheelchair would fold as well as a traditional wheelchair. The benefits of this feature will be the same as a normal wheelchair; however, more significance will be placed on the ability to pack up this new wheelchair to take it to parks and on trips.
An operator of this new device will have a wheelchair which is easier to use, is more capable, and has a greater range of motion than a typical wheelchair. This device will allow him or her greater freedom. Use of this wheelchair could help accelerate rehabilitation or, in the case of permanent use, lead to a more active and healthy lifestyle.

TECHNICAL DESCRIPTION

The device is designed around an alternative propulsion method. Instead of the traditional wheelchair input, which is tangential force on the outer edges of the large wheels, this device has input levers in a more ergonomic location. They are positioned right where a user’s hands comfortably rest, past the ends of the armrests (see Fig. 10.3).

There is one lever on each side of the device, each controlling the motion of the corresponding wheel. These levers each rotate a driving sprocket, which is linked by chain to a sprocket cassette located axially on the large (driving) wheel. This cassette contains seven sprockets of varying size (see Fig. 10.2). Although the gear settings are controlled independently on the prototype to retain maximum flexibility during testing, their incorporation into a single control could be easily accomplished in production if the current system were determined to be overly complicated for a typical user. Furthermore, a second set of gear sprockets could be utilized to add additional versatility to the wheelchair by providing more gear ratios similar to that found in a bike. In the prototype, the driving sprocket is a set selection. If the gear sets were codependent and controlled from a single controller, utilization of the second set of selectable sprockets would become possible, resulting in even greater adaptability.

Through the use of a derailer, the chain can be moved to each of the seven sprockets. This gives the device selectable mechanical advantage. For a given input, the user can select an output that can offer a high torque and low speed, or a low torque and high speed, depending on his or her current needs. The controls for these derailers are located right on the input levers, allowing the user to change the sprocket ratios during travel. Each sprocket can be selected by making use of the gear shifter mounted on the control lever (Fig. 10.4). These shifters change the tension on a cable leading to the derailer. They are calibrated so that a detent in the shifting mechanism corresponds to the proper tension required for the selected gear.

The input levers do not make full revolutions. They are pushed forward through a partial revolution (varying from 100 to 150 degrees, depending on the user) and then pulled back to their initial position before being pushed forward again. The chain is only engaged when the controls are being pushed forward. When they are being pulled back, a ratcheting mechanism prevents the driving sprocket from turning, thus keeping the chain stationary with respect to the sprocket cassette. This is necessary because the derailer requires that these sprockets go through a ¾ revolution in order to change gears. This means the chain cannot travel backward, as that would undo any progress it has made switching
between gears. One of the disadvantages of this particular driving mechanism is that the mechanism cannot power the chair backward. The wheels must be gripped and moved like a traditional wheelchair to accomplish this. This limitation results from the bicycle mechanism itself, which does not allow for a powered “reverse” mode. Time constraints prevented the pursuit and incorporation of a selectable “reverse” gear; however, its inclusion would make the gear system more complete.

The wheels are spaced slightly farther apart than they would be on a traditional wheelchair. This provides greater stability, as does the use of wider rubber air-filled tires. These tires also allow the chair to travel more easily over rougher terrain than could a traditional wheelchair by taking advantage of deep traction grooves. For instance, the user could easily transition from a paved surface to a grassy field with minimal additional effort. These tires also provide increased traction which contributes to its overall safety. The tires resist sliding on slippery surfaces and by gripping the ground better when braking fast, contribute to a quicker, more controlled stop.

In many cases it will become necessary for the user to decrease speed. Pressure controlled brakes allow this to occur in a smooth controlled manner. On each wheel rim there is a clamp that, when actuated, presses rubber against the wheel and causes the device to slow down. The controls for the brakes consist of levers which put increasing tension on a cable. The cable leads to the aforementioned brake clamps, causing them to close together and press against the wheel rim with a force proportional to the applied tension (see Fig. 10.4).

The wheelchair steering is accomplished through the use of independent control levers. For gentle turns, one control can be operated while the other one remains motionless, or moves at a slower speed. This device is also capable of completing tight, fast turns. Instead of leaving one wheel free one can apply the pressure sensitive brakes on the control to lock it in place. This causes the wheelchair to pivot around the stationary wheel which means that the turning radius is limited only by the width of the device.

Since the goals of this device are comparable to those of creating a bicycle, there are many safety considerations. Armrests were created to keep the operator’s hands and arms away from the sprockets and chains. These armrests function as guards but are also cushioned for comfort, as can be seen in Fig. 10.5. A seat belt was included to keep the operator safe and secure. Although not illustrated, a helmet should also be worn at all times when using this device. The device is shown in Fig. 10.6.

The total cost of this device was $381, not including the wheelchair, which was donated.
Fig. 10.6. User Operating the Device.
INTRODUCTION
The Wheelchair Pouch is a device to be used on a wheelchair to store personal items such that persons with limited hand function are able to access them with ease. This personal foldable pouch, shown on a wheelchair in Fig. 10.7 and alone in Fig. 10.8, is designed to fit on either arm of a wheelchair to accommodate all users. The goals for the pouch were that it be easy to use, convenient, durable, inexpensive, and aesthetically pleasing.

SUMMARY OF IMPACT
The convenience of this device will benefit anyone who uses a wheelchair and has limited use of his or her hands. The pouch increases user independence by providing storage and quick, easy access to personal items. It is simple, durable, lightweight, and easier to use than a pocketbook. The handle is placed strategically and Velcro is used as the closure mechanism so that any user can independently access his or her belongings.

TECHNICAL DESCRIPTION
The design of the pouch was based on a discussion with a person with paraplegia and a physical therapist. Weatherproof vinyl was used to manufacture the pouch because it is durable. Cardboard and a flexible fiber material were added to provide stiffness and form.

The device is shown alone in Fig. 10.8, partially folded. The dimensions of the pouch are 7 by 19 inches unfolded and 6 by 7 by 1 ½ inches folded. In the folded position, the pouch can hang on the arm of a wheelchair via two small loops. It is kept closed using hook and loop fasteners. A large loop handle is attached near the inner side of the wheelchair arm. This allows for the user to slide a hand into and pull the fasteners apart, opening the pouch. The pouch then unfolds onto the person’s lap like a book, as in Fig. 10.9. There, a cell phone, a mirror, or any small item may be stored and tucked away for later access. The pouch has three sections, two of which are for personal storage.

A standard sewing machine with a leather needle and black thread were used to stitch the pouch. The vinyl and reinforcement were stitched together along with the two small hanging loops. The large handle loop was then stitched, followed by the hook and loop fasteners. Fabric glue was also used to secure the fasteners to the storage compartments.

The design was tested using a cell phone as a personal item stored in the pouch. The final assembled pouch is simple and sleek. The completed pouch weighs approximately one pound.

The total cost of this project was $25.
Fig. 10.8. Wheelchair Pouch Partially Folded.

Fig. 10.9. Wheelchair Pouch in Use.
INTRODUCTION
Most exercise stations on the market today are designed to target a particular muscle group; thus, to work on various muscle groups one has to move from one machine to another. The Wheelchair Accessible Exercise Station, shown in Fig. 10.10 can assist anyone who uses a wheelchair to take advantage of multiple exercises on one machine.

SUMMARY OF IMPACT
The Wheelchair Accessible Exercise Station allows individuals who use wheelchairs to perform varied exercises. They can target the upper and lower body, without the hassle of moving from one machine to another. By incorporating various exercises into a single station, this device helps the user stay in shape and maintain overall health.

TECHNICAL DESCRIPTION
This device is comprised of two main components: the exercise unit (frame) and the base. The frame is the upright section where the pulleys, cables, and weights are located, while the base is the part into which the user rolls his or her wheelchair (see Fig. 10.11). Both the frame and the base are constructed of 1 ¾-inch square 18-gauge steel tubing. Steel tubing was selected because the device has to be strong enough to withstand heavy and repeated loading. The frame measures 73 inches high by 31 ¾ inches long and the base measures 70 inches long by 31 ¾ inches wide. These dimensions were chosen so that the device can accommodate a wide range of users.

To use the device, the user wheels into the base and secures the wheelchair in place with the help of a rod located on the base. The user can choose to perform exercises such as cable pull-down, as shown in Fig. 10.11, or cable pull-back, shown in Fig. 10.12.

A cable and pulley system is used to help pull the weights up. In addition the user can engage muscles of the lower body by using the stair-stepper that is attached to the base. The stepper can be easily detached from the base when not in use to provide more leg room.

For ease of shipment, the exercise station is designed to be easily disassembled.

The total cost of the project was $191.
Fig. 10.11. Cable Pull-Down Exercise.

Fig. 10.12. Cable Pull-Back Exercise.
COLLAPSIBLE WHEELCHAIR LIFTING SEAT

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INTRODUCTION
The objective of this project was to design and build a seat to lift a person who uses a wheelchair for transfer to or from a bed. Currently straps are often used to lift a person from bed. Caretakers as well as people who use wheelchairs can become injured from moving and placing these straps into position. A solution to this problem, shown in Fig. 10.13, is a collapsible seat for transfer to and from a wheelchair. Design requirements include a collapsible seat that can remain beneath the user while sitting in a chair or lying in bed.

SUMMARY OF IMPACT
The collapsible lifting wheelchair seat provides assistance to people who use wheelchairs and their caregivers, and in addition provides comfort. Straps can be removed and adjusted, which permits a person with no or reduced abdominal strength or fractured vertebrae to be lifted. This is achieved by allowing the person to recline into the seat.

TECHNICAL DESCRIPTION
The seat consists of a nylon waterproof canvas with military brass grommets. The canvas distributes the load evenly across the seat. It also allows for reliability and compactness.

Carabiners are used to attach the seat hoist. The carabiners are load rated for 600 pounds and can easily be attached or detached from the seat. Polyester webbing load rated at 1200 pounds is attached to the carabiners with industrial strength stitching to serve as adjustable arms to lift the seat.

Fig. 10.13. Collapsible Wheelchair Lifting Seat.

Two stainless steel O-rings loaded for 2500 pounds are located where the seat is attached to the lift, as shown in Fig. 10.14. These rings have an inner diameter of 2 inches and a material diameter of 5/16 inches and can be easily attached to a series of lifts.

A double-fold cushion covers the seat and can be easily removed by pulling apart the hook and loop fasteners that attach it. Also, the cushion can be washed by removing the inner cushions from the cover through a series of zippers.

Six arms and a chest strap ensure stability of the seat on the hoist and the safety of the user. Each of the arms is attachable and detachable and a series of color-coordinated markers allows the user to connect the correct strap with its position on the seat.

The total cost of the project was $124.
Fig. 10.14. Lifting Seat Loaded onto Hoist.
INTRODUCTION
The Shoulder Steerable Tricycle, shown in Fig. 10.15, was designed to provide a means of transportation for people who do not have full use of their arms. Traditional bicycles are steered by moving the handlebars; this tricycle can be maneuvered through shoulder movement. The rider simply fits his or her shoulder into the specially made shoulder clam to control the direction of the tricycle. Also, activation of the brakes is incorporated into the pedals, rather than at the handlebars.

SUMMARY OF IMPACT
This project eliminates standard hand-operated bicycle braking and steering systems and substitutes foot braking and shoulder handling mechanisms. The result is increased independence and mobility for those who otherwise would not be able to use a bicycle.

TECHNICAL DESCRIPTION
The Shoulder Steerable Tricycle consists of a pedaling and braking mechanism, and a shoulder handling mechanism. The tricycle is driven by two front wheels and direction is changed by steering its rear wheel. A gear chain located at the center of the double wheels is used to drive the shaft of the two front wheels. The gear chain is linked to a coaster brake hub installed at the front of the tricycle. The coaster brake hub allows single direction pedaling. The rider pedals forward to move the tricycle, and backward to engage the brakes.

The shoulder mechanism is comprised of a differential and a shoulder harness. The differential component, shown in Fig. 10.16, is important to avoid confusion of the turning state; without it, the actual direction of this rear-wheel-steered tricycle would be opposite the movement of the body. The differential was installed with the function of reversing the steering direction so that shoulder movement to the left results in a left turn, and vice versa. This makes steering more intuitive to the user.

The shoulder harness, shown in Fig. 10.17, is attached directly to the differential, which allows the rider to be secured to the steering device.
The prototype works in accordance with the design specifications. The only major problem of this design is the small turning angle of the tricycle. The maximum turning angle for this tricycle is 20°, but the intended turning angle was 45°. Observation and analysis of this problem lead to a solution of installing a two-to-one gear transmission to increase the turning angle.

The total cost of the tricycle was $239.
INTRODUCTION
The objective of the One-Handed X-Box Control Joystick was to enable a person who has limited or no mobility in his or her arm to interact with X-Box video games. The standard X-Box controller requires two hands to play a game while this new design implements every function on the paddle in a configuration that can be operated with one hand. The final product, shown in Fig. 10.18, was constructed by modifying a store-bought joystick to include all of the features and functions of the standard X-Box controller. The controller may be built for use with the right or left hand. With its square base, it can be placed on an arm of a chair, a desk, a coffee table, etc., without slipping. It is a mobile unit and can be used on any X-Box system.

SUMMARY OF IMPACT
Playing video games is a popular activity among people of all ages. It is typically a two-handed procedure, leaving out those who do not have full functionality of both hands. With this design a person who has the use of only one hand due to amputation, birth defect, or injury is able to play a video game. This device allows individuals with a lost or non-functioning hand to enjoy video games alone or in a social setting. Fig. 10.18 shows the hand placement on the joystick.

TECHNICAL DESCRIPTION
The prototype of this design was constructed from a joystick and an X-Box control paddle, purchased off the shelf. The control joystick has two parts: the handle and the base. First, the joystick handle was modified to allow more wires to run through it. Next, different sized holes were tapped in the handle to accommodate the additional buttons needed to emulate the X-Box controller functions. A metal housing was bolted onto the top of the handle for a 360° switch, shown in Fig. 10.19. Finally, electrical tape was used to cover the wires running down the handle.

Fig. 10.18. Joystick Assembly Hand Placement on Joystick.

The purpose of the base is to store all of the wires used in the handle and throughout the control joystick. It also houses the main circuit panel of the unit. The base was designed for stand-alone stability and it was fabricated from a high strength, low weight polymer. Several 90° metal braces were bolted to the base to add strength and durability. Once the user interface and casing was complete, the circuit board from the X-Box control paddle was soldered into place to connect to the new controls. A low wattage soldering gun was used to prevent against heat damage to the waffle board.
The device was tested by a 14-year-old boy, who was able to enjoy playing many different video games for several hours. As all of the control buttons were proven to be functional, the design is a success.

The cost of this device was $80.

Fig. 10.19. 360° Switch on Joystick.
INTRODUCTION
People who have limited vision often experience more difficulty seeing objects in low-light environments. The Light Emitting Slipper, shown in Fig. 10.20, was designed to provide illumination to help these individuals see better while walking around the house at night. The sources of illumination are lights mounted in the front of the slipper. Although this product was designed to assist individuals with vision impairments, it could be used to increase visual perception for anyone while walking in the dark.

SUMMARY OF IMPACT
The concept of nighttime illumination applied to slippers has already been developed and produced. This product will impact the users in a more positive way due to advantages it has over others. They include: 1) more light sources; 2) a focusing function to ensure optimum light beam distribution; and 3) a power management system. These slippers combine user comfort with the proper light displacement necessary to increase visual perception at night.

TECHNICAL DESCRIPTION
There are three technical aspects of this product that distinguish it from similar products:

- A multi-source lighting system;
- A light-focusing function for each slipper; and
- A power-management system using a tilt sensor and phototransistor.

Each slipper provides three separate light sources to ensure that the maximum amount of light is provided. Most of the similar products researched provide only one light source in the form of an LED. The lights used in this design are small light bulbs surrounded by reflectors to project a solid beam of light, expanding outward as it extends further from the slipper. The light sources are located at the front of the slipper’s sole to concentrate all of the light in front of the user. These lights are also connected to the circuit in a series configuration. The inner electrical components can be seen in Fig. 10.21.
The light bulbs are secured into a male bulb housing, which is threaded to mate with a female housing that protects the bulb and also contains the light reflector. This assembly is similar to that of a flashlight. This approach was taken in order to allow light to be focused to the optimum beam projection before the slipper is fully assembled. Adjustments are made by twisting the female housing tighter or looser onto the male bulb housing, which changes the bulb position with respect to the reflector. The greater amount of light provided to the reflector, the more concentrated the light beam will be and the further it will be directed from the slipper.

Three AAA batteries provide 4.5 volts of power to the circuit. They are secured in a battery pack in the heel of the slipper sole (See Fig. 10.22). Wires are directed to a circuit board through wire channels built into the sole. The circuit that powers the light sources was designed to act as a power management system, to ensure that power is used only when necessary. The circuit uses NAND gates and inverters to interpret the signals sent from each sensor. When motion is detected, a tilt sensor sends a signal of one to an inverter, converting it to a zero. This signal proceeds to a NAND gate.

If a zero and anything else is detected, a one is distributed to the next NAND gate which is connected to a phototransistor. If this detects darkness, the NAND gate receives a zero, which recognizes a one and a one, producing a zero, and charges a capacitor so the lights stay on. The lights will stay on eight seconds after no motion is detected, and distributes a zero to another inverter. This is converted to a one again, which trips the Darlington transistor and the lights turn on.

If at any time the phototransistor, located in the back of the slipper sole (See Fig. 10.23), detects light, then a signal of zero is sent through the circuit, tripping the NAND gate, cutting off power to the circuit.

The total cost of this project was $85.
LIFT-UP OVEN RACK

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INTRODUCTION

For people with knee or back pain, moving a heavy item into or out of an oven can be a challenging task. Additionally, leaning over a hot oven door can be quite dangerous. The goal of this project was to create a device to assist in lifting or lowering items into an oven. This device is also intended to allow the oven rack to be held in place at stovetop level.

SUMMARY OF IMPACT

The Lift-Up Oven Rack, shown in Fig. 10.24, allows users to place food items on or take them off the oven rack without having to bend over. With its elevated handle, people who are only able to use one hand can also benefit from the Lift-Up Oven Rack. An additional advantage of the device is its ability to be installed into existing ovens.

TECHNICAL DESCRIPTION

The Lift-Up Oven Rack was designed to be installed in existing ovens; however, as ovens vary in size, it should be noted that the device described here was designed specifically to fit the following inner oven dimensions: 15¾-inch height, 22¾-inch width, 18-inch depth.

A working prototype was not created for this project due to the need of high temperate roller bearings for the slider. A mostly wooden prototype was therefore created to demonstrate the general concept of the design.

The foundation of the design is a parallelogram mechanism with four-bar linkage. The parallelogram design, which guides the path of the rack, ensures that the rack remains level. The mounting shelf made of sheet metal (See Fig. 10.25) allows the device to slide into the existing oven on its top rack level.

Wooden triangles are attached to each side of the mounting shelf, providing the stationary axes of rotation for the parallelogram mechanism. Two 18-inch steel bars pivot freely in two holes drilled in each triangle. The bars extend down from each triangle and connect to two identical triangles below (See Fig. 10.26). Thus, there are four triangles and four bars in all, making up the four-bar mechanism.

Because of space limitations and oven rack height requirements, a slider was needed to slide the rack out of the oven before lifting up. A set of 16-inch full extension ball bearing slides were mounted on the lower two triangles. A wooden rack was then

Fig. 10.24. Lift-Up Oven Rack.

Fig. 10.25. Mounting Shelf Pulled out of Oven with the Rack in Lowermost Position.
mounted to the sliding mechanisms on both sides, connecting the four-bar mechanism. Although adding the rack did increase the stability of the mechanism, a rod was installed beneath the rack, connecting the two lower triangles for additional support. A metal handle was then added to the rack to aid lifting. Fig. 10.27 shows the rack fully extended from the oven, in the lowermost position.

To hold the rack in the uppermost position, as shown in Fig. 10.28, a ledge was added to the underside of the mounting shelf. When in its uppermost position, the rack slides back slightly so that it rests on the ledge.

Although changes in material selection would have been made if it were being designed for production, proof of concept was shown.

The total cost for this project was $16.
INTRODUCTION
Entering and exiting a vehicle is a common task that can be difficult for those who use a wheelchair. To alleviate this difficulty many lifting systems have been developed to lift safely the user out of his or her wheelchair and place him or her safely into the passenger or rear seat of a vehicle. Current lifting systems are not portable and are designed for exclusive use with large vehicles that have a considerable amount of interior space, such as a van or mini-van. Most often these units must be permanently installed on vehicles, thereby altering the vehicle from its original condition. The innovative design presented here and shown in Fig. 10.29 maintains the structural integrity and functionality of existing lifting systems, plus it is easily transportable, may be stored in the user’s trunk, and may be used with a wide range of standard wheelchairs and vehicles.

SUMMARY OF IMPACT
As of 1997, the National Highway Traffic Safety Administration estimated that approximately 100,000 vehicles on the road had been modified by adding a wheelchair lift. These numbers demonstrate the need for a portable, more user-friendly device that accomplishes the same function as the permanent wheelchair lifts. The strong, lightweight materials used here and the collapsibility of this new design allow users to easily transport the device itself and then use it to transfer a person from his or her wheelchair to a vehicle. The key advantages of this device over existing lifting devices are that it is portable and that it does not require permanent modification of the wheelchair or vehicle.

TECHNICAL DESCRIPTION
The system consists of the main lifting section, telescoping legs, and a customized seat harness (See Fig. 10.30). This lifting device utilizes a modified lightweight aluminum racecar jack. The lifting point for this jack incorporates both vertical and horizontal movement. The horizontal component, along with the tendency of the unit to lean forward, was addressed by designing a linkage that connects to the rigid portion of the lifting section and the upper part of the moving tower.

The lifting tower, rigidly connected to the aluminum jack, consists of a slot to insert the fork-lift bars, which then attach to the seat harness. These bars, made from a high strength alloy steel, are easily
attached and secured by using quick-release push pins. All of the components that can be disconnected from the main unit can be placed inside a slot within the main unit when it is in its collapsed position, as shown in Fig. 10.31. This allows for easy storage, preventing the misplacement of pieces.

Two telescoping legs connect to the main lifting section with quick release pins. These pins are also used to lock the legs in the fully extended position. The length of the fully extended legs must be longer than the lifting point (location of the seat harness). Attached to the end of each leg are hard rubberized casters, which provide ease of movement.

The third assembly component is the seat assembly. The seat is constructed of heavy-duty canvas material which covers a wood base and composite wood board backing. It has a hinged back, which allows for easy storage. The seat assembly is intended to be placed into the wheelchair prior to the user entering the wheelchair. Once the user is placed into the wheelchair, the seat assembly latches onto the fork-bar and hoists the person into the passenger seat of the vehicle.

Although the total weight of the system is approximately 82 pounds, the weight of all of the separate detachable pieces totals around 30 pounds. The unit could be made lighter by removing sections of the outer housing that were built around the aluminum jack, replacing the ¼-inch aluminum that was used to ensure a high factor of safety to 1/8-inch, or changing the material of the legs to aluminum square tubing instead of galvanized steel.

The cost of this device was $300.
INTRODUCTION
The goal of this project was to devise an affordable support and harness system that would fit over any existing treadmill. This unit was made to be capable of being taken down and stored out of the way. The harness of the system is shown in Fig. 10.32.

SUMMARY OF IMPACT
The Treadmill Guardian Angel is strong and sturdy enough to prevent individuals on treadmills from falling and potentially injuring themselves. This apparatus will allow individuals to rehabilitate from injuries at their convenience in their own homes. Persons living with disabilities will be more confident in increasing the intensity of their therapeutic exercise on their own knowing that they have a safety net should a leg give out or light-headedness occur. This product will enable those who are not able to attend physical therapy outside the home to help themselves gain strength and flexibility through exercise.

TECHNICAL DESCRIPTION
The Treadmill Guardian Angel, shown in Fig. 10.33, is a supplement to any treadmill. It consists of five pieces of cold drawn steel tubing of 1 7/8-inch diameter, two nylon ropes, and a harness. The tubing and rope selected are rated to withstand in excess of 300 pounds. The harness and D-Clips are rated to withstand a 10 kilos Newton load. The harness height is adjustable as is the harness itself, allowing for a snug, comfortable fit for people of various heights and sizes. The overall dimensions of the Treadmill Guardian Angel are 84 inches wide, 82 inches deep and 90 inches tall, which allows it to accommodate a wide variety of existing treadmills. The Treadmill Guardian Angel was weight tested up to 250 pounds dynamically loaded and 270 pounds statically loaded. The four legs have smooth 6-inch-diameter circular plates mounted to their base to help distribute the user’s weight.

The steel tubing of the Treadmill Guardian Angel must first be assembled. The ropes must be installed on the top tube crossbeam. The structure is then centered over a treadmill. The individual must put on the harness and tighten it to a snug fit. Next, the user simply attaches the harness to the rest of the structure with two simple D-clips. The ropes are then adjusted to eliminate any slack.

The cost of this project was $340.
Fig. 10.33. Complete Treadmill Guardian Angel System in Use.
INTRODUCTION
The Carpet Cleaner Attachment for a Wheelchair, shown in Fig. 10.34, is a device that allows persons who use wheelchairs to easily vacuum a carpet. This device can be installed on a standard wheelchair without any modification and can be easily detached. The attachment is adjustable so that the user can lower the cleaner to the floor to clean an area of carpet and raise it when it is not in use.

SUMMARY OF IMPACT
This device enables people who use wheelchairs to clean a carpeted area by themselves. The user can easily attach and detach this device without help from others. It increases the user’s independence, and it may even help him or her to take advantage of employment opportunities in the housekeeping field.

TECHNICAL DESCRIPTION
There are six main components in the design: a modified hand winch, plastic clippers, a 17½ x 9½-inch piece of three-layered wood, a 2-inch spring, a cylinder, and ‘L’ brackets. Most of the components are made of aluminum, wood, or plastic. The dimensions of this device without attaching the carpet cleaner are 17 ¾ inches wide by 13 ½ inches high by 9 ¼ inches long. When the carpet cleaner is attached to the device, the dimensions are 17 ¾ inches wide by 15 inches high by 9 ¼ inches long.

Four plastic clippers, shown in Fig. 10.35, were installed on both sides of the wheelchair to ensure a firm attachment of the device to the wheelchair. The clippers also facilitate easy detachment.

The device is adjustable up to 1 ½ inches through a modified hand winch, a spring, and a cylinder. The details of this system are shown in Fig. 10.36. Using the ergonomic design of the handle, the user can turn the hand winch easily. A steel rope was used to connect the hand winch to the cylinder. Two pulleys were installed to allow the steel rope to move smoothly. Therefore, when the user desires to clean the floor the device is easily accessible, and when its use is no longer needed, the cleaner is secured 1 ½ inches above the floor.

The cost of this project was $112.
Fig. 10.35. Attachment Clips.

Fig. 10.36. Details of Cleaner Lifting System.
INTRODUCTION
The Simultaneous Multiple Keystroke Supplement for Keyboards, shown in Fig. 10.37, assists individuals who have had an amputation of a finger or arm in completing keyboard commands involving simultaneous keystrokes on a PC. For maximum functionality of the device at minimal cost the following four commands have been addressed: 1) Ctrl-Alt-Delete, 2) Shift-Delete, 3) Alt-Escape, and 4) GUI-E.

SUMMARY OF IMPACT
Several common computer functions require the simultaneous depression of multiple keys. Using the current standard keyboard design, it is challenging, if not impossible, for people who have had an amputation of one or more fingers or an arm to perform these simultaneous keystroke operations. The Keyboard Supplement enables such individuals
to complete the multi-key functions necessary for many computer related jobs and activities. The result is increased quality of life through greater computing capabilities.

TECHNICAL DESCRIPTION

The Simultaneous Multiple Keystroke Supplement for Keyboards is a 6 x 6 x 2½-inch box with four buttons on top and two six-pin mini DIN female receptacles on the back. One of the receptacles is for data input from the regular keyboard and one is for the data output (See Fig. 10.38). The top and back of the box are fastened with screws and therefore can be removed in order to access the logic board. Inside the box is a CME11E9-EVB board which has been wired and programmed to assign the appropriate PS/2 Set 2 scan codes to each button and send these codes to the PC via a six-pin mini DIN cable.

The standard keyboard plugs into this device so that all of the keyboard data, regardless of origin, arrives at the PC via the same cable. As a result, the PC will not detect a difference between a standard keyboard and the supplemental keyboard. Because of the way the device is wired, the logic board can easily be programmed to reassign the scan codes of any key on the standard keyboard as it passes through the device. For example, the device can be programmed to output the print screen scan codes when the F12 key is pressed on the regular keyboard. This is possible because all of the data are passing through the device already, and a simple line of computer code calls for the replacement of a specific scan code should it pass through. This will allow effortless personalization of this device to each user's specific needs.

The cost of this project was $138.

Fig. 10.38. Internal Components.
MANUAL WHEELCHAIR WITH PNEUMATIC HEIGHT ADJUSTABLE SEAT

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INTRODUCTION
The device shown in Fig. 10.39 was designed for use with a wheelchair. The goal was to provide easy access to high tables and countertops, cupboards, shelves on demand, while allowing the usual lower ride height associated with unmodified wheelchairs. The product was designed to be lightweight and collapsible and to allow for transport and storage.

SUMMARY OF IMPACT
People who use wheelchairs may experience limited reach or sight due to the fixed height of their wheelchairs. This device addresses these limitations by providing convenient height control anywhere inside or outside the home. This device increases the independence of the user by extending ranges of reach and sight.

TECHNICAL DESCRIPTION
The base for the additive hardware is a standard collapsible wheelchair made by Everest and Jennings. U-brackets were made to fit over the upper bars on the chair. Holes were drilled to match the pattern on the foot mounts provided with the cylinders. The foot mounts and cylinders were purchased from McMaster Carr. The air cylinders are aluminum and double-acting, which provide 90 pounds of force at 100 psi each. Standard pneumatic lines and fittings were used to control the inflow to and outflow and from the cylinders. Fig. 10.40 provides a detailed view of the lifting system.

With air pressure supplied by an outside source, the cylinders raise the seat to a maximum increase of eight inches (See Fig. 10.41). The air can then be bled out of the cylinders to the atmosphere, comfortably returning the user to regular ride height.

The seat was taken from an office chair with similar dimensions to the unfolded stock seat. Rectangular

Fig. 10.39. Wheelchair with Adjustable Seat

½ x 1-inch steel stock was welded together to create an H-frame, to which the seat was bolted. At the end of each leg of the H-frame a hole was drilled to allow the ends of the cylinder rods to set in, and the whole frame was rested on nuts threaded tight to the end of the thread pattern on the rods. This arrangement allows the cylinders to have some flexibility during ascent and descent so that they do not bind up, which was a major design challenge. Collapsibility was accomplished by lifting the rigid seat frame off of the cylinders.
The wheelchair, pneumatic lines and fittings, and office chair seat were donated for this project.

The total cost of the project was approximately $150, not including a controller and pressure supply source that would be needed for operation.

![Fig. 10.40. Lifting System Components.](image1)

![Fig. 10.41. Adjustable Seat at Maximum Height.](image2)
ADJUSTABLE SEAT HEIGHT ATTACHMENT FOR WHEELCHAIRS

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INTRODUCTION
The Adjustable Seat Height Attachment for Wheelchairs, shown in Fig. 10.42, provides vertical mobility to people who use wheelchairs. The device is portable and can be used with any wheelchair. It allows users to sit at a standard wheelchair height during normal activities and to adjust their position as needed to reach or work at a higher surface such as a table or countertop.

SUMMARY OF IMPACT
This device provides safe assistance to wheelchair users to elevate vertically to a desired sitting height while in their wheelchairs. It minimizes users’ dependence on other people to reach things at a higher level and allows them to work on higher surfaces without moving to a different chair. Ultimately, it improves the quality of life of people who use wheelchairs by making everyday tasks easier.

TECHNICAL DESCRIPTION
This device is constructed of top and bottom plates that are Poly-Carbon, a material similar to Plexiglas but lighter weight. This material was selected because of its strength and ability to support the weight of an average person, as well as its clarity, which allows easy inspection of the inner parts. The top part of the upper plate has a cushion for user comfort (See Fig. 10.43). The cushion seat is attached to the device using hook and loop fasteners so that it can be easily removed for cleaning or substitution of a different cushion.

The bottom part of the upper plate is connected to an air spring bellow, which provides the force to vertically move the plate. The two sides of the upper plate are connected to the lower plate by scissors beams and a ratcheting device for stability. The two scissors beams, 1½ x 1½ -inch aluminum, are angled to provide support and stability while the height varies and vertical force is applied to the connecting plates. Aluminum was chosen as the beam material for its strength and light weight. At the connecting points of beam and plate, a ratcheting device was designed for additional stability at any desired height.

There are three levels of desired height, each allowing the user’s weight to be uniform to prevent any form of tilt. The desired height levels can also be changed easily from level to level using the
unlocking ratchet device and the valve to release the air from the bellow, as shown in Fig. 10.44.

The device at its maximum height is shown in Fig. 10.45.

The total cost of this project was $123.
INTRODUCTION
The Human Powered Off-Road Wheelchair, shown in Fig. 10.46, can go almost anywhere a bicycle can be ridden. The device is powered and steered solely through movement of the user's arms. A natural rowing-style motion exerted on handlebars, which are set on a slider, generates power. These same handlebars provide steering capability by simply turning them as one would turn the steering wheel of a car. The handlebars also contain a shifter to change gears and bicycle-style brakes to slow or stop the wheelchair. The design requirements for this device include ease of entry and exit, ability to accommodate users of all sizes, and intuitive operation.

SUMMARY OF IMPACT
This device allows people who use a wheelchair to experience the outdoors without needing smooth paved pathways. It provides an exciting new way to be independently active.

TECHNICAL DESCRIPTION
The wheelchair consists of four main components: the frame, drive system, steering mechanism, and wheel assemblies. The frame is comprised of welded aluminum tubing. The main components of the frame are 1 ½ inches in diameter with a 1/8-inch wall and the roll bars are made from one-inch diameter, 1/16-inch wall tubing. The frame provides structural stability to the entire vehicle and locations to mount other components. Two roller bars on either side of the vehicle protect the rider in the event of a rollover. They also aid in entering and exiting the vehicle by providing a stable place for an individual to hold while lifting into the seat.

The drive system is the most complex and significant aspect of the vehicle. It is comprised of several individual components including the slider body, drive links, drive shaft, front sprocket, Nexus hub, rear sprocket, and drive axle. The individual systems work together to provide power to move the vehicle forward.

The slider body is an aluminum box with a cylindrical rod protruding from it. Polyurethane rods were placed into holes that were cut in the square body. Handlebars were attached to the cylindrical rod on the slider body, which the rider holds to pump the slider body back and forth along a square tube. This square-profile length of aluminum was rounded and pressed into bearings on each end, allowing it to rotate. A bearing was pressed on the cylindrical piece so that when the slider body is rotated, the links attached to the outer race of the bearings do not rotate. These links, which are connected to the outer race of the bearing, are the drive links, which consist of two sets of two bars. The slider body along with the drive links creates a typical slider-crank four-bar mechanism.

The slider-crank converts transitional motion into rotational motion to spin the drive shaft. The slider-crank linkages were configured so that the free wheel mechanisms in the second links allow for one set of links to power the shaft in each stroke direction. A sprocket on the drive shaft spins and transfers power to the Nexus hub via a chain. The Nexus hub is a contained unit of planetary gears.
used on some bikes, which replaces the standard set of front and back sprockets. It enables a range of seven speeds and transfers the input to the rear axle via a second chain. The specific advantage of the Nexus hub is that it allows gears to be shifted at very low speeds or at a complete stop, a capability that is essential for an off-road vehicle.

The steering mechanism in Fig. 10.47 is comprised of two links, the first of which is connected to the slider shaft, and the second of which connects to the aforementioned link to the steering rods on the front wheel fork. A connecting rod in turn links the two forks together to ensure that they turn in unison.

The last major components of the vehicle are the four wheels and their associated assemblies. The rear wheels, shown in Fig. 10.48, came as a pre-assembled wheel and axle unit used to convert a two-wheeled bicycle into a tricycle. This component was ideal for the purposes of this project as it provides a way to power the vehicle effectively. All that was necessary was to connect the assembly to the frame and run a chain to the already-installed sprocket on the axle. The front wheels are two bicycle tires, which were attached to the frame with their respective forks.

The total cost of this project was $560.
ACTIVELY ADJUSTABLE CANE TO ASSIST STANDING FROM A SITTING POSITION

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INTRODUCTION
This project addresses the needs of individuals who require a cane or some other form of walking aid. The purpose of this project was to expand on the concept of a conventional cane so that it can be of greater assistance. Canes have a fixed length based on the standing height of the user. When a person is moving from a sitting position to a standing position, however, a normal cane often cannot provide the necessary leverage to help him or her stand. The modified cane shown in Fig. 10.49 is able to assist the user as a standard walking cane, but it also provides superior assistance as the user stands from a sitting position.

SUMMARY OF IMPACT
In many cases, individuals who use canes require another person to help them stand up from a chair. The modified cane is a portable device that can help anyone who uses a cane rise from any chair, anywhere. People who take advantage of these two canes-in-one will have more independence.

TECHNICAL DESCRIPTION
The cane consists of three major parts: a prefabricated ratcheting device, a slide rod, and a pair of telescoping rods. The ratcheting device, shown in Fig. 10.50, was taken from a caulk gun. It uses springs and small plates to form a trigger and a locking mechanism. The locking mechanism prevents the rod from sliding when it is not desired. The rod from the caulk gun was removed and replaced by a 40-inch-long slide rod. A set of two telescoping rods was attached to form the body of the cane. One of the telescoping rods was attached to the ratcheting device from the caulk gun using a caulk adhesive. The other telescoping rod was attached to the bottom of the slide rod with a pin.

The cane can be set to its minimum height, shown in Fig. 10.49, by first pushing down on the locking mechanism to unlock it. The ratcheting device can then be moved down the slide rod so that the telescoping rods are completely overlapping. At this height individuals can use the cane to help themselves stand up from a sitting position. Once a person is standing, the trigger can be pulled repeatedly, until the cane is at the maximum height, shown in Fig. 10.51. At the maximum height, the cane can function as a normal walking cane. The total weight of the cane is two pounds, which is comparable to the weight of other common canes.

The total cost of the project was $15.
Fig. 10.50. Ratcheting Device and Handle of the Cane.

Fig. 10.51. Cane at Maximum Height.
INTRODUCTION
Fitness centers often do not provide exercise equipment that is appropriate for use by people who use wheelchairs, which makes working out difficult. If people who use wheelchairs want to exercise they often have to find a facility that has equipment designed specifically for them. The Wheelchair Exercise Station, shown in Fig. 10.52, addresses this need by enabling people who use wheelchairs to get a full upper body workout in the privacy of their own homes. With the exception of initial assembly, the user can operate the station independently. Several different exercises can be done with this one device.

SUMMARY OF IMPACT
Exercise is essential to everyone’s health and well-being. For example, people that exercise regularly have a reduced risk of developing heart disease, high blood pressure, depression, and anxiety, just to name a few. The wheelchair exercise station allows people who use wheelchairs to do exercises such as butterflies, arm curls, tricep extensions, rows, and shoulder presses. The user can control the amount of weight that is being used in order to get the most effective workout without requiring the assistance of others.

TECHNICAL DESCRIPTION
The exercise station consists of a frame, two cables, two sets of wooden weights, six hooks with threaded ends (three on each side), four pulleys, and a grip on one end of each cable. The frame was built out of two-inch inner diameter PVC piping. Six hooks with threaded ends were attached to the PVC piping (three for each set of wooden weights) with the purpose of holding the pulleys in place. By using hooks to attach the pulleys to the frame, it is easy for the user to take the pulley off of one hook and place it on another in order to do different exercises. Only four hooks and four pulleys are used at one time (two for each set of weights) leaving one hook on each side unused. One hook is attached straight above the weights on the top pipe of the frame. One pulley is always attached to this hook. One of the two other hooks is used in collaboration with the hook that is always attached. The pulleys fit onto the hooks such that they are tight enough to stay on the hook but at the same time have a bit of freedom to move. The moving capability of the pulleys ensures that the user can perform a variety of movements. For example, two exercises that use the same hooks (such as arm curls and butterflies) work different muscle groups due to different motions. Arm curls involve a back and forth motion with the cables and...
butterflies take the cables across the body. This variation is possible because of the freedom that the hooks have to move around.

Rope was used as the cable in this project. One end of the rope has a rubber covering that serves as the grip, shown in Fig. 10.53. The other end of the rope is attached to the inside of a ¾-inch inner diameter PVC pipe. The PVC pipe extends vertically through the middle of a stack of wooden weights. There are two stacks of wooden weights, one on each side. Holes were drilled horizontally through the middle of the wooden weights and through the PVC pipe to allow the user to change the amount of weight used for each exercise. The weights each have semicircles drilled vertically through both ends. The weights were placed between two 2½-inch PVC pipes that run vertically. This makes it possible for the weights to travel in a straight line up and back down when an exercise is being performed, as shown in Fig. 10.54.

The cost of this project was $90.
STAIR TO RAMP CONVERSION KIT

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INTRODUCTION

The purpose of this device is to increase the mobility and freedom of people who use wheelchairs. Stairs often inhibit the movement of wheelchair users; however, having a compact set of stairs can be beneficial to save space. The Stair to Ramp Conversion Kit, shown in Fig. 10.55, allows the conversion of a set of stairs into a wheelchair ramp with the flip of a switch. The ramp can be custom built to the dimensions of any size stair.

SUMMARY OF IMPACT

The main impact of this project is the increased accessibility that results from having a wheelchair ramp. This ramp is designed to convert two or three average size stairs into a fully locking and retractable wheelchair ramp. It also enables those who do not want a large permanent ramp in their home to have a set of stairs as well. The design allows anyone who can operate a light switch to deploy or retract the ramp.

TECHNICAL DESCRIPTION

The system includes the ramp, stairs, motor, connecting rods, hinges, and electric switches operating as one unit. Flipping one of the three-way switches activates a reversible motor. The motor is connected to a threaded rod that begins to rotate. While the threaded rod spins, a nut travels along the length of the rod. Welded onto this nut are two metal strips with holes in them. This makes a traveling bracket. A universal rod end was aligned with the holes of the traveling bracket and secured together using a machine screw and nut. The other end of the universal rod end is connected to the ramp. As the nut travels across the threaded rod, the rod that connects the nut to the ramp is forced to raise or lower the ramp depending on which direction the motor is rotating. The universal rod end is important to allow a slight pivot in the connection since the angle between the connecting rod and threaded rod will vary. Fig. 10.56 is a close-up view of the mechanical components.

When the ramp reaches the desired position, the switch is flipped in the opposite direction to stop the motor. Either switch can cause clockwise or counterclockwise rotation of the motor since they are three-way switches connected to a reversible AC motor. A standard 120 Volt AC outlet supplies power.

When the nut reaches a bracket or the stairs block the ramp movement, the AC motor will be overloaded and will stall for a split second. After the
motor stalls, the rotational direction is reversed automatically. This eliminates the need for a complicated wiring system. Flipping either switch will reverse the motion of the ramp to either stair (see Fig. 10.55) or ramp mode (see Fig. 10.57), depending on the previous position.

The total cost of this project was $30.
AUTOMATIC TELESCOPING REACH EXTENDER

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INTRODUCTION
For people with limited mobility or for those who use a wheelchair, accessing an object that is out of reach from the sitting position can be difficult. The aim of this project was to provide a device that allows a person to reach and grab objects that are out of reach and bring them close with minimal effort. The Automatic Telescoping Reach Extender in Fig. 10.58 can easily extend to a desired object with the use of a trigger. It then grips the object with the use of a switch and retracts back to the user with the use of the trigger in another position. The entire device is compact for optimal portability and storage.

SUMMARY OF IMPACT
The Automatic Telescoping Reach Extender allows people who would normally be dependent on others for tasks such as picking something up or reaching for something out of range, to have the ability to complete these tasks by themselves. This device can be of help to people who use wheelchairs and those with back problems that limit their ability to bend down.

TECHNICAL DESCRIPTION
The project is based around the telescoping characteristics of three round thin-walled aluminum tubes. These tubular sections were taken from an extending pole that is normally used for reaching areas in houses for dusting or painting. The three sections are each of different diameters so that they can slide within the next larger diameter tube, extending or retracting a total of 14 inches. Fig. 10.58 shows the device in full retraction, while Fig. 10.59 demonstrates full extension.

The extension and retraction of the aluminum sections is achieved with the use of a DC servo. The servo is a small motor that is geared down in order to decrease the speed and increase the torque. A setup of 50-pound test fishing line is used to extend and retract the two smaller tubes. Extension is obtained by pulling one line that is directed by a series of pulleys through the smaller diameters. Retraction is achieved by a straight line attached to the end of the smallest tube. The power to pull the two lines is provided by a modified Futaba S3004 servo. The servo has been modified to allow the output shaft to rotate continuously without restriction when the trigger is pulled. A multi-diameter plastic spool was manufactured and
attached to the output shaft of the servo to reel the line as it is pulled. The special design allows for smooth extension and retraction of the arm when the trigger is toggled.

The diameters of the notches in the spool are critical because as one notch in the spool fills up with line, the other notch is feeding line back into the tube assembly, and slack must be minimized. This reduction of slack allows the user to stop the arm at any distance within the maximum reach and have the arm rigid and resistant to compression or strain. High tensile strength wire could be used to improve this performance.

The servo mentioned above is the main servo and is powered by a nine-volt battery. The direction of the servo is controlled by a double pull double throw (DPDT) momentary switch used for the trigger. The extension and retraction of the tubular assembly is limited by two mini lever switches. These switches stop the extension and retraction slightly before the maximum is reached in order to prevent stress on the servo and fishing line.

The rotation of these tubes is stopped using a pin and slot setup. The two smaller tubes have slots machined into them, and the two larger diameters each have a rivet that runs into these slots. The tube assembly is held into a plastic case from a cordless drill with the use of an aluminum collar. This drill case houses the main servo, spool, two DPDT momentary switches, a nine-volt battery, and wiring (See Fig. 10.60).

The other automated portion of the automatic telescoping reach extender is the gripper that is mounted at the end of the tubular assembly, shown in Fig. 10.61. The gripper is powered by a modified HiTec HS-65MG servo. This servo drives a threaded rod that goes to a coupler that is mounted in the gripper. The movement pushes or pulls one jaw of the gripper closed or open respectively. The location of the coupler dictates the speed with which the gripper closes as well as the force with which it grips. If manufactured, this location could be adjusted for various applications and performance requirements.

The gripper is mounted by use of an L-bracket, which allows a plastic part at the end of the tubular assembly to thread into it. The power for the gripper servo is provided by wires running through the tubes and down in the handle.

The total cost of the project was $228.
RADIO CONTROLLED BRACELET FOR OPENING DOORS

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INTRODUCTION
The Radio Controlled Bracelet for Opening Doors is a device worn around the wrist of a person to remotely activate motorized handicapped-access doors. By wearing the bracelet around the wrist, as shown in Fig. 10.62, it is readily available to the user. A simple push of a button on the bracelet opens doors that would otherwise be activated by pressing a wall mounted button. The device is mated with an existing handicapped door button to allow the current functionality to remain.

This device fits inside the electrical box so that, on the exterior, there would be no change to the door button design. The device was aimed to have a plug-n-play feature that would allow the person installing the button to simply swap out existing buttons with those equipped with the radio receiver device. The device utilizes the existing wiring and power supply that the current buttons use.

SUMMARY OF IMPACT
This device allows a person to easily activate automatic doors by pressing the button on the bracelet or by using the remote that can easily be attached to a key chain. With this device, powered doors can be opened much more quickly as the user approaches them. This way the wearer does not have to reach out to the mounted button or lose momentum while they wait for the doors to open.

TECHNICAL DESCRIPTION
This design uses a radio remote and receiver set from a remote car starter. The receiver is placed inside the existing button housing typically found mounted on the wall near the door it controls. Connection to the existing handicapped door button circuitry allows the door to be operated by remote control or by pressing the wall mounted button. This configuration allows general use of the door system so that users that do not have a remote are still able to operate the door.

Fig. 10.62. Radio Controlled Bracelet for Opening Handicapped Doors.

Fig. 10.62 features designs of both a keychain and bracelet. The adjustable wristband also allows this device to be fastened directly to a crutch or wheelchair arm. The bracelet itself is made of ABS plastic for durability. The process used to make the bracelet was stereolithography (SLA), or rapid prototyping.
First, an Audiovox AS9055T remote control car starter was stripped of all unnecessary parts to minimize size. Such parts included wires used to install the device on a car and excess length of the antenna wire. This insured that the starter would fit inside a standard MS Sedco square automatic door control box (Fig. 10.63).

The red light mounted on the top of the device serves the purpose of demonstrating that the button or the remote control device can close the circuit, and thus activate the handicapped-access door.

One problem addressed in the design was the proper supply of power to the device. The remote car starter runs on a 12 Volt DC setup, while the handicapped-access door button and the motor that operates the door itself run on 110 Volts AC. The best choice was to use an AC adapter with 12 volts of DC output by plugging into a 110 volt AC power outlet. To make the device easy to plug in, an old telephone power jack plug that matched in size was wired into the circuitry of the remote car starter.

Another design challenge was programming the remote car starter itself. The Audiovox AS9055T remote car starter required the calibration of the unit itself by reading a tachometer signal (engine speed) of the automobile telling the device that the car is running. The remote car starter is not being used in a car and there is no tachometer signal. A square wave generator and amplifier running an electrical signal at a frequency of 16 Hz, which is equivalent to 960 revolutions per minute, were used. This is an acceptable engine speed for the remote starter to understand, and allowed for proper programming. Once this programming step was complete, the remote starter worked correctly and gave the proper signal to close the electrical circuit and allow the door to activate.

The approximate cost of this device is $320.
INTRODUCTION
If a person who has limited mobility needs to escape from the first, second or third floor of a residence, there are few options currently available. Fire escape ladders are currently on the market and attach easily to any window. To successfully escape using a fire escape ladder, however, one must be in good physical condition and have unrestricted mobility. Thus, ladder devices are not beneficial to individuals with impaired mobility and limited strength.

The Multi-Story Window Fire Escape enables individuals with limited mobility to safely descend from a multi-story living arrangement to the ground in the event of an emergency. The device, shown in Fig. 10.64, attaches to a window and provides a secure place from which the occupant can descend. The device is electrically powered and can carry one person at a time. The occupant simply pushes a button and the platform is lowered safely to the ground. The platform can then be returned to the window and can be used by another occupant, if needed.

SUMMARY OF IMPACT
Since the device is powered, it can be used multiple times to save other people or even pets. The Multi-Story Window Fire Escape is unobtrusive and requires no modification to a building. To install, the unit is simply set in the window. Operation of this device is effortless and could potentially save lives.

TECHNICAL DESCRIPTION
The Multi-Story Window Fire Escape consists of three main components: the frame, platform and hoist setup. The frame is constructed of mild steel hollow 2-inch square cross-section tubing with a wall thickness of 1/4 inch.

The vertical support is 10 feet long and is welded to the horizontal support, which extends four feet at a 90° angle. To reduce the stress on this joint, a diagonal support spans from the end of the horizontal support to the middle of the vertical support. The window sill clip is constructed of the sill and wall support, which are both two feet in length. They are welded together at a 90° angle to each other and then welded to the vertical support, creating a clip. This forms one of the legs of the frame. The complete frame consists of two legs, which are held together by 34-inch leg spacers. There are six leg spacers between the vertical supports, one at each of the following locations: at the bottom, five feet from the bottom, at the end of window clip’s horizontal and vertical components, at the top of the vertical support, and at the end of the horizontal support.
The frame of the plate is constructed of the same material as the main frame. The platform is a four-foot square made of the mild steel hollow square tubing described above. The platform is covered in perforated 3/8-inch plate steel. The perforation serves to reduce weight and to prevent accumulation of rain or snow. Each corner is connected to a high test cable used to raise and lower the platform.

The final component of the Multi-Story Window Fire Escape is the hoist setup. The hoist setup is powered by a low-speed reversible high torque electric motor. The motor is mounted perpendicularly to the horizontal support. The spool shafts are 1-inch cold rolled steel with a 2-inch diameter at the cable spool. The shafts are held in place with completely sealed roller bearings to prevent the need for any future maintenance. The spool shafts are connected to the motor via a #60 roller chain and corresponding gears. The spool shafts are fitted with a 4-inch gear while the motor uses a 2-inch gear to provide an increase in torque. The hoist setup, shown in detail in Fig. 10.65, is sealed from the environment in a tin enclosure.

Proof of concept was demonstrated using a scale model. The mild steel was replaced with ¾-inch square aluminum tubing with a wall thickness of 1/8 inch. All dimensions were reduced to 3/8 scale. The hoist was powered by a 14.4 volt drill motor and bike chain was used to drive the spool shafts. The high test cable was replaced with 30-pound fishing line. The model in the lowered position is shown in Fig. 10.66.

The total cost of this project was approximately $300.
PORTABLE AUTOMATED MULTI-PILL DISTRIBUTOR AND MEDICAL NEEDS KIT

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INTRODUCTION

The goal of this device was to properly dispense medication over the course of one week. Similar existing products only provide stationary automation or portable pill trays. This design is a unique, low-tech approach that meets the need for portable automated medication dispensers. The Portable Automated Multi-Pill Distributor and Medical Needs Kit (see Fig. 10.67) was designed to be usable in travel situations so that people who require the assistance of pill distribution devices can maintain an effective, healthy medication regime. The pill dispensary is intended for one week worth of dosages, which could include 20 or more pills per day. This amount of medication could lead to confusion at any time, especially when traveling. A secondary function of this device is storage for other medical supplies an individual may require during travel. Such items might include diabetic testing supplies, general first aid supplies, epinephrine shots, and medical ointments.

SUMMARY OF IMPACT

A consistent medication regime is important to the continued health of any patient. This device was designed to provide portable automated multi-pill distribution for individuals that use many medications and medical products daily. This device can increase the patient’s independence by ensuring that the correct medications are distributed at the appropriate times without frequent visits from a caretaker. It also helps to ensure the safety of a
patient by protecting them from missed medication and incorrect dosages.

TECHNICAL DESCRIPTION
The prototype is made of wooden components due to this material’s ease of machining. If this product were mass produced, all of the parts could easily be converted to highly durable plastics.

The process of operating this device begins with assembling all of the pills needed for each day of the week. To load the machine with pills, the mechanism must be advanced by pressing the momentary switch located on the lid of the box, as seen in Fig. 10.67. Once the alignment of the slot and the pill void are in view, one day’s worth of pills can be deposited into the void. This process is continued until the user returns to the starting position. Then, the box is closed and the clock and alarm are set for the intended medication administration times.

When the alarm sounds, the user will need to turn off the alarm and press the momentary switch on the lid. The mechanism will advance to the next slot, and the pills will be dispensed into a cup located inside the box, shown in Fig. 10.68. The user will then open the box and retrieve the newly dispensed medication. At this point, the box is ready for the next medication distribution time.

The total cost of this project was $95.

Fig. 10.68. Internal Mechanism and Dispensing Cup.
WHEELCHAIR DIP STAND

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INTRODUCTION
The Wheelchair Dip Stand, shown in Fig. 10.69, is designed for use by individuals who use wheelchairs. The user sits in the device, then raises and lowers his or her body in a dipping manner to strengthen the arms and chest. It is safe and lightweight. It can be adjusted to target the chest and triceps. This device is ergonomically designed to fit a wide range of users, male and female, 12 years of age and up. It is relatively small and conveniently folds flat for easy storage.

SUMMARY OF IMPACT
This device is exceptional as a means of exercise for people who use wheelchairs. This specially designed dip stand could be especially beneficial to people who are beginning to use a wheelchair, helping build the upper-body strength required for mobility and daily activity.

TECHNICAL DESCRIPTION
Various ergonomic requirements were taken into consideration for the detailed design of the device. The primary restraints were dip height, dip width, grip diameter, and total weight. These criteria were modeled to the United States population of males and females aged 12 to 74 using the program People Size**. Users from the fifth to 95th percentile can be comfortably accommodated. Two critical design elements that allow this device to accommodate such a wide range of user body-types are the adjustability of all four legs by four inches each (See Fig. 10.70) and the pivoting arms.

The original design called for an aluminum frame; however it was decided that PVC would be a good alternative material, satisfying all design criteria, providing sufficient strength at a low cost, and weighing only 14 pounds. The frame of the device is composed of 1 ½-inch outside diameter, 1/8-inch wall PVC tubing, which includes eight joints and 86 inches of straight tube. Each of the four adjustable legs is made from 1 ¼-inch-diameter tubing, 6 inches in length with four drilled holes to provide an additional 4 inches of height range. Each leg is fit with a black rubber butt cap to provide stability on most surfaces. At its lowest setting the stand provides a dip height of 11 inches and a dip width of 16 inches, while at its highest setting it provides a dip height of 17 inches and dip width of 30 inches or more. Various combinations of height and width provide for a variety of exercises for a wide range of body types. Fig. 10.71 shows the device collapsed for easy storage.

An alternative version of this device may be constructed from 1-inch-diameter anodized
aluminum with 1½-inch outside diameter rubber grips. This design would be less bulky while maintaining the appropriate gripping diameter where necessary. With this material selection, based on weight, strength, and cost, the device could provide sufficient strength for a user weighing up to 300 pounds, would weigh approximately 10 pounds, and would be relatively inexpensive to produce.

The total cost of this project was approximately $25.

** People Size Version 1.40, Licensed to Colin Drury, Copyright Friendly Systems Ltd. 1994,1995
THERAPEUTIC INJURY MASSAGE

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INTRODUCTION
The Therapeutic Injury Massage device, shown in Fig. 10.72, was developed to allow patients to self-administer massage treatment.

SUMMARY OF IMPACT
The Therapeutic Injury Massage provides the convenience of independent massage treatment. This device could be used by athletes to provide stimulation of specific muscles or by any individual to administer a general massage for relaxation.

TECHNICAL DESCRIPTION
The Therapeutic Injury Massage uses pneumatic flow to fill two vesicles that have a known control volume. The filling rate and final volume are precisely controlled electronically with a programmed micro-controller. The device consists of: 1) one pump; 2) one microcontroller; 3) one pressure transducer; 4) three X-valves; 5) one six volt DC power supply; and 6) two vesicles (blood pressure cuffs). The normally-open ports of valve one and valve two are connected to control volumes one and two respectively, while the port of valve three vents to the atmosphere. The common port of valves one and two is connected to the pressure transducer while that of valve three is connected to the intake of the pump. The pressure transducer is connected to the exhaust of the pump. All three valves are connected to the same normally-closed port for venting. The pump and the transducer are connected to a battery-powered micro-controller.

The pump, which is powered by a six-volt DC power supply, inflates the control to a pressure of approximately 1.8 kips. This pressure corresponds to a voltage programmed in the micro-controller of 4.5 Volts DC. Once this voltage is reached, a series of pump and vent scenarios programmed in the micro-controller are activated. This throttles the vesicles and creates a pulsation effect, which is used to massage the area. There are eight scenarios because three valves are used. The pressure transducer measures the gauge pressure of the control volumes. It is programmed to accept a maximum gauge pressure of 2.4 kips; if this pressure is exceeded, the bladder will vent. As an auxiliary safety feature, the vinyl tube used for plumbing also dislocates from valve two to interrupt the air supply when maximum pressure is surpassed. Fig. 10.73 shows some of the inner components of this device.

Below is the software sequencing applied to run the pump continuously when power is supplied to the pump, x-valve, and processor.

1. Valve 3 (on) - Air supply to pump blocked and vent line open.
   
   Valve 2 (on) - Bag 2 to vent line.
   
   Valve 1 (on) - Bag 1 to vent line.

2. Sample pressure sensor for output < 1.0V DC.

3. Valve 1 (off) - Bag 1 to air fill line.
   
   Valve 3 (off) - Air supply to pump and vent line closed.

   Valve 2 (on) - Bag 2 to vent line.
4. Sample pressure sensor for output > 4.5V DC.
5. Valve 3 (on) - Air supply to pump blocked and vent line open.
   Valve 1(on)- Bag 1 to vent line.
   Valve 2 (on)- Bag 2 to vent line.
6. Sample pressure sensor for output < 1.0V DC.
7. Valve 1 (on) - Bag 1 to vent line.
   Valve 2 (off) - Bag 2 to air fill line.
8. Sample pressure sensor for output > 4.5V DC.
9. Valve 3 (on) - Air supply to pump blocked and vent line open.
   Valve 2 (on) - Bag 2 to vent line.
   Valve 1 (on) - Bag 1 to vent line.
10. Go to 2.

The total cost of this project was $524.
DEVICE FOR DETERMINING DIRECTIONALITY OF SOUND

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INTRODUCTION
The Device for Determining Directionality of Sound, shown in Fig. 10.74, is worn on the head. It receives sound input from the environment and converts it to visual representations that can be seen by the wearer. Two LED lights are mounted on the hat such that they can be seen in the wearer’s peripheral vision. The LED lights begin to blink in response to sound detected by the device. The blinking lights alert the user to the source of sound.

SUMMARY OF IMPACT
This device will allow people that have partial or complete hearing loss to be more aware of their environment. Since sound is often used as a means of warning, such as a car horn or emergency vehicle siren, it is especially important for a person’s safety that he or she be made aware of a sound source as quickly as possible. Such a device could save the life of a person with hearing loss. Additionally, this device has social benefits in that users can become immediately aware of someone speaking to them and where that person is.

TECHNICAL DESCRIPTION
The device has two circuits: one for each side of the wearer. (See Fig. 10.75) Each circuit contains an amplifying circuit that converts sound waves into light emitted by an LED. The LED was chosen because of its immediate and variable response to sound. The LED is able to emit high and low levels of light for the different levels of sound.

The sound is received by omni-directional microphones, shown in Fig. 10.76, so that sound can be picked up in a 180-degree cross-section. The gain of the circuit is controlled by a potentiometer. This potentiometer is important when adjusting the device for indoor or outdoor use. This is necessary because of the effect of sound waves bouncing off walls.

The two halves of the device oppose each other and when properly tuned, effectively pick up the sounds that are coming from their own direction as well as the other direction; however, the sound coming from their direction has a far greater amplitude and is thus displayed this way as the LED emits light.
Fig. 10.77 shows the batteries and electrical components that are housed in the utility belt connected to the hat. Fig. 10.78 shows the device in use.

The total cost of the prototype was $100.
CHAPTER 11
STATE UNIVERSITY OF NEW YORK AT STONY BROOK

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INTRODUCTION
The Chaircycle is the fusion of a wheelchair and a bicycle for individuals who normally use a wheelchair. The purpose was to create a practical way to travel short to intermediate distances on a daily basis. The Designers are shown creating the device in Fig. 11.1. It provides an alternative motion for propelling the wheelchair using cycling components. Users will be able to travel longer distances without having to switch their mode of transportation.

SUMMARY OF IMPACT
The Chaircycle will impact users by giving them a new degree of freedom and mobility. It will eliminate the hassle of getting into an automobile to travel moderate distances. The user can utilize the Chaircycle as an everyday wheelchair but can also use it to travel distances ranging from one to five miles on paved roads. This will impact users in their added motivation to travel and enjoy the outdoors. It will also give them another medium of exercise to improve cardiovascular health.

TECHNICAL DESCRIPTION
The Chaircycle provides an alternative input motion for propelling the wheelchair. Instead of directly spinning the wheels, the Chaircycle provides a more ergonomic motion in driving the wheels indirectly. This motion is made possible by a crank-slider mechanism. The rotational motion generated by this mechanism is transferred to an input gear, which is then transmitted to an output gear via a chain link. This output gear is attached to the 20-inch bicycle wheels. There are two identical systems, one for each side, which are not connected. They are completely independent to allow a method of maneuvering the Chaircycle. If the velocity of the right wheel is slower than that of the left, the Chaircycle will veer to the right and vice versa. The handbrakes, which are attached to each wheel and handlebar, can also provide maneuvering.
capabilities. These two methods work in conjunction with one another to provide sensitive and meticulous maneuverability.

The frame of the Chaircycle is constructed of stainless steel tubing of 1-inch diameter and 0.054-inch thickness (Fig. 11.2). There are a total of 14 individual pieces adding up to over 23 feet in total length. There are 20 weld points connecting the pieces to create the frame with eight 90-degree bends. The cycling components, which consist of the slider, input and output gears, chain link, connection hub, and main drive wheels, are all fitted into the frame, as shown in Fig. 11.3. The components work together (see Fig. 11.4) to provide the drive motion necessary to propel the Chaircycle to a speed over 10 miles per hour.

The total cost was $554.

Fig. 11.3. Exploded View of the Chaircycle.

Fig. 11.4. Isometric View
INTRODUCTION
The goal of this project was to design an adjustable weight support system to use with a treadmill. It was developed to alleviate stress for rehabilitation patients with neurological disorders of the lower limbs who want to revitalize or increase lower body locomotive functions. Such patients often have a hard time exercising and stimulating the lower body and often require assistance in their exercises. This support system eliminates the need for help from an assistant, allowing the patient to exercise independently.

SUMMARY OF IMPACT
The primary function of this machine is to hold and slightly lift the patient. This way the patient’s legs will not be required to support his or her total body weight. With less weight on the legs, the user is able to simulate walking motion more easily.

TECHNICAL DESCRIPTION
The device consists of a metal frame with a stack of weights held on the bottom. The weights are connected to a cable that runs through a hole in the middle bar of the structure. The cable then loops through two pulleys, one at the top plus an angled cantilever pulley. At the end of the second pulley a harness is attached. The harness, weights and pulley system are shown in Fig. 11.5.

To operate this device, a weight selector pin is inserted to counterbalance a selected amount of weight. The weights and pin are shown in Fig. 11.6. The harness is placed high enough to keep the patient’s feet from making full contact with the treadmill. In order to strap into the harness, the individual must step onto something slightly higher than the treadmill. The patient then steps down into the harness and can begin exercising, carrying just a fraction of his or her body weight. The frame is designed to fit electric treadmills of all sizes.

The frame is made of extruded aluminum tubing and is structurally safe for the purpose of alleviating a maximum of 100 pounds. Most stress is concentrated on the angled cantilever. With this in mind, welding was used to increase the strength of this component. A CAD drawing of the system is shown in Fig. 11.7.

The total cost was approximately $1013.
Fig. 11.6. Lower Half of Treadmill.

Fig. 11.7. CAD Drawing of Device (Isometric View).
INTRODUCTION
The objective of this project was to create an add-on device that can assist users with limited mobility in moving up and down stairs. To use the device, the user must be able to maintain a seated position in the chair as it ascends the stairs, and must be able to grip the device manually. In addition, the chair and device must be pushed and supported by a caretaker.

SUMMARY OF IMPACT
To suit the needs of the broad range of users, the add-on device attaches onto an already existing wheelchair. It enables the user in a wheelchair to scale stairs.

TECHNICAL DESCRIPTION
A schematic of the design is shown in Fig. 11.9. Track [A] is attached to Track Leg [B] via a rectangular piece, Track Adaptor [K]. Track Adaptor [K] acts as a joint connector with a bolt inserted through the bottom hole. Since this adaptor must be able to rotate, a shoulder bolt secures the two together.

Track Leg [B] is inserted directly into the Track Adaptor [K]. Here it is pegged on the side, in the upper hole, to keep it in place.

The Secondary Wheel [J] is made to be in plane with Track [A] in front of it, so that contact can be initiated. Fig. 11.8 shows the device at rest position. The Track’s lower edge is higher in this position.

Fig. 11.8. Isometric View of the Device.
than the Secondary Wheel [J].

Track Leg [B] is made of two segments, allowing it to extend and retract; the segments are made of two hollow tubes. The larger diameter tube is attached to the Track Adaptor [K]. The smaller diameter tube is located within the larger tube at one end, and the other end is attached to the Rod Ends [C]. Use of a spring latch allows the two bars to catch within each other, preventing further extension.

The Secondary Wheel Leg [I] is attached at one end to the Secondary Wheel. The other end is attached to the axis where the Rod Ends [C] turn.

There are a total of three other adaptors, not including the Track Adaptor [K]. The Front Track Adaptor [D] and Back Track Adaptor [G] both attach the Slider Tube [F] to the perpendicular joints of the wheelchair. Four-fingered or three-fingered grips are designed to be able to wrap around the wheelchair tubing. Nuts and bolts are then used to clamp the ends down.

The Sliding Tube Adaptor [E] is the most complicated of the four. This is because it is multi-functioning as a corner rotating joint. The Sliding Tube is inserted into one end of it and pegged down. On the other end is a square opening for insertion of the Rod Ends. In addition, there is a tube that enters the side of this opening to act as axis on which the Rod End rotates. The Rod End [C] is used as a rotating joint for the track leg.

To elaborate on the Sliding Tube [F], both ends are inserted into adaptors that are then pegged in. A slider attachment is attached to the tube. The Connecting Bar [H] connects the slider attachment with the outer tube of the Track leg assembly to cause the rotating and extension property.

The cost of the device is roughly $1000.

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Fig. 11.9. Component Breakdown of Design.
INTRODUCTION
The Multifunctional Quadricycle was designed for working parents of a family of four living in a suburban neighborhood. They wished to have more time for their children while also exercising and accomplishing chores around the home.

SUMMARY OF IMPACT
This machine will allow the clients to spend time with the whole family while exercising and mowing the lawn. A CAD drawing of the prototype is shown in Fig. 11.10.

TECHNICAL DESCRIPTION
The Multifunctional Quadricycle has two seats for adult passengers located at the rear. It also accommodates two small child passengers in the front two seats. The children can be seated with their feet resting on a bar, and they have a long handle bar to hold. The adult passengers power the vehicle.
by pedaling. The steering is controlled by one adult. The frame is roughly 3’ by 5’. It is tapered in front to allow for steering by turning the front wheels. The steering system is aided by a double U joint which is connected to several eye joints that help to direct the wheels. Brackets are extended for easier turning abilities.

The brakes are caliper brakes, similar to those of a bicycle. Braking may be controlled by either of the adult passengers. Reel mowers can be pulled along behind the quadricycle or easily detached. The mowing part of the project was not completed due to lack of time and funds. A finished prototype is shown in Fig. 11.11.

The total cost of the prototype is approximately $1500.

Fig. 11.11. Quadricycle Prototype.
ACCESSIBLE MEDICATION DISPENSING DEVICE

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Client Coordinator: Thomas Rosati, Premm Learning Center, Oakdale, NY
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INTRODUCTION
Many people have to take several medications with specific dosages on a daily basis. Difficulties can arise when trying to remember to take a specific dose of a particular medication, especially for patients with disabilities.

SUMMARY OF IMPACT
The goal of this project was to develop a device to keep track of a patient’s complicated medication schedule. The dispenser automatically alerts and dispenses the proper dosages necessary. To accommodate patients of different abilities, the dispenser has a variety of notification methods. The system can also keep track of what medications have been taken and what is currently in the inventory. The final product is shown in Fig. 11.12.

TECHNICAL DESCRIPTION
Figure 11.14 shows an assembly drawing of the prototype. The device stores medication in carousel systems, as discussed below. The mechanical structure has a flat square base. Two crossbar uprights are erected on the opposite sides of the base with three beams. These beams support the dispensing structure. Four right-angle brackets are erected from the four corners of the base to support the enclosure. Clear polycarbonate lexan is used to make the cover for the enclosure and is attached to the uprights. For the front, a lexan door (Fig. 11.13) is attached via a hinge to the enclosure. A magnetic latch is used to hold the door closed. The thickness is 0.25” for the uprights and beams to provide rigidity while keeping them light in weight. One stepper motor is placed at the middle of each beam. A large hole at the center of the beam allows for an adaptor shaft, which transmits power and motion from the motor to the carousel and dispensing system.

Dispensing System:
The dispensing system begins at the storage area. The medication pills, tablets, or capsules are contained in the dispensing carousel, which has 31 usable compartments. The carousel tray has a cover that fits tightly with an o-ring seal between the cover and the tray wall. The carousel tray is located on the beam of the machine via two ¼” pins. This prevents any motion along the beam surface, which might otherwise cause the carousel to move upward or fall off the motor shaft. A ball detent locks it into the divider disc. The dispensing system releases the medication by incrementing a stepper motor 11.25 degrees. Each rotation moves a filled compartment over an identically shaped hole in the carousel tray. The medication then falls into the dispensing chute.

Electrical System:
The design of the medication carousel depends on a specific rotation each time. The design requires 11.25 degrees of rotation. This is accomplished by half-stepping the stepper motor. The motor has a 7.5
degree step; pulsing the motor to increment 3 half-steps provides 11.25 degrees. The motor and LCD screen are controlled through a parallax electronic board powered by a 12V power supply. The microcontroller is programmed with BASIC Stamp.

**Operation:**
The first step in using the accessible medication dispenser is for the user to enter his or her medication schedule. Each carousel is simply loaded by placing the medication into a compartment. If the user is not capable of loading his or her own medication carousels, loading may be done offsite by a caretaker.

When it is time to take the medication, an alarm sounds and a light flashes to alert the user. Upon hearing the alarm, the user pushes a button that causes the system to dispense the proper medication into a tray. The LCD screen displays a message that dispensing is complete and shows how much medication is left in the carousel. If the button is not pressed after two minutes the alarm and the buzzer stops and it records the event.
INTRODUCTION
At a school for children with physical disabilities, students often must transfer from a wheelchair to a floor mat, where they sit during lessons, and then back to a wheelchair. This requires the caretakers to move each student in and out of a wheelchair numerous times a day. This can be strenuous for caretakers. The goal of this project was to reduce the burden on caretakers through assistance in transfers from a wheelchair to bed or floor mat.

SUMMARY IMPACT
The users are children with a maximum height of five feet and weight of 150 pounds. The energy spent in lifting and lowering a child manually is lessened by a mechanical crank winch. The mobility of the device allows it to be used in various situations and locations.

TECHNICAL DESCRIPTION
The device has two main components: the frame and the car. Each component was treated as two smaller projects although the design and manufacturing of the frame relies heavily on the design of the car.

The frame acts as a support for the lifting mechanism. It is designed to support a load of 600 pounds, which includes a factor of safety for four children, at any point along the track. Buckling and balance issues were checked through analysis. Steel was selected as the best material for the frame. The track is attached to the top of the frame at a height of 60 inches to provide an elevation range of 0-30 inches. Casters are attached to the bottom of the frame to allow mobility (see Fig. 11.16).

The car (Fig. 11.17) provides a simple translation motion in both horizontal and vertical directions. Aluminum was used to construct the car because it weighs less than steel. A winch with a high load capacity is used to lift and lower the user. The V-groove wheels of the car enable the user to be moved along the tracks of the steel frame to the desired location of a bed or floor mat. A brake system (Fig. 11.18) is installed on the rear two wheels of the car for safety. The wheels on the car and on the frame can be locked during loading and unloading to prevent injury. A three-dimensional view of the device is shown in Fig 11.15.
Fig. 11.16. Prototype.

Fig. 11.17. 3D View of Car.

Fig. 11.18. 3D View of Brake System.
ARTICULATING THERAPEUTIC WHEELCHAIR

Designers: George Lau, Steven Plaxsun, Jainarine Ramkumar
Client Coordinator: Thomas Rosati, Premm Learning Center, Oakdale, NY
Supervising Professor: Prof. Chad Korach
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INTRODUCTION
The goal of this project was to design a wheelchair that allows the children with physical disabilities to move from a sitting position to a standing or lying position. For lying down, the seat of the wheelchair remains stationary while the back reclines and the leg support is raised. For standing up, the seat and back of the wheelchair are moved together to a vertical position as the leg support lowers to the ground for stability. The ability to move from a lying down position to a standing position promotes physical health by increasing circulation, preventing muscle atrophy, and preventing respiratory problems. It also enhances the user’s independence.

SUMMARY OF IMPACT
Children with disabilities can have difficulty laying
down when they are tired, or standing up to move their muscles. The children for whom this project was created had to be moved by caretakers every half hour from a stressed to an unstressed position. This takes significant time and effort for both the child and caretaker.

**TECHNICAL DESCRIPTION**

The articulating wheelchair has two linear actuator systems to control its motion. System A has a single actuator mounted to the bottom of the seat. It controls sitting to lying down or lying down to sitting. As the linear actuator pulls the bottom shaft, it raises the leg support and the vertical shaft lowers the back support. The central pivot is grounded to the main pin connecting the back support plate to the thigh support plate. The linear actuator is connected to the quaternary link at the node closest to the main pin. The two other nodes connect to links going to the back support plate and the leg support plate. The leg support plate is shown extended in the CAD drawing in Fig. 11.21.

System B moves the device from sitting to standing or standing to sitting. Two linear actuators are mounted on both sides of the device for strength and balance since these support the user’s weight while in the sitting position. The system is directly linked to the main pin support, and connects the back plate to the thigh plate. Three actuators are used, one with 10 inches of travel, and two with 16 inches of travel. They have self-locking power screws and have a maximum load rating of 250 pounds. The control system has two switches, one switch for each system. The circuit design enables the switches to reverse automatically and independently the polarity to each system. The wheelchair was manufactured using wood to reduce manufacturing and material costs. The actuators chosen were from automotive applications to cut actuator costs by two-thirds while still meeting design requirements. Fig. 11.19 and 11.20 show the prototype design.

The total cost of the prototype is approximately $742.

![CAD Drawing of Articulating Wheelchair](image)
INTRODUCTION
The Easy Toilet Access Wheelchair was designed to allow individuals with disabilities easier use of the restroom. The objective was to design a wheelchair that allows individuals with disabilities to use the toilet without having to physically move from their own wheelchair. This design will also function as a normal wheelchair. Overall, the design will make the task of using the restroom more convenient and hygienic.

SUMMARY OF IMPACT
For wheelchair users to use the restroom, they must get out of the chair and sit on the toilet seat. This can be time consuming and may even require the assistance of a helper. The Easy Toilet Access Wheelchair helps the user use the restroom more conveniently. It also helps avoid the dirty surfaces common to public restroom seats. Fig. 11.22 shows how this product can easily be used in a public restroom.

TECHNICAL DESCRIPTION
Wheelchair Frame
The design contains a frame that is modified from a standard wheelchair, the Invacare Tracer Ex2 Swingaway. The tubing is chrome plated carbon steel with an outer diameter of 0.875 in. and inner diameter of 0.75 in. The Tracer Ex2 is a foldable chair with a crossbar under the seat. The crossbar imposed a problem with backing the wheelchair into the toilet seat area, and was eliminated in the new design. The toilet dimensions of 14 in. width and 17.5 in. height were used to calculate modifications needed to provide clearance of the toilet. In the new design, the height from the seat to the floor is 21 in.

The first modification done to the frame was to weld three horizontal bars along the width of the frame. The three bars measure 21 in. each. The frame is wider than most standard wheelchair frames. This design allows enough room for the wheelchair to clear the width of the toilet. The second modification made to the wheelchair was to raise the height of the wheelchair. The height of the seat of the original frame was about 17 inches.
**Seat and Cutout**

The seat (Fig. 11.23) is rectangular, with a width of 22 in. and depth of 16 in. There is a cutout section at the back of the seat. The seat is made of 0.5 in. hard plywood, a strong material that will be able to hold the required weight. There is a piece of aluminum sheet metal below the plywood to help keep it clean and dry when used. The aluminum surface also permits easy cleaning.

The seat cutout contains two symmetric sections made of the same material as the rest of the seat. The two sections are 11 in. long and 4 in. wide at one end and 2 in. wide at the other. This is the approximate shape of a toilet seat. Each piece is 4.25 in. diameter and 0.5 in. deep. This allows it to connect to the linkages.

**Mechanism for cutout motion**

The mechanism for raising and lowering the cutouts consists of a series of linkages. The system has one degree of freedom with one driving bar. It has a four-bar linkage, two on each side, to allow the load to be distributed equally four ways. As the bottom piece connected to the ground rotates, the other bars are forced to follow a set pattern. This makes the section open and close. The section is shown open in the CAD drawing in Fig. 11.24.

The total cost of the prototype is approximately $469.

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*Fig. 11.24. CAD Drawing of Easy Toilet Access Wheelchair (Isometric View).*
INTRODUCTION
The objective for this project was to design a device that allows persons who use wheelchairs to traverse the rough, uneven, shifting beach terrain. Two designs were considered and manufactured: a manually driven separate chair (see Fig. 11.25) and an electrically powered platform. The platform is compatible with the individual’s original chair (Fig. 11.26).

SUMMARY OF IMPACT
The BANDIT was designed as a treaded cart, capable of going over rough terrain. In the ideal situation, the BANDIT will give users independence. Current designs, including the manual wheelchair design presented here, usually require a caretaker to push the user. The BANDIT eliminates the caretaker’s driving or pushing role.

TECHNICAL DESCRIPTION
Of the two designs built, the manual wheelchair design (Fig. 11.25) is much simpler. It is a basic wheelchair with oversized, under-inflated tires. These tires yield a larger surface area in contact with the sand, which prevents them from sinking and jamming. Four tires are used to increase stability compared to a three-tire option. This design requires a second person to act as the driving force. Towards the back of the assembly, an arm is attached to assist the second person with pushing or pulling the chair. This arm also acts as a lever; when lifted or lowered it allows the vehicle to pivot around a point for steering.

In contrast, the BANDIT is a much more complex design. The design resembles a treaded cart, and can be compared to the system seen on a tank. The user is transferred onto this cart and drives it onto rough terrain. Each track is driven and controlled independently. This is done by using two separate 600-watt motors and twist-grip throttle controllers. Each side also utilizes a contactor that reverses the electrical poles, which allows the motors to drive in reverse. Because each track is driven independently, the steering mechanism employed involves driving one track faster than the other. A CAD drawing of the tracks can be seen in Fig. 11.26. This method is called skid steering and turns the vehicle in one direction or the other. An Electrical Control Unit was utilized to control the voltages in the motors, and to change the rotations per minute of the output.

The frame of the vehicle is made of aluminum, which was found to be structurally sound. Using aluminum reduces weight and cost, while still providing enough structural stability to withstand a variety of load intensities. A simple suspension system is attached to this frame. For each track, a bogie system is utilized, similar to the suspension found on a snowmobile. These systems have a torsion spring to enable suspension travel. They also act to increase the tension applied on the tracks.

The total cost of the prototype is approximately $1,700.
Fig. 11.26. BANDIT.
PATIENT TRANSFERRING AND POSITIONING AID (PTP)

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INTRODUCTION
The Patient Transferring and Positioning Aid (PTP) was designed to make it easier for patients with disabilities to have access to medical imaging devices with less effort for the doctor or caretaker. It will help patients with limited leg movement be transferred onto a medical imaging table, such as for MRIs, CTs, and X-rays. It will also help patients remain in a static position during a medical imaging scan.

SUMMARY OF IMPACT
The PTP was designed based on the needs of six patients with disabilities such as paralysis, heart failure, diabetes, obesity, stroke, and Parkinson’s disease. The PTP will make it easier for these patients to have access to medical imaging devices. The seating frame can be transformed from a seat to bed and raised to heights of medical imaging devices. This makes it easier for patients to get onto high tables. The positioning aids are placed on a mat, and the mat is placed on the seat. The PTP can be slid onto imaging tables, and will assist in keeping a patient in static position during a scan.

TECHNICAL DESCRIPTION
The PTP is made of two parts, the transferring device and the positioning mat. The transferring device is a metal frame that can be folded down from a seat to a flat bed. It consists of three hydraulic jacks, one for raising and lowering the back, one for the legs, and one for raising and lowering the seat. A scissor bar linkage provides extra support and prevents tipping of the device. The frame is made of steel and steel tubing. A track with rollers on top of the aid allows the positioning mat to be slid on and off the device. The positioning aid contains no magnetic parts, which is crucial for use with MRI and CT machines. It is made of wood with mattress foam for cushioning. The positioning aids are similar to pillows filled with cotton fiber.

The cost of the project is approximately $785.
Fig. 11.29. Cad Drawing of Transferring Frame (Isometric View).

Fig. 11.30. Positioning Mat and Body Segment Aids.

Fig. 11.31. Positioning Mat Layout.
INTRODUCTION
A client who has muscular dystrophy is able to work from home and is able to move about his house without a caregiver’s assistance or the continual use of his wheelchair or walker. However, his disability is progressive, and he anticipates having to use his wheelchair more frequently in the future. His wife will provide some assistance, but she is not always available. This system will provide access to his back yard, where he spends most of his days writing.

The house and path to the back garden are narrow. The only available entrance is accessible via steps from ground level to an elevated front porch shared with his neighbor. There were many challenges to creating a system (Fig. 12.1), including the narrowness of the side yard, existing steps at the side of the house, landscaping, an air conditioning unit, building codes, leasing agreements, and the client’s desire to have unobstructed access to the back courtyard.

A chair lift was considered, but could not be installed because it would infringe on the neighbors’ access to their adjoining home. Another concern was power outages due to inclement weather. A back-up power system would be necessary, increasing cost and introducing additional maintenance issues. Two ramps at the side entrance of the house provide the best solution for entry into the house and access to the outside garden. There was insufficient space for one ramp with a ground level pathway beside it.

SUMMARY OF IMPACT
The client may enter and leave his home unassisted with much less difficulty than before. The ramp system is aesthetically pleasing and occupies space that was previously unused. A secondary means of egress as well as additional recreational space are provided. The client stated, “This ramp and deck have really changed lives for the better. I can get into my house much faster and my wife doesn’t have to spend her time spotting me as she did when I used the steps.”

TECHNICAL DESCRIPTION
Fig. 12.2 illustrates the narrowness of the space available, including the neighboring firewall, as viewed from the courtyard. As depicted in Fig. 12.3, the accessibility solution consists of a ramp from the front of the house with a grade of 1:12 to a small intermediate deck located at the side entrance of the
house, to a more steeply graded 1:6 ramp with a railing leading to the back courtyard.

A steeper grade was required for the back ramp to preserve the existing landscaping and to permit access to an air conditioning unit. The client is able to negotiate both ramps in his wheelchair or walker, unassisted. His wife can more easily assist him on the ramps than on the front steps.

The system was built of pressure-treated pine and fastened with galvanized carriage bolts and screws. It can be disassembled if needed and any future additions can be easily added. The posts are made from 4” x 4” supports and the decking from 5/4” x 6” wood. The railings are made of 1.5” x 1.5” balusters and 2” x 4” supports. A sturdy railing surrounds areas of the deck and ramp system not bound by walls. A bumper curb prevents any collision with the railing should the client lose control of his wheelchair. The existing concrete side steps were left in place and used to partially support the deck stringers. The ramps and deck were constructed in nine modular pieces bolted together, which allow individual sections to be disassembled. City building codes classified this structure as temporary. The landlord agreed to the reversible installation.

The total accessible surface area is approximately 170 ft². The deck area is 72.5 ft²; the long ramp is 59 ft², and the short ramp is 37.5 ft². The approximate strength of the structure is 86-lbs/sq ft live load. A limit of four persons per section is recommended to ensure an appropriate factor of safety.

The cost of this project was $2344.
ELEMENTARY SCHOOL COMPUTER LAB ACCESS RAMP

Designers: Apu Borcar, Lauren Lipuma, Shawn Sarwar, Heather Vinet
Project Advisors: Cedric Walker, Ph.D., P.E., David Rice, Ph.D., Donald Gaver Ph.D. and Kathy Olsen, O.T.
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INTRODUCTION
A client has congenital amyoplasia, a degenerative muscle disease in which muscle tissue is progressively replaced by adipose and fibrous tissue. She is unable to use her arms or legs. She can shrug her shoulders and move her head. She controls her wheelchair using her head and mouth. Her school’s computer lab is located in an outbuilding classroom without wheelchair access. Lift systems are too costly and no continued lift maintenance would be available. A ramp and deck system was most appropriate. Space limitations required that the ramp and deck double back to an unused door.

SUMMARY OF IMPACT
The ramp and deck system permit the client safe and easy access to her computer laboratory, greatly improving her educational experience. Her teachers say that she will be able to participate with her peers in one more school activity. The system was constructed to be compliant with ADA specifications.

TECHNICAL DESCRIPTION
For durability and strength, pressure-treated southern pine and stainless steel connectors were used. The ramped portions of the system were treated as posts and were cut at an appropriate length to provide the required grade in the space available. The posts stand on pre-cast concrete footers. The joists were placed 24” apart, allowing four 2” x 6” joists to support each deck landing. Three such joists were spaced 21” apart for each ramped section. The ramp posts were placed at 6’ intervals. The posts for the landings were spaced at 4’ or 5’ intervals. The ramps were constructed in sections so that the system can be disassembled and easily moved.

The total cost of the materials was $2,350.
Fig. 12.5. ADA Construction Requirements and Ramp Design.
INTRODUCTION
A preschool student with congenital amyoplasia cannot support her upper body without assistance. She and her therapist requested alterations to an existing adaptive chair. These alterations included replacing the casters, adding a footrest, adding a storage bag, developing a head pointer, upgrading the cushions and upholstery, relocating the seatbelt to a more comfortable position, and making it aesthetically pleasing for a five-year-old in a preschool environment.

SUMMARY OF IMPACT
The client said that she was comfortable. She was able to color using the head pointer. The therapist reported that it was an improvement from the old one, and the client was enjoying the new chair.

TECHNICAL DESCRIPTION
A Kaye Kinder Chair was adapted for classroom use. Four new casters were fastened to the chair and the back two were equipped with brakes. The overall height of the chair was not altered so that it would still fit under the preschool classroom tables. The casters were attached to two finished pieces of ¼” birch plywood. The plywood was then attached to the legs of the chair using hinges that serve as self-adjusting angle brackets.

A footrest made from birch plywood with rounded edges was added. Polyurethane was used to seal the edges. A non-slip surface was added to the top to minimize the risk of slipping. The footrest was...
attached by L-brackets to the chair using four wingnuts to permit adjustment.

A storage bag was hooked to the back of the chair using grommets. The bag was made from a durable fabric treated with Scotchgard® and was also removable and machine-washable. A Dora the Explorer patch was added to make the bag more appealing to the client.

The cushions are double the thickness of the client’s previous seat and are contoured to provide optimal comfort. The bottom cushion is sloped back to help the client stay in her chair. The back cushion conforms to her upper body. The seat cushions are made of 2-inch-thick foam and were molded by adding layers along the appropriate edges. The cushions were attached to a piece of birch plywood and then upholstered with sturdy vinyl that can be wiped clean with a damp cloth. The cushions are covered with vinyl for protection. Pink slipcovers were made to go over the upholstery. The slipcovers were treated with Scotchgard® and are machine-washable.

Because new seats were attached to the seat cushions, it was necessary to create a new seatbelt. The seatbelt was made of 2” nylon webbing. It is adjustable and has a side-release buckle. It was attached to the seat back using two grommets to reinforce the webbing on each side, and then bolted to the wood. Acorn nuts cap the bolts.

The head pointer allows the client to access a computer and to draw by translating her head movements onto paper. Markers were attached to the end of the head pointer using Velcro. The head pointer was constructed using nylon webbing and a wooden dowel. The head webbing was made adjustable in circumference by using Velcro. A strip of nylon was attached across the top of the head from ear to ear to help support the weight of the pointer. The pointer itself was sewn into the nylon webbing and has a rubber tip at the end. The pointer was shortened to an appropriate length upon delivery.

The total cost of the parts and supplies was $58.
SPOON SUPPORT AND ORIENTATION DEVICE

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INTRODUCTION
A feeding device was designed for a ten-year-old girl with cerebral palsy. She has limited control of her arms, which makes feeding herself difficult. The goal was to promote her ability to feed herself with minimal assistance. Previously she used a self-leveling spoon and a lipped plate to feed herself. However, she had trouble getting the spoon to her mouth without spilling or tipping it over due to an involuntary reaction that causes her head to turn away when she brings her hand to her mouth. The new device helps the client to scoop her food from her plate. Upon release of the spoon, the device lifts and turns the spoon toward her. The spoon orients itself, allowing her to bring her mouth to the spoon to eat.

SUMMARY OF IMPACT
The occupational therapist was pleased with the result. The device addresses the client’s tendency to turn her head away when trying to eat. It also guides her scooping. Spilling and inaccuracy associated with bringing the spoon to her mouth was eliminated.

TECHNICAL DESCRIPTION
The device is lightweight, weighing 5 pounds, and is durable. The device is portable and suitable for use in any setting where a tabletop or other stable surface is present. The spoon support device has three main components: an arm system (with clamp for attachment to a tabletop), a turning mechanism, and a raising mechanism.

The arm system is part of an architect’s drafting lamp, which was slightly modified by strengthening the springs to provide stability and by removing components that restricted its range of motion. One important parameter that was optimized was the spring constant of the springs in the arm system. This optimization was done by trial and error during proof tests with the client.

The turning system includes a spiral spring obtained from a retractable tape measure and damping elements. All of these are enclosed in a PVC casing. This turning system, screwed onto the arm system at the floating end, contains a PVC spoon attachment piece at its base.

The spoon fits into the attachment piece and is fastened in place using Velcro straps to allow for easy removal. The raising mechanism relies on springs that are loaded when the client grips the spoon and pulls it down toward the plate to scoop. The spoon is removable and dishwasher safe.

Neoprene arm covers were added to prevent finger pinching by the arm system. The covers are removable and washable.

The final cost of the feeding device was $60.
Fig. 12.7. Deeding Device (Without Safety Covers).
INTRODUCTION
A client with cerebral palsy attempts to draw pictures, letters, and numbers with crayons or pencils using a tilted paper holder, but has difficulty controlling her hand and arm movement. The client is right-handed. Her left arm is subject to frequent, sporadic, and powerful extensions that interfere with most tasks. She has a firm grasp in her right hand and presses down powerfully on the paper when she draws. Therefore, she tends to break pencils and crayons. Her most successful drawings are produced when an assistant guides her hand. The client requested a means to express herself independently on paper. The pantograph table reduces many of the client’s previous difficulties. It provides a stable surface and has a large handle for ease of grasp and control. It resists force overload. The crayon or pencil is held in place and cannot fall. Various wooden guides allow the client to trace a given shape and produce a repeatable result.

SUMMARY OF IMPACT
The device allows the client to grasp and use her writing utensils without the help of an assistant. She can now write or draw without dropping or breaking her writing utensils. The guides allow her to draw or color shapes (e.g., circle, square, heart, flower) without the help of an assistant. The device reduces the extraneous motions that interfere with most of her tasks and permit the use of large motions to draw small figures. Her teacher is pleased that she can now draw almost independently.

TECHNICAL DESCRIPTION
The solution (see Fig. 12.9.) is a modified pantograph attached to a freely moving joint at the top of a wooden board. A pantograph is an instrument for copying on a predetermined scale, and consists of light, rigid wooden bars joined with pins. The pantograph permits the client to draw by grasping a softball, which is mounted on a dowel at the end of the pantograph. A pantograph frame is attached to a 3” dowel rod at one end, a utensil holder in the middle joint, and a wooden cube on the other end. The drawing utensil is contained in a separate spring-loaded barrel at the middle joint of the pantograph, away from the client’s grasping point, to produce a constant pressure on the paper. When the client draws, the pantograph scales down her drawings by one half.

The wooden cube fits neatly into a stationary stand that is attached to the lip of the 2’ x 2.5’ drawing board. The lip is attached to the perimeter of the drawing board and is 1” x 2”. The wooden cube has a rotating joint, allowing the pantograph to move in all directions.

The board sits on a desk at an incline, making it possible for her to see from her chair without having to bend over the table. A Velcro strap attached to the board and around her desk prevents movement by the board during drawing. Rails on the sides and top of the board keep operations within the board area.

The major parts of this project were made of wood. The device was sanded, painted, and covered with several layers of polyurethane. Dangerous edges were rounded so that injury would not result. Drawing guides were created out of four 3”x3” squares of 3/8” plywood. These guides were a circle, a square, a heart, and a flower. They fit onto the board with peg feet that insert into predrilled holes in the board.

The final cost for this project was approximately $90.
Fig. 12.8. Drawing Table/Pantograph Being Used by Client.

Fig. 12.9: Pantograph Drawing Aid Viewed as Schematically.
INTRODUCTION
An Emergency Call Device (ECD) was designed to enable a person with a disability to contact someone in an emergency. It is a stand-alone communicator that will work when power, land phone lines, and cellular phones are not operable. The device consists of a control unit, a transmitter, a battery back-up, and an antenna. It device can be activated to transmit a pre-determined emergency message programmed at the time of installation and customized for each user. A potential rescuer would need only a standard AM portable or car radio to pick up the signal.

SUMMARY OF IMPACT
The ECD has the potential to impact the lives of numerous persons. There is no product currently available that enables calling for help when the power and telephones are not working. Any person with an AM radio can receive the signal.

TECHNICAL DESCRIPTION
The ECD was built primarily of parts that are readily available. The human interface device constitutes the principal workings of the ECD. The primary micro-controller was built using a Javelin stamp module. This allowed control of all the device’s systems using the Java programming language. Additionally, the ECD is composed of two text-to-speech cards, which convert pre-programmed text into audio output. Direct recording of voice is also possible. One card is used to deliver the emergency message via AM transmission. The other card is used to provide audio feedback to the user.

The operation of the device is achieved in two ways. The buttons on the front of the ECD can operate the system allowing the user the ability to see via LCD the mode and operation of the ECD. The same operation can be achieved through use of an included hand-held remote. The remote transmits to the interface device and allows the user to activate the system from anywhere in the home. The main interface device is hardwired to the AM transmitter and the transmitter is wired to the antenna. The AM transmitter has a transmission range of up to 2 miles. The battery provides up to 72 hours of operation and can be placed anywhere in the home.

The following features were included in the design:
Chapter 1

Processing: A principal component is the Javelin® stamp (Parallax stock # JS1-IC). This microprocessor is the brains of the device and is programmed in Java. To mount the micro-processor and provide power control as well as a serial port for programming the chip, a carrier board was installed (Parallax #27130). This provided the basis for which all other components were attached.

Interface: The design of the ECD was made using a 20 character by 2-line LCD display (Parallax #30057). The device is small enough to conserve space, and big enough to give the user adequate feedback (see Fig. 12.11). In addition to the LCD, three LEDs were selected: blue, red, and green. The blue LED was selected to be the indicator of normal operation to let the user know the device is on. The red LED was chosen to indicate that something is wrong or that the system is being turned off. The green LED was chosen to show that the system was being activated or transmitting. The user’s manual contains complete description of what each light color and pattern indicates. Included in the interface are an on/off switch, speaker, text-to-speech card and wireless remote. The switch controls the main power for the system. It glows red when the system is receiving power. The speaker gives feedback as to the status of the system and provides audio instructions and warnings to the user. A text-to-speech card in the interface device (Parallax #30006) provides an audible output. The card converts text sent to it from the Javelin stamp microprocessor and converts it to a voice output.

Activation: There are two ways in which the device can be activated or deactivated. First, it can be activated by the interface. There are three buttons: Activate, Deactivate, and Mute. The wireless remote included with the receiver in the interface device (Parallax #28005, #28004) transmits at 418 MHz and should provide a range of activation larger than most homes. Although the remote has a total of five buttons, only three are used. The buttons that are used correspond to activate, deactivate, and mute as on the interface device. Transmission is carried out in a way similar to the speaker output. The programmed emergency message is sent to a text-to-speech card where it is converted to a voice signal. That signal is then sent to the transmitter. A low-power FM transmitter for demonstration was used. An AM transmitter capable of transmitting at least 2 miles was determined to be the best option for use. This will be connected to the interface device through the use of coaxial cable via port on the side of the interface device.

The cost for parts to build this system and battery back-up was $640.

Fig. 12.11. Interface circuit schematic.
EMERGENCY LOCATING SYSTEM

Designers: Nathan Southard, HoChi Sit, Lee Crawford, Oluimide Aruwajoje
Project Advisor: Cedric Walker, Ph.D., P.E.
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INTRODUCTION
The Emergency Locating System was designed to permit individuals with disabilities to call for help during a natural disaster when other forms of communication are inoperable. With the device, the clients will have the ability to contact the proper authorities and alert them of their location along with other important and vital information. The product represents an adaptation of the technology used by available EPIRBs (Emergency Positioning Indicating Radio Beacon). The device will mount onto the client’s wheelchair. In an emergency, he or she will activate the system. The EPIRB sends a signal to Coast Guard monitored satellites and forwards the signal to the proper headquarters. Once the headquarters have received the signal, they will contact the local rescue authorities, who will execute the necessary rescue mission. The system uses a GPS (Global Positioning Satellite) with 250 feet accuracy and a response time within 5 minutes.

SUMMARY OF IMPACT
Emergency preparedness has become a more prevalent issue in the United States because of events involving terrorism, natural disasters, and possibly personal health-related issues. For example, during Hurricane Katrina several people lost their lives or are still missing as a result of their inability to call for help because cell phones and landline phones were down. Had emergency personnel been able to locate these individuals, several lives may have been saved. The elderly and persons with disabilities were at particular risk. For example, approximately 40% of the individuals that died as a result of Hurricane Katrina were over the age 71 (disabilities not specified). Further, the scope of this problem is easily appreciated with the statistic that of the 44,000 persons with disabilities in Orleans Parish, approximately 19,000 are over 65 years of age. For New Orleans and many other areas, the threat of natural and manmade disasters continues. Therefore, the large-scale need exists for a service that will permit people to be located and helped when all other established communicative options have failed. With the Emergency Locating System, persons with disabilities will have the means to be identified and located.

TECHNICAL DESCRIPTION
The product uses the EPIRB system. This system is currently in operation to provide distress calls and location assistance for ships and other watercraft. The product’s components include a GPS receiver, an antenna, a transmitter, and a battery. GPS is a satellite navigation system that broadcasts precise timing signals by radio to GPS receivers, which allow them to accurately determine their location.

The device can be activated manually or automatically to transmit emergency locating signals to proper rescue authorities. Satellites detect the signals from the 5-watt radio transmitter operating at 406 MHz. The accuracy of location is within 250 feet and the activation delay time is about 5 minutes.

Included in the signal is a serial number as well as the unit’s location (determined by GPS). Pre-registration is required. The serial number permits linking the call to personal information (e.g. owner’s name, address, phone number(s), disability(s), and any other facts. This data permits the responders to develop the most efficient rescue plan. Non-marine use is not yet approved, but must be before this system can be made available for general use.

The cost of this device is under $1000.
Fig. 12.12. Emergency Locating System based on a modified Emergency Positioning Indicating Radio Beacon (EPIRB).
INTRODUCTION
The client, a high school student, has osteogenesis imperfecta (OI). OI, a brittle bone disease, is a genetic disease characterized by bones that fracture easily. The genetic defect affects the body’s normal production of collagen. In particular, bone growth and strength are greatly reduced.

For transport, she rides in her family’s minivan. She is most comfortable lying flat due to scoliosis of her spine and limited ability to raise her head. She lies on a pad or blanket on the van floor behind the driver’s seat. Due to her bone strength and body size, the client is unable to use a normal restraint system such as seatbelts, a child restraint seat, or car beds. Not only is this method unsafe, but the client is also not able to see outside the van.

The team designed a van transport system to allow for her safe transport while also allowing her to look
out the window.

**SUMMARY OF IMPACT**

This system will allow the client to ride in her family's van and see out the window. It will keep her safe and comfortable and provide her with a much improved transportation experience.

**TECHNICAL DESCRIPTION**

The van transport system consists of three main components. The first component is the PVC frame. The pipe segments have a nominal inside diameter of one half inch and are connected with standard and custom joints. There are two ninety-degree, two cross, two five-way, thirty-six tees, eight three-way corners, and four four-way corner connectors. The PVC frame is joined to the existing car seat frame with four two-and-a-half inch long 3/16” machine screws.

The second component is the reinforcement, which consists of a 1/8” inch diameter steel wire rope. The rope was galvanized and has ultimate tensile strength of 1,700 lbs. The wire rope is joined using standard 1/8” inch crimps. The wire rope runs through the two highest rectangle structures of the PVC frame as well as the ten vertical sections that connect the two rectangles. There are eight safety wires that exit the lower rectangular PVC section and secure to the car seat frame by forming a loop and being crimped. Sections of the PVC pipe are removed from the frame to allow the exit of the safety wires; these are covered with PVC patches connected to the frame using hose clamps. Two hose clamps are used for each patch.

The final component of the design is the mattress and the net. The mattress is a four-pound rated Tempur-pedic® pad. Standard cargo netting covers the pad. The cargo netting is held into place in sixteen locations. Two adjoining sides are attached at 8 places to the PVC frame. The remaining eight connections are made using 2” carabineers. The net is held free of the client by a line that extends from the roof of the mini-van.

In a crash event, the system will absorb energy through the frangible PVC frame. It also spreads deceleration force. This restraint system is designed to protect the client in the event of a front, rear, or side collision as well as a rollover event.

The total estimated cost of the transport system was $460.
CHAPTER 13
UNIVERSITY OF ALABAMA AT BIRMINGHAM

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ESSENTIAL TREMOR MEASURING DEVICE

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Client Coordinator: Dr. Leon Dure, Division of Pediatric Neurology
Supervising Professor: Alan W. Eberhardt, Department of Biomedical Engineering
University of Alabama at Birmingham, Birmingham, AL 35294

INTRODUCTION

Essential tremor (ET) is one of the most frequently occurring tremor disorders and is commonly observed in limbs or the head during performance of an action, and in certain postures. When observed in children, diagnosis is crucial to improve the quality of life and ensure the ability to develop needed skills. A device was developed to measure ET in children and to create a database for comparative analysis. This will help further investigate and improve diagnosis for the disease.

Design requirements were to measure ET of the hand and arm (5 to 12 Hz) and physiological tremor (up to 30 Hz). It is to be used in small examination rooms (12 ft by 12 ft); therefore the device was to be simple, compact, portable, and easy to set up. Based on these constraints, the client required the device to interface with a laptop system. Due to the patients’ range of ages (5-18 years) it also had to be adjustable to different sized arms. The device was to have a shock resistant rating of at least 1000g to ensure adequate protection from misuse or fall, and to ensure sustainability of the device. It had to be made of materials that can be cleaned using antiseptics to ensure sterile use for each patient.

The software was to provide graphs of frequency, display the value of the tremor frequency, and store data to be used for later analysis.

SUMMARY OF IMPACT

The resulting design is compact, portable, and easy to set up. The system measures ET of the hand and arm (5 to 12 Hz), is adjustable to different sized arms, and is shock resistant. The software is user friendly, displays the value of the tremor frequency, and stores the data to be used for later analysis. This will allow the client to perform routine exams on patients with ET and ultimately may improve his ability to diagnose and treat the condition. The ability to extract a dominant frequency will also permit the clinician to compare the condition of the patient before and after taking medications, and to perform comparative studies of patient response to physical therapy.
TECHNICAL DESCRIPTION
Three tri-axial accelerometers (Kistler 8690C5 PiezoBEAM) were interfaced with three separate Dynamic Signal Acquisition modules (National Instruments USB-9233), which connected directly to the laptop (Dell Inspiron 680m). The assembly of the prototype can be seen in Fig. 13.1a.

The materials used for the strapping system were elastic bands with Velcro strips sewed to them. The finger accelerometer is attached the patient’s finger using bandaging tape. A third elastic band was constructed to hold wires running from the accelerometers against the patient to allow more patient mobility. Accelerometer mounting brackets were mounted to the hand and forearm straps using fabric glue to create a firm interface between the straps and the accelerometers. The set-up of the strapping system can be seen in Fig. 13.1b.

The Dynamic Signal Acquisition module contained built-in filtering. Filters consisted of a passband filter, stopband filter, and alias free filter. The software design incorporated LabVIEW (National Instruments), which uses block diagram programming to build user-defined applications. There are numerous tools and functions predefined to acquire and analyze data, called Visual Interface modules (VIs), within this program. The prototype’s software was initialized using a visual interface, named Introduction, where the user can select to test the patient, compare data, cancel, or quit the program by clicking on the appropriate VI button. When the Test patient or Compare data buttons are pushed, a new visual interface is displayed to the user where two separate sets of code are used to accomplish appropriate tasks.

The test patient interface functions by first prompting the user to enter information. The user then selects the type of test (postural, finger to nose, or nose to target) and then clicks start in the visual interface window to begin data acquisition. A built-in module in LabVIEW (called data acquisition assistant module) collects data from the accelerometers three times at a rate of 2,000 samples per second. It then converts the signal from volts to acceleration. The data acquisition assistant module outputs a clustered signal that contains data for the x, y, and z axes of the accelerometer, which allows for easier processing in the LabVIEW environment. The acceleration data are plotted onto three separate viewgraphs and are sent to the FFT spectral analysis module for frequency measurements. The frequency spectrum is then sent to three separate viewgraphs to display the peak frequencies of the data set to the user.

The acquired data are saved using a built-in write-to-file module. The module creates an Excel data sheet containing patient and test information, including the mean frequencies for each axis of the three accelerometers. A second method uses LabVIEW’s built-in database connectivity to transfer data collected in the Test Patient VI to an Access Database named Acceleration data. Once the data have been entered into the database, the user can then perform other tests on the patient or exit back to the introduction interface.

To protect the device during transport, the design team purchased a hard case (Pelican) with foam padding.

The total cost associated with the system was $9,199.
INTRODUCTION

The goal of this project was to design and construct a multi-purpose computer table, to accommodate the children with cerebral palsy at a daycare center.

The table was to accommodate children ages two through five. For those children who use wheelchairs, the table had to be adjustable to different heights (21 - 30 in.). It had to support a number of loads, including a touch screen monitor (39 lb), computer processor (32 lb), printer and other accessories (~25 lb).

The monitor was to be easily adjustable within the horizontal plane to suit the sight and arm ranges of the children. A large keyboard tray able to adjust to various heights and tilt, which could slide under the table when not in use was needed. To prevent the children from tampering with the computer tower (processor), it had to be concealed and locked. Also, the various accessories used with the computer required a storage area for organization. The system was to be easy to use by the staff, quiet, child-proof, safe, and cleanable. The client requested that the table surface be made with a light wood laminate top, and that the complete system have blue accents to go with the existing daycare center decor.

SUMMARY OF IMPACT

The adjustable computer table meets all the design constraints. It permits children of varying size and ability to access the computer and use the keyboard or touch screen monitor. The result is an increase in computer use by children who previously were not able to access the computer. The system is safe and portable, and allows the staff to control the use of the system and position the table for each user. Storage units for the computer tower, cords and accessories prevent undesirable access by the children.

TECHNICAL DESCRIPTION

The tabletop was made of light wooden particleboard laminate. The keyboard tray (Versa Products, Inc) met ANSI/BIFMA standards and was rated to support a maximum load of 70 lbs, which exceeded the design load for the largest child (weight = 55 lbs) supporting his or her weight entirely on the keyboard tray. A flat panel, touch-screen monitor (PLANAR) and fully adjustable monitor arm (Neoflex, Ergotron) were purchased.

For the table adjustment, two lifting columns (LINAK) were chosen, which provided support against bending moments resulting from the monitor being mounted at the rear of the table. LINAK donated two DL1 lifting columns as well as the control box and button control. The minimum height of the actuator was 17.5 in. and it had a maximum stroke length of 11.8 in., satisfying the adjustability constraint.

A basket that could slide under the table was attached to hold various computer accessories. A work surface on a gooseneck arm provided an additional surface for accessories. All work surfaces were coated with polyurethane. The final table design (Fig. 13.2) met ANSI/BIFMA Standards x5.5-1998.

The total cost was $1,371.
Fig. 13.2a. Adjustable Computer Table.

Fig. 13.2b. Ergotron Neo-Flex Monitor Arm.
BABY CARRYING SYSTEM

Designers: Idris Lawal, David Sewell, Asaf Stein
Client Coordinator: Michael Papp, Alabama Department of Rehabilitation Services
Supervising Professor: Alan W. Eberhardt, Department of Biomedical Engineering
University of Alabama at Birmingham, Birmingham, AL 35294

INTRODUCTION

A child carrying system was built to assist a client with paraplegia who uses a manual wheelchair in transporting her toddler during daily activities. The product had to safely support and restrain the toddler who at the time was 12 months old, weighed 22.5 lb and was 30.25 inches tall. Also, the device had to be versatile enough to allow for his growth over the next two years. The carrying system could not impede the mobility of the wheelchair; it could not bind or hit the sides of the wheel chair when performing turns or backing up. The product was to be lightweight (<25 lb), and sufficiently collapsible in order to fit into the client’s vehicle (width of standard door = 32 in). Once unfolded, the product was to be self-standing. While seated in her chair, the client should be able to easily attach and detach the device to and from her wheelchair. The product had to withstand the stresses resulting from both the torque created from turning the wheelchair, as well as the weight of the frame and child combined.

ASTM standards for strollers stipulate child restraints as well as folding and latching mechanisms that involve a two-step process. The stroller should support a static load of 100 lbs. in the center of the seat.

SUMMARY OF IMPACT

The baby carrying system satisfied the client’s needs by allowing her to transport her toddler. Its lightweight design minimized the total amount of added weight. The product did not compromise the mobility of the wheelchair and was found to be easily attached to and detached from the wheelchair, and easily stored in or removed from the back seat of her vehicle. The final product met all of the design constraints and operated fluidly. The device allowed the client to conveniently and independently transport her toddler without assistance, thereby providing her with greater independence and improved quality of life.

TECHNICAL DESCRIPTION

The final design consisted of the main stroller frame (Maclaren Stroller, which met all design specifications and came with desired accessories, such as a rain cover) and rear swivel wheels (Sportaid Wheelchair & Stuff), which were purchased from commercial vendors. A ball and socket “trailer hitch” included a 1 7/8 in. diameter stainless steel ball and allowed for ample rotation about three axes. A one-half inch cylinder was bored out of the trailer ball to reduce weight. The receiving socket was attached at the stroller’s front, and the hitch attached to the rear of the wheelchair via existing open-ended tube receptacles. Aluminum tubing was chosen for the connector components because it is lightweight and strong. Polyurethane swivel wheels were chosen for good traction and optimal wear properties.

The resulting device (Fig. 13.3) adheres to the ASTM safety standards. Bending, bearing and shear stress calculations were performed; the design was predicted to withstand the stresses resulting from turning the wheelchair and travel over uneven terrain given the weight of the frame and child. All results fell well below ultimate and fatigue strengths of aluminum. The total weight of the product was 21 lbs.

The total cost was $1260.
Fig. 13.3a. Rear View of Client’s Wheelchair Shows the Open-ended Tubes Used to Attach the Trailer Ball Connector.

Fig. 13.3b. Adapted Stroller with Trailer Hitch and Trailer Ball Connector.
INDEPENDENTLY-OPERATED LAPTOP MOUNTING SYSTEM

Designers: Jonathan Dennis, Peserai Chinoda
Client Coordinator: Michael Papp, Alabama Department of Rehabilitation Services
Supervising Professor: Alan W. Eberhardt, Department of Biomedical Engineering
University of Alabama at Birmingham, Birmingham, AL 35294

INTRODUCTION
The Independently-Operated Laptop Mounting System was designed for a male in his early twenties who had spinal muscular atrophy (SMA). This condition is characterized by muscle fatigue and muscle pain. The client had a laptop mounting system that permitted him to use the laptop, and that stored the laptop in a rear position during normal operation of his wheelchair. The system required an aid to change the laptop position for use or storage. As a result, the client’s independence was restricted.

The design was required to be detachable in order to ensure the original manual system would still be usable in case the new system was to malfunction. The device was also required not to exceed a clearance of four inches from the side.

SUMMARY OF IMPACT
This device eliminates the need for an assistant each time the client wishes to use or store his laptop, thereby providing him with greater independence and improved quality of life.

TECHNICAL DESCRIPTION
The system was designed using a CAD program (Pro-Engineer) to establish the necessary stroke lengths and attachment points for system actuators. A CAD image of the final design is shown in Fig. 13.4. The approved design for the laptop system involved new structural stainless steel tubing with an inner diameter of 0.7 in., an outer diameter of 0.9 in., and a yield stress of 75,000 psi. Two linear actuators (Firgelli Automations) were attached to move the arm holding the laptop (3 in. actuator) and the main arm (4 in. actuator). The linear actuators are controlled by a timing system and two micro-light switches. The actuators are resistant to splash and dust damage. The maximum force produced by the linear actuators is 110 lbs, which was determined to be more than enough to move the laptop from the rear storage location to the front of the wheelchair for use. The actuators move at 1 in. per second, which translates into a total movement time of 10 seconds from storage to use position of the laptop. Each one of the actuators was attached to the tubing using special brackets (Firgelli Automations) that allow movement of the arms in an arc.

The torque required to lift the laptop lid was calculated to be 32 in.-oz. A small dual-direction rotary motor was used to open and close the laptop (Herbach and Rademan), which produces a maximum torque of 40 inch-oz.

The motor was attached to the laptop cover by a small rod with a bracket attached at the end. This bracket was attached to two thin strips of acetal-delrin plastic that hold the cover in place while it is moving. A control system composed of a programmable logic controller, relays, one micro-light switch (Tash, Inc.), and three limit switches, was used in order to move the arms of the mount. The arms move to open and close the laptop. The switches were mounted next to the joystick, which controls the wheelchair. Both the actuators and the motor run on the 24-volt source that powers the client’s wheelchair.

This device cost approximately $900.
Fig. 13.4. ProE Drawing of the Independently-Operated Laptop Mounting System.
MODULAR COMPOSITE WHEELCHAIR RAMP

Designers: Genevieve Martin, Donald Pritchett, Jessica Robertson, Regina Scarber
Client Coordinator: Alan Eberhardt, Department of Biomedical Engineering
Supervising Professors: J Barry Andrews, Gregg Janowski, Uday Vaidya, Department of Materials Science and Engineering, Tina Oliver, Department of Mechanical Engineering
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INTRODUCTION

A non- or semi-permanent wheelchair ramp was requested. Careful consideration was given to the potential clientele and observation of housing subdivisions in the surrounding area. It was concluded that the ramp would not be custom-designed for one specific home. Instead, it would be sufficiently flexible in design to accommodate nearly all dwellings that use stairs to gain entry.

The ramp had to comply with the American Disabilities Act (ADA). ADA compliant ramps cannot have slopes exceeding a ratio of 1:12. The maximum rise for any ramp run is 30 inches. The ramp landing had to be at least 60 inches long and at least as wide as the ramp run. Both ramp runs and landings must have handrails, which must extend 34-38 inches high. Handles must be easy to grab and remain rigid in their fittings. Handrail edges must be rounded; if they are circular, the outer diameter must be between 1.25 and 2 inches. They must extend horizontally above the landing a minimum of 12 inches. The width between handrails must be at least 36 inches wide.

Curbs are required on the ramp and landing and necessitate a minimum two inches in height. The ramp must have edge protection, by means of either extended floor or curb/barrier protection. Other factors and project limitations included sensitivity to ultraviolet light, water absorption, corrosion, and supporting the live load of a person whose weight is in the 99th percentile, and who is in a motorized wheelchair. Modularity was also required, such that the ramp should be easily maneuvered by two average adults.

SUMMARY OF IMPACT

There are a variety of ramps on the market today; however, most are very expensive. Many people who use wheelchairs cannot afford a very expensive ramp system. The current ramp system has the potential to be an improvement over commercially available ramps by providing an affordable and safe means to enter a home from a wheelchair. It helps the user to be more independent.

TECHNICAL DESCRIPTION

The prototype system was comprised of two pieces: one sloping and one landing platform made from a sandwich composite which would minimize weight. The legs of the structure contained a mechanism for height and slope adjustments to provide maximum flexibility. The rails were prefabricated and held in place by custom-made aluminum brackets.

The ramp deck was built of carbon fiber, a polypropylene honeycomb core, 1-inch square steel tubing, 0.75-inch square steel bar, epoxy resin, and polyurethane stiffeners coated with fiberglass. The ramp and landing were constructed by hand. The steel bar was cut to length and ground to form a tight fit in the ends of the steel tube when driven into place. The tubing was then welded to form the outside dimensions of the ramp deck. The railing was made from 6061 aluminum and connected with couplings fitted with set screws. Post testing included testing the deflection of the deck and strength of the legs and bolts. The result was a composite ramp system that was modular, but heavier and more expensive than desired. The manufactured platform pieces were too large for easy assembling. The ramp landing was not as strong as desired, but corrections in manufacturing errors promise to increase stiffness in future designs. For future work on this project, stainless steel tubes will be replaced with fasteners. Vacuum Assisted Resin Transfer Molding (VARTM) will be used instead of hand lay-up. Materials will be ordered much earlier to extend the period needed for revisions.
Fig. 13.5. Composite Modular Ramp System.
CHAPTER 14
UNIVERSITY OF CONNECTICUT

Biomedical Engineering
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VERSATILE PAINTING SYSTEM: AN ARM SUPPORT AND WRIST ATTACHMENT FOR PAINTERS WITH LIMITED MOBILITY

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Client Coordinator: Brooke Hallowell, Ohio University, Athens, OH
Supervising Professor: Dr. John Enderle
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INTRODUCTION

Lack of adequate muscle control caused by cerebral palsy (CP) interferes with some artists’ ability to draw and paint. The first part of the Versatile Painting Solution consists of a support system that mimics the movement of an arm. This helps to prevent difficulty with painting and drawing due to limited mobility. The support system is made to easily attach to the side of a wheelchair. It is adjustable in terms of height, arm length, and positioning angle. The arm rests in a comfortable support to allow for an extended painting session.

The second component of the Versatile Painting Solution Support System is a wrist attachment. This element is designed to provide a mechanism for optimizing marker control. The wrist attachment is a modified wrist guard that has a comfortable fit. The art of painting requires fine motor skills and precise movements; however, some patients with CP lack this motor control, and therefore, require assistance from outside sources. The support system, coupled with the wrist attachment, make up the Versatile Painting Solution. These devices operate collectively to enhance the artistic experience.

SUMMARY OF IMPACT

The task of painting with limited hand and arm mobility requires the attention of an aid. This support was designed for a client that needs an aid to hold his arm extended towards the canvas while brush strokes are made with small movements of his wrist. This device allows more independence for the artist and requires less physical attention from the aid. The aid can make adjustments to the joint position and the support will remain static while the artist works on one part of a canvas. The wrist attachment allows a marker to be held at the wrist with maximum comfort.

TECHNICAL DESCRIPTION

The Articulating Arm Positioning Support (Fig. 14.1 and 14.3) is a device designed for a user to rest his arm on during painting. The cushion will provide support for the user’s arm and allow for a longer, easier, and more satisfying painting experience. The device features an ergonomic design with a molded composite arm support. The fiberglass composite support is a lightweight and durable material that can endure the stress of everyday use. The aluminum stock and joints provide a lightweight structure to support several ranges of motion that include movements from side to side, up and down, adjustable arm angle, and even rotation.

The Articulating Arm Positioning Support features a variety of mechanisms to maximize the amount of positions available for a user in a wheelchair. Two ultra-high molecular weight polyethylene linear slides offer a durable low-friction method to adjust the height and side position of the support. These...
slides are durable and long-lasting because they are constructed with such a quality plastic. The five locks allow the device to be positioned in the exact necessary support position and also offer a method to adjust the device quickly and easily. The three joints in the support provide many supporting positions and also allow for easy no-lock positioning adjustments. Each joint uses a special bolt that rests on a bushing to prevent loosening of the bolt caused by vibrations and operation. The bolts sit in straight brackets that reinforce the structure and contain the brass bearings.

The device features an ergonomic molded composite arm rest. The fiberglass arm rest was made with nine layers of fiberglass mat and polyester resin. The composite rest is covered with foam cushioning and a durable cloth cover that provides a comfortable resting surface. The device can be optionally attached to the arm by Velcro and elastic straps. The cushioned arm rest has a 360 degree swivel mechanism which allows the support to be adjusted to the ideal position. The swivel is designed with three durable 1 1/8” nylon washers. It has integrated Velcro straps for additional support.

A heavy-duty clamp was added to the design to interface with a variety of wheelchairs. The clamp is a compact design that can be easily adjusted by the user with a comfortable knob. The clamp has a duty rating of 30 pounds. This is sufficient to accommodate the weight of the support infrastructure as well as the arm of a 300 pound person. The clamp requires a small amount of force for any adjustment allowing a quick and easy connection to the wheelchair.

The wrist support, with small spring action dial attached, provides comfortable structure. The wrist attachment is shown in Fig. 14.2 and 14.4. The dial allows for angle adjustment of the marker by pulling out the tube and twisting it into the notches. The PVC tube tightens down on the marker and fits into the dial with a spring. Hollow PVC tube with a small inner diameter was used for the dial. The inside was machined out to provide a shelf for the spring compression. Holes were machined onto the flat surface of the PVC in order to provide adjustment slots. Notches were added to a smaller piece of PVC that holds a marker. Wing nuts are the clamping mechanism that keeps the marker stable in the tube. The spring is on a bolt that is inside the dial and connects to the marker tube. This whole subunit is fastened securely to the wrist guard. A marker is clamped into the tube then the tube can be pulled out and rotated to a proper drawing angle. The spring holds the marker securely in place allowing the artist to comfortably draw from the wrist level.

The approximate cost is $600.
EASEL 5000: A DIFFERENT ADJUSTABLE EASEL FOR ARTISTS WITH CEREBRAL PALSY

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Primary Client Coordinator: Patty Mitchell, Passion Works Studio Art Director, Athens, OH
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INTRODUCTION
The Easel 5000 project (Fig. 14.5) is for an artist with cerebral palsy. The artist has a loss of fine motor ability, abnormal muscle tone, abnormal muscle movements, and vision problems. The goal of the project was to build an easel that will allow the artist to paint from his wheelchair. This device is an easel that will attach to the artist's wheelchair tray. Once the easel is secured on the tray, it can be adjusted into various positions to ensure the easiest method of painting for the artist. The artist will be able to paint in whichever position he is most comfortable.

SUMMARY OF IMPACT
The artist was in need of an easel that can be easily adjusted. Since the artist has a limited range of motion, painting with a single-position easel is difficult. The artist cannot use a standard easel with tripod legs due to the fact that he is in a wheelchair. In addition, he is unable to paint unless the canvas project is close to his wheelchair. The Easel 5000 allows the artist to paint from the wheelchair and adjust the easel in whichever position is most beneficial.

Fig. 14.5. Easel 5000.
TECHNICAL DESCRIPTION

The overall structure of the Easel 5000 was made from aluminum extrusions, brackets, and screws (80/20 Corporation). The use of these parts allows for easy assembly, maintenance, and parts replacement. With the aluminum extrusions used, adjustment for various pieces of the easel are easy and can be accomplished with hex wrenches. Most extrusion pieces are attached with 90-degree angle brackets with screws and t-nuts that slide directly into the t-slot. Since the t-nuts can slide over the length of the extrusion, any additional position adjustments can be made if default positions are not to the user's liking. The easel was designed to slide directly onto the artist's wheelchair tray and then be fastened onto the tray using knobbed screws on the underside of the easel.

The easel can be adjusted via dynamic pivot joints (80/20 Corporation). There are a total of two pivoting joints on the easel (Fig 14.6). These allow the canvas face to be adjusted into numerous positions and then locked into place using l-brakes. Having pivots on symmetrical sides of the easel supports safety. If one of the l-brakes is accidentally unlocked, one l-brake is still able to hold up the entire easel system. The use of the l-brake not only allows for positional adjustment, but it is also used to adjust the canvas clamp. Two l-brakes allow an extrusion to clamp down onto any canvas size as large as 20 inches tall, and then lock into place to ensure that the canvas does not move, even when facing downward.

A lighting system was included in the top of the canvas holder to illuminate the painting surface. The LED system consists of a PCB with all LED components soldered into it. These components are safely encased in a black plastic case. The LED system comes equipped with an easy on/off switch and a dimming system to allow for brightness adjustments. The light system can be adjusted to any angle through use of a friction hinge. The user can adjust the lighting system to a specific position and it will stay. The lighting system is powered by a battery, which is located in a white PVC battery case at the bottom of the canvas holder. On a full charge, the battery will be able to power the lighting system for a total of six painting hours. Once the battery is diminished it can be removed from the Easel 5000 and taken to a wall socket to be recharged. Recharging to full power can take up to 8.5 hours. The battery can then be replaced onto the easel using a Velcro attachment.

The total cost of the parts and materials was about $800.

Fig. 14.6. CAD Drawing Showing Pivot and Adjustment Points.

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The total cost of the parts and materials was about $800.
EASELECTRIC: AN ELECTRICALLY CONTROLLED EASEL FOR PATIENTS WITH LIMITED DEXTERTY AND MENTAL DISABILITIES.

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INTRODUCTION
The Easelectric is a unique electrically-powered easel capable of assisting an artist with the placement and positioning of a canvas. Using a single joystick, the artist is able to move the canvas horizontally and vertically as well as tilt the easel toward and away from himself. In addition, a linear tracking system allows the entire easel to slide along its base and be moved closer to the user. The easel (shown in Fig. 14.7) was designed to be simple and compact, yet sturdy. It was created for a client with cerebral palsy and limited dexterity who had difficulty reaching all areas of a large canvas. Using the easel, an artist is able to remain stationary and bring the inaccessible regions of the canvas within his range of motion.

SUMMARY OF IMPACT
The project specifications required that the easel be able to safely operate within a community of individuals with mental retardation and developmental disabilities (MRDD), and every aspect of the easel was designed to meet those specific needs. Due to the limitations that individuals in this community experience on a daily basis, art has become a very influential part of their lives and allows them to express themselves in beautifully imaginative ways.

The program’s vision is as follows: “To create and live out a best practice model for collaborative art making between artists with and without development disabilities. This new mindset demonstrates that creativity is innately a part of all people and recognized that art enhances the quality of life and strengthens communities.” The Easelectric project is significantly influenced by this vision and is meant to help these talented artists achieve the program goals.

TECHNICAL DESCRIPTION
The design for the easel involves a square base that is attached to a series of aluminum frames, which are attached to the table on which the easel is mounted. The base of the easel is clamped to the table with an adjustable screw clamp assembly (Fig. 14.8). This provides added stability to the device, keeping it sturdily attached to the table while the client is painting. The adjustability of the clamp allows for the accommodation of different sizes and shapes of tables. Besides providing stability, the base of the easel also allows for the canvas to be manually adjusted closer to the user by means of aluminum extrusion and ultra high molecular weight polyethylene linear bearings (UHMWPE). Additionally, using a joystick, an artist can control the tilt and vertical placement of the canvas, which
is controlled by two 165-lb force, 12-volt DC linear actuators, each which has a stroke length of six inches. The horizontal placement is controlled by a small 12-volt DC gear motor connected to a 24-inch screw drive.

Aluminum was chosen as the ideal building material due to its low weight, high strength, relative inexpensiveness, and resistance to corrosion. As a result, the easel is extremely strong and weighs only about 50 lbs. To further reduce corrosion and also enhance the aesthetics of the easel, portions were painted blue using a corrosion-resistant paint.

The joystick used for the easel was custom-made for the project and included four micro-switches activated by the joystick's position as well as a large thumb rocker switch mounted in the top of the handle. The large joystick and rocker switch make moving the easel simple for a person lacking fine motor skills. The joystick connects to the easel via a standard 9-pin serial cable (see Fig. 14.9) and the switches activate a number of relays on the easel. The actuators and screw drive control the movement of the easel and operate at around one per second, allowing the artist to move the canvas to its desired position.

Exposed wiring was kept to a minimum in order to ensure safety. The relays, circuit breakers, and power supply are safely housed in an enclosure designed to isolate any potential electrical dangers. The device plugs into any grounded 120-volt AC wall outlet.

The approximate cost of parts and materials was $815.
HUMAN INTEGRATED GRIPPING DEVICE

Designers: Philip Batista, Lyndon Charles, Emily Pribanic
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Supervising Professor: Dr. John Enderle
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INTRODUCTION
The Human Integrated Gripping Device is a universal device that allows users with limited hand strength and dexterity the ability to perform everyday tasks. This project is specifically aimed at helping those who are living with disabilities as a result of stroke. The device facilitates the user’s ability to grasp objects. Products currently on the market do not integrate the user’s hand into the device. Instead, they replace the hand. The Human Integrated Gripping Device is user friendly, light, and functional. These objectives are accomplished through a mechanical ratchet mechanism design that enables the user to adjust his or her degree of gripping with a lightweight and user-friendly system.

SUMMARY OF IMPACT
The Human Integrated Gripped Device was designed for a client who had a stroke. Because of the stroke, the client lost hand strength and, consequently, the ability to maintain a grip with sufficient strength for a prolonged period. A glove system allows the user to grip objects. The user hopes to have sufficient grip to swing a golf club, sweep the floor, and rake the lawn.

TECHNICAL DESCRIPTION
The Human Integrated Gripping Device is comprised of three components: 1) the ratchet mechanism; 2) the release mechanism; and 3) the glove interface. The following paragraphs describe these sections in more detail.

THE RATCHET MECHANISM
The ratchets are the basic core of this device. They function by allowing motion to proceed in one direction (indicated in Fig. 14.10). The user is able to close his hand, and once closed, the hand is locked into position. This is possible because the teeth on the ratchet, combined with the pawl, restrict any movement in the opposite direction.

THE RELEASE MECHANISM
Once the user wishes to release his or her grip he or she simply pulls on the strings of the release mechanism (seen in Fig. 14.11). The release mechanism is comprised of tubing inside of which Kevlar strings run, connected to each pawl. The tubing of the release mechanism is attached to the inner glove to prevent shifting of the tubes, which could result in decreased effectiveness. One way the tubes are attached is by sewn supports similar to that of the ring supports. Multiple locations along the length of the tubing are stitched to the inner glove, encompassing all three tubes per release mechanism. This helps keep all the tubes not only bundled but also in the correct position for optimal functionality. As the user pulls on a string, the corresponding pawl is pulled backwards, releasing the contact between the pawl and the ratchet surface. This enables the user to freely move the joint in question, allowing the segment to straighten. This process is repeated for each joint until the hand is released.
THE GLOVE INTERFACE
The inner workings of the device are unseen to the user in the final product. The user simply sees the glove interface as seen in Fig. 14.12. The user pulls these strings to release the device. There are two release holes located on either side of the outer glove that allow the Kevlar strings from the inner release mechanism to come through to the outer glove. For the release strings to be secured to the outer glove, two rubber rings are attached approximately two inches away from the release holes, towards the wrist. These rings are attached by sewing supports. The release strings are tied to these rings, forming a closed loop and preventing any dangling strings.

The cost of parts and materials was about $180.
CLASSIC ROCKER

Designers: Thomas Dabrowski, Sarah Philo, Adam Rauwerdink
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INTRODUCTION
An electronically-controlled legless rocker with a self-rocking motion was requested for the multisensory stimulation room in a facility for adults with developmental disabilities. Activation of the rocking motion must be through a simple switch that a user with special needs will be capable of controlling. Further, caretakers must be capable of turning the chair on and off through a switch that is not accessible to the user in the chair.

In addition, a speaker system to provide sensory stimulation to the chair user was requested. Like the rocking motion, the choice to have music play is controlled by the caretakers by way of a simple switch. The caretaker has control of the power, volume, and choice of music to be played.

SUMMARY OF IMPACT
The Classic Rocker (Fig. 14.13) was designed to be operated by adults with multiple disabilities. Individuals wishing to rock in a legless rocking chair previously required the direct aid of a caretaker. The users are capable of controlling the rocking motion.

TECHNICAL DESCRIPTION
The chair is built on an 8020 aluminum extrusion frame. This material allows for easy modification of the frame during the design and construction process. The frame consists of two parts: a base and an upper frame. The base frame is in contact with the ground and is attached to the motor and control towers. The upper frame is attached directly to the purchased video chair. A machined hinge connects the base frame and the upper frame. The hinge position is optimized in order to minimize the forces.

Fig. 14.13. Classic Rocker.
A 1/6 horsepower DC electric gear motor supplies the necessary rocking force for the chair (Fig. 14.14). The motor is powerful enough to rock users well beyond the specified user weight limit of 190 pounds. This will ensure that the motor is not stressed which should improve its lifetime. The motor has a speed of 80 RPM which is well above the desired speed of 20 RPM. The motor was slowed using a gear system. A 12 tooth gear is attached to the motor shaft. This gear is in contact with a larger 50-tooth gear, and slows the rocking speed to the desired 20 RPM.

A cam and linkage bar system attached to the back of the chair provides the rocking motion. The cam converts the rotational motion of the gear motor into the desired rocking motion. The size of this cam determines the range of rocking. It was found that a 1.4” cam provided an optimal rocking range. The cam is attached to the shaft of the large gear and therefore spins at 20 RPM. A linkage bar connects the cam to a pivot on the back of the chair frame. This pivot was placed in order to minimize the required rocking force.

Power is supplied by a 216W 12VDC, which plugs into a standard wall outlet. A caretaker control tower houses the caretaker control panel and a CD player. From this control panel the caretaker can switch on and off all parts of the chair. The panel also houses circuit breakers which protect the motor and CD player. The CD player feeds speakers which are implanted inside of the chair. A motor controller is also placed in this tower. This controller allows the caretaker to slow the speed of the rocking by turning a potentiometer on top of the control tower.

The user controls the rocking motion and music by two large switches: a touch switch and a squish switch. The switches are designed for simple operation with the physical and mental capabilities of the target user in mind. The motor control switch starts and stops the rocking motion. The music control switch functions as a mute switch for the CD player. If the caretaker shuts off the chair at their control tower the two user switches have no effect. The caretaker can interchange the function of these switches by changing socket connections on the caretaker control tower.

For safety, all electrical wires are run within the extrusion tubing and hidden by extrusion covers. The power supply and the drive system are covered by plastic shields.

The cost of parts and materials was about $1100.
INTRODUCTION
The goal of this project was to build a safe, user-friendly, low-maintenance, and battery-powered device for the multi-sensory stimulation room for an agency serving adults with developmental disabilities. The goal was to stimulate the olfactory senses of adults with disabilities. Olfaction Satisfaction (Fig. 14.15) emits scents upon input from a simple adaptive switch interface that is controlled by the user. Simple interactive devices had previously been developed to stimulate individuals' senses of touch, sight, and hearing. However, the sense of smell was not tapped by existing devices. Olfaction Satisfaction stimulates the olfactory senses in conjunction with the other senses of touch, sight, and hearing.

SUMMARY OF IMPACT
Olfaction Satisfaction was designed with the cognitive and physical abilities of the user in mind. Users can select from multiple scents by using two interchangeable switches: a large touch-pad and a squish switch. Ultimately the device serves to improve the client's quality of life by promoting interaction with the environment and providing adequate stimulation of visual, auditory, olfactory, and tactile senses. Client supervisors expressed a need for research about any potential hazardous exposure to the scents used. Further strengthening of the structure is required to avoid damage when used. In a future design, elimination of sharp corners would be helpful.

TECHNICAL DISCRIPTION
The user interface is easy to use. A versatile interface consisting of interchangeable switches connected via ¼” stereo jacks ensures that the device can be used by any user regardless of motor skill or disability.

The base and device casing are constructed out of 0.125” Gray PVC sheeting. The smooth exterior of the design also contribute to user safety.

A lever system was incorporated with a 12-Volt solenoid to provide the force necessary to release fragrances from the aerosol cans contained within the fragrance chamber. Since the aerosol cans can be
removed from the fragrance chamber, it is easy to clean, and to install new fragrances. This allows Olfaction Satisfaction to accommodate a wide variety of scents, giving the device the ability to offer a constantly changing and engaging sensory experience.

A PIC16F874 Microcontroller is responsible for taking input from the switches and processing them into output, which controls activation of the various sound chips, LEDs, and solenoids of Olfaction Satisfaction. In this regard, the PIC Microcontroller is the “brain” of Olfaction Satisfaction. A control circuit containing the PIC, Solenoid Drivers, 7405 Hex Inverter Chips, Voltage Regulators, and other components enable the PIC Microcontroller to control every component of Olfaction Satisfaction. The main circuit is shown in Fig. 14.16. Pull-up resistors make interactions with the user interface seen as a binary pattern of high (+5 Volts) or low (~0 Volts) voltages at the input terminals of the PIC Microcontroller. In response to a specific input pattern from the switches the device will: 1) indicate the currently selected fragrance and wait for input from user; 2) change the currently selected fragrance and play a sound; or 3) release the fragrance, play sounds and display an LED visual stimulation pattern.

The cost of parts and materials for the device was approximately $650.

Fig. 14.16. Main Circuit.
PATIENT POSITIONING AID

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INTRODUCTION
A Patient Positioning Aid (Figs. 14.17 and 14.18) improves patient positioning, which includes transferring patients onto medical devices and maintaining static positions during medical procedures.

Static positioning aids, such as foam wedges and wraparound coils, in use today for CT and MRI scan technologies are not especially effective. The current options only satisfy the needs of specific patients. A broader positioning aid with a wider range of capabilities is needed. The goal of this project is to create a versatile, low-cost, easy-to-adjust patient positioning aid that will work with a range of examination tables and imaging platforms.

When designing The Positioning Aid, hospital staff and the patient needs were taken into consideration. It was to be lightweight and easy to adjust, transfer, and store. It also had to be comfortable for the patient, sturdy, strong, and able to immobilize patients. A fairly lightweight and strong material, PVC, was chosen for the base. Foam padding and a gel-based headrest ensure comfort. Arm and leg stabilizers control the patient’s extremities.

SUMMARY OF IMPACT
The Positioning Aid eliminates the need for hospital staff to purchase multiple components in efforts to meet the needs of various patients. This device incorporates upper body and lower body-positioning components, and both are easily adjustable using a track system. The track system helps in accommodating the different sizes and heights of patients. Foam padding was added to provide additional comfort during the often-lengthy imaging procedures. It is strong so that the segment weight of patients weighing up to 500 lbs can be supported and transported. The device better immobilizes patients so that, for example, patients with diseases such as Parkinson’s, can have an accurate image taken without having to worry about tremors. Since it is thin, it does not add extra height to imaging tables. It is also durable. Lastly, The Positioning Aid is compatible with various imaging technologies including but not limited to MRI, CT, and x-rays by using all non-ferrous materials as well as radiolucent materials.

TECHNICAL DESCRIPTION
The first major component of our design is the base. A polyvinyl chloride (PVC) board was selected as the base, because it is lightweight and durable. The board dimensions are 72” x 22” x 0.5”. The tables and platforms at the hospital measure 6’ long and 22” wide; therefore, the transfer board is compatible and interchangeable with the various imaging device platforms.

Due to the large weight that needs to be lifted on this board, cross members are needed to ensure structural integrity. Two aluminum cross members (which are nonferrous and therefore safe in an MRI) that measure 1” x 0.5” x 72” run the length of the board set 2.25” from the sides of the board. Along with these, three PVC cross members measuring 1” x 1” x 17” run laterally across the board between the aluminum cross members. Attached to the PVC...
board are four aluminum handles, which are used to lift the board. Also, foam is attached to the bottom of the board along the sides and top and bottom, allowing the user to lift from the bottom side of the board as well.

The second major component of the design is the arm bar and head rest. The rod of the arm bar is 1” in diameter, and the handle bar is 16.5 “ wide. The headrest is a donut shape and is 8.5 “ in diameter for the adult size. The donut shape benefits patients because it allows them to place both the back of their head and their forehead on it.

The arm stabilizers consist of a base, a pivot, a linear bearing and an arm rest. The base has the dimensions of width 2”, length 7”, and thickness 1”. Attached to the base is a piece of gray PVC (type 1), 3” x 6” x 1”, on which the patient’s arm can rest. The leg fixation device is comprised of two bases, measuring 10” x 2” x 0.75 “ and is made of gray PVC (type 1). Along with these two bases, there are two leg stabilizer bars. The bars consist of a piece of high density polyethylene (HDPE). The bar was cut so it has a recess in it where the legs will be stabilized. The bar has dimensions of 2.5” x 1”. On each side of the bar an aluminum linear bearing is attached by aluminum bolts. These bearings attach to one of the aluminum extrusions on one of the leg stabilizer bases, and the other bearing attaches to the aluminum extrusion on the opposite leg stabilizer base. The bearings have a hand knob on them allowing users to position themselves.

The part of the fixation bar that comes in contact with the patient has a T-foam covering it to ensure comfort. This T-foam eliminates pressure points, absorbs shock and vibration and recovers completely after being used. The foam is breathable and lightweight. The track system used in this design involves silicon bronze carriage bolts. The bolts go through a slit in the base and attach to the arm stabilizer and knee fixation device.

The cost of parts and materials was about $1100.
ADJUSTABLE ART TABLE

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INTRODUCTION
An adjustable art table (Fig. 14.19) was designed for artists with cognitive and physical disabilities at an art studio for adults with disabilities. The project was to fulfill a need for a wheelchair-friendly art table. The client requested that the table be sturdy, not electronic and accommodate multiple users at once. A mechanical approach was taken and various raising devices were explored. A mechanical height adjustment makes for greater stability and does not require electricity or a motor. The table was built with a large, smooth tabletop, designed specifically for multiple users making art. The height adjustment feature allows the table to adjust between 29 and 42.5 inches. The table requires just one person to raise it, and two people to lower it.

Fig. 14.19. Final Product.
SUMMARY OF IMPACT

The art table adjusts to different heights smoothly and efficiently. This table is useful in that it can seat three wheelchair users comfortably on each side. There are also no sharp edges. The tabletop is made of plastic and has smooth corners and round edges for safety. The hydraulic release button is placed so that if the tabletop were bumped on any side, the button would not be able to be activated accidentally. If this does happen however, the table will raise instead of lowering onto the user.

The table allows people with disabilities to easily and safely pursue their artistic endeavors. The artists will feel a greater sense of independence due to the lack of assistance they will need when using the table. Artists can easily hit the release button and raise the table to a desirable height independently. Further efforts to ensure a consistent height on both ends, yielding a consistently flat surface are in order.

TECHNICAL DESCRIPTION

The table (Fig. 14.20) adjusts using a simple pneumatic device. There are two gas springs located at opposite corners of the tabletop, which, when engaged, each apply 14 pounds of force to the tabletop. The gas springs are nitrogen-gas-filled cylinders that apply a constant pressure against a piston. When unlocked, the piston is free to move. When the load applied to the two gas springs is less than 28 pounds, the combined force of the two gas springs, the piston will extend from the gas spring and raise the tabletop. The piston can be extended 13 inches, which allows the table to be adjustable between 29 and 42 inches high. The locking nature of the springs also allows the tabletop to be stopped at any position in this range. The gas springs are controlled using a parallel hydraulic release system. The release system controls both gas springs using one button, which allows them to adjust equally. This also makes it easy to adjust the table because only one person is needed to press the button.

Since there are only two gas springs, the tabletop would be unsteady if there were not supports in the other two corners. This is accomplished using aluminum legs that are composed of two separate bars, one attached to the upper framing of the table and the other attached to the base, joined by a linear motion bearing. This bearing allows for unhindered sliding between the two parts of the leg, which allows them to adjust easily when the gas springs are in use. The bearings are equipped with brakes that lock the leg securely in place. These brakes were tested to hold at least 300 pounds without failing. These legs also maintain stability if the gas springs are accidentally engaged while someone is using the table, providing vital safety measures for protecting the artist. The brakes must be disengaged before adjusting the height of the tabletop, and locked again before use.

The tabletop is made of a strong plastic, but it is also very light. The table is 30 by 72 inches in size, but only weighs approximately 20 pounds. This means that the gas springs can raise the tabletop without the assistance of the user. The large table surface allows for a great group area for producing art work. A smooth surface allows for easy cleaning.

The tabletop is attached to an aluminum framing that runs under the middle of the table and along the sides. This framing provides support under the table to prevent any bending of the table when under large stresses. It also provides an area for the attachments of the gas springs and the aluminum locking legs. The locking legs are attached using simple L-shaped brackets. The gas springs are attached by screws in the top of the hydraulic release. Brackets are attached at the two sides of the gas spring to prevent sideways torque. The legs are attached to bases that are three inches wide by 30 inches long. The bases extend along the sides of the table. The locking legs were mounted to this base in the same way as they were to the top framing. The bottoms of the gas springs are threaded, so special mounts were made with a hole that screwed onto the gas springs. The mount was then screwed onto the base.

To adjust the tabletop, one simply presses the release button. To lower the table, a second user is needed to provide force to press the piston back into the gas spring. A person stands at each end of the table and applies five to ten pounds of force down on the tabletop while pressing the release button. The button is released when the table is at the desired height. During initial tests of the prototype there were issues with friction between the two parts of the locking legs. The weight of the corner, which is unsupported during adjustments, caused the corner to dip slightly instead of remaining even with the corners supported by the gas springs. This caused the top parts of the legs to press against the bottom part and to come slightly off of the bearing.
To fix this an additional bearing pad between the two legs was inserted. This kept the table more level because the top leg could not move closer to the bottom leg. Also, it made the movement between the two parts much smoother by providing a surface with less friction and also by forcing the parts to stay aligned in the bearing. The table is easy to adjust, and its price is comparable to other art tables on the market, many of which are difficult to adjust or require electricity.

The table cost about $710 to manufacture; this was mostly due to the expensive gas springs, which cost about $300.

Fig. 14.20. Adjustable Art Table.
CHAPTER 15
UNIVERSITY OF MASSACHUSETTS AT LOWELL

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A NAVIGATION VIDEO GAME FOR PERSONS WITH LIMITED MOBILITY

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Client Coordinator: Kathy LeBlanc, Shore Educational Collaborative, Chelsea, MA
Supervising Professor: Alan Rux
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INTRODUCTION
Due to the lack of fully functional three-dimensional (3D) games that can be controlled by a one-button input device, a navigation game was designed. It helps those with limited mobility develop hand-eye coordination. The player controls the game characters using a one-button input device. The goal of the game is to navigate the character to an object, collect that object and then proceed to the next object. Currently, the games that allow one-button interaction are two dimensional (2D) “cause and effect” type games. The video game created for this project incorporates the cause and effect functionality and adds direction control. The one button action in the video game allows the player to control the direction in which a game character moves. The characters in the game move in a forward direction and when the button is pressed the character turns. When the button is released the character moves in the new direction tangential to his release point, thus enabling more interaction with the user.

SUMMARY OF IMPACT
The video game requirements were derived in collaboration with care providers. Also taken into account were the preferences and abilities of the clients using the game. The video game has allowed its users to exercise what limited control they have while experiencing a 3D video game. One client uses video games as part of his physical therapy sessions (Fig 15.1). The client’s mobility is limited to short movements of his left arm. To maintain and build strength in this ability he spends a few hours a day playing video games via a PC and custom-made joystick. Prior to receiving the navigation video game he spent hours playing cause and effect type games, which prompted him when to “hit the button”. Now he can control direction and action of the player, allowing him to decide when to turn and when to push the button.

TECHNICAL DESCRIPTION
The game was created using 3D Game studio’s A6 authoring system. The authoring system allowed the creation of a 3D multi-level game with multiple control inputs in a matter of months. The A6 system is separated into three parts: the world editor (WED), the model editor (MED), and the script editor (SED). The WED is used to create the game’s environment. The MED is used to create the 3D characters and objects to be used in the WED. The SED is used to provide instruction to control interaction between the user, WED, and MED. The language used in the SED is a C-based scripting language called “C-Script”. C-Script is interpreted by other high-level programming languages and not compiled by a CPU. The interpreting behavior limits the different types of data structures allowed by the scripting language, which reduces the robustness of the language and simplifies its learning curve for new users. The C-Script language uses functions and actions to allow reliable interaction between models in the game. The function is passed information that is processed and returned. The action, similar to a function, is associated with the model(s) from within the WED. The action invokes the function to be performed by the model. Multiple models can reference the same action, but the values altered remain with the model and not the action. This property allows the controlling code to be minimized and to be distributed through the game. One example of this is the action to collect the object by the player. Multiple object models in the same level reference the same action but the model’s values remain independent so that when one model is collected the other model remains to be collected.

The varying functions were separated into several modules. The modules work together to complete
the game. Those modules are: 1) Main; 2) Sound; 3) Video; and 4) Movement. The core of the source code is the Main module that invokes the game and “listens” for keyboard commands. Keyboard commands were incorporated so that the care providers could turn the sound on or off, pause the game, or quickly exit the game with minimal effort. The mouse clicks are provided by the custom joystick that plugs into a custom PC mouse. The module contains the functions that call WAV format files used for the sound effects and level background music. The module contains the functions to call BMP files that display the opening and closing credits, as well as the images that indicate the level number. The module contains the functions that control the game character movement. At the start of the level the movement is initiated in an endless loop that moves the player in one direction. Pressing the button interrupts the loop to update the model’s PAN value turning the character. Once the button is released the model’s vector value is updated and the player moves in the new direction. The movement module also contains a random number generator to randomly start the character in a different position and direction for each level.

The levels are associated so that the order is one through five. Once the fifth level is complete it loops back to the first level. Game termination comes from the keyboard input of ‘q’ or ‘Q’. The player is then prompted to press ‘Y’ or ‘N’ to quit or continue, respectively.

The software cost was about $199.

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Fig. 15.1. Client Playing the Game.
INTRODUCTION
The powered wheelchair (PW) was designed to enhance mobility (Fig. 15.2) of people with various disabilities. This device is a motorized wheelchair with many convenient built-in features. As shown in Fig. 15.2, the PW is a joystick controlled power-chair with a maximum speed of 8 mph and options such as actuated seat height adjustment and the ability to be easily disassembled into four main pieces. Upon completion, the PW was formally presented to the client.

The client is a 40-year-old woman with multiple sclerosis (MS), currently in the process of receiving a hip replacement. She will have significant trouble sitting and standing due to her pending hip replacement. The PW is intended to provide the client freedom to move within her environment unassisted.
SUMMARY OF IMPACT
Many of the wheelchairs on the market today are “institutional” in terms of appearance. It can also be very difficult to find a chair with the options that one requires at a practical cost. The design criteria for the PW were defined by the capabilities and preferences of the client. A variable-height swivel seat will assist the client in transition into or out of the chair. Also, aesthetics became a major focal point in the design as well. The client now has a power-chair equipped with all of the specified options in a great-looking and well-proportioned package.

TECHNICAL DESCRIPTION
The fabrication of the wheelchair chassis (Fig 15.3) was accomplished by means of a “design around major component dimensions” approach. With the two 12V batteries and the lift actuator positioned in a manner to achieve equal weight distribution from front to rear, the “backbone” of the chassis was constructed around these components. Due to the lack of mechanical engineering resources available for the design, a 100% safety margin was adhered to for all aspects of the chassis fabrication.

As shown in Fig. 15.3, the chassis was constructed entirely with stainless steel, once the major components were incorporated into the central portion of the chassis. The wheel mounting points were welded in place to obtain a 23” by 21” wheelbase. Upon completion of the chassis fabrication, rigorous testing was performed by means of extensive loading and flexing. Body filler was applied to all weld-points prior to painting in order to achieve a quality finish beyond industry standards. Strict adherence to a 100% safety margin resulted in a heavier total weight.

Using two 12V batteries wired in series, the 24V source was wired directly to a junction block using 8-gauge wire. Exiting the junction block was a 14-gauge fused 24V input for the lift actuator circuitry and an 8-gauge fused 24V output for the Courtney Electronics PWM controller that was used to control the drive motors. Ultimately, it was decided that the analog Op-Amp circuit design might compromise reliability and longevity of the wheelchair operation due to high power consumption characteristics. With a three-month deadline and most efforts devoted to the wheelchair fabrication, using a pre-manufactured PWM controller was the most logical option.

The lift actuator circuitry is mainly comprised of an in-line fuse and a double-pole double-throw switch. The maximum input voltage for the actuator’s motor is 24V, so the actuator could be operated directly from the 24V source. The Dynamic joystick was powered at 5 volts constantly supplied by the PWM controller. The joystick control inputs consist of two wipers, a forward/reverse and a left/right control wire. Prior testing and data acquisition of the joystick characteristics enabled custom control circuit tuning by means of programming the PWM controller.

The cost of parts and materials was about $1500.
VOICE-ACTIVATED TELEVISION REMOTE CONTROL

Designers: Christopher Robinson, Joseph Tice, Nga Nguyen, Justin Ulrich, Radhames Martinez, and Anthony Serino
Supervising Professor: Professor Alan Rux
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INTRODUCTION
This project was designed and built for an Assistive Technology showroom. This showroom allows students to view exciting, challenging and useful devices that can be built based on theoretical knowledge obtained in college.

The project is an Environmental Control System (ECS). An ECS enables anyone to operate a wide range of domestic appliances and other vital functions by remote control.

SUMMARY OF IMPACT
This ECS (Fig 15.4) was designed to enhance the ability of people with disabilities. The ECS allows for independence to be maintained.

TECHNICAL DESCRIPTION
There are two main hardware components for the Voice Activated Television: 1) the transmitter box and 2) the receiver box.

The transmitter box is white and is where the components for the user group interfaces. Three out of six people in the group can transmit from the same transmitter. The circuitry was placed inside the box with the following dimensions: 3 inches high, 5 inches wide, and 8 inches long. This box was attached to the parallel port with a 50-line ribbon cable.

Inside the transmitter box are the two main components: 1) an encoder (HT12E); and 2) a transmitter (TWS-434a) (Fig 15.5). The encoder converts the parallel signal to series, which makes the transmitter send the data faster.

The receiver box is black and has the following dimensions: 3 inches high, 5 inches wide, and 8 inches long. The remote control for the 15-inch Magnavox flat screen television was mounted on top of the box.

The receiving circuit has the following main components: the RWS 434 receiver, decoder (HT12D), Basic Stamp 2e, and 5 dip relays that were hard wired to a microcontroller inside a remote control. The signal sent from the receiver to the decoder is converted back to parallel after going through the decoder. It then goes to the Basic Stamp, which is the IC that communicates with the relays.

The cost of parts and materials was approximately $500.
Fig. 15.5. Inside the Voice-Activated Television Control.
INTRODUCTION
The Light and Sound Box (LSB), shown in Fig. 15.6, was designed to provide multiple sensory stimulations for children with multiple disabilities. The LSB is a box that will display a colored output along with a voice recording, given a colored input button press. After the LSB has been powered it begins blinking a default light pattern and continues to blink that pattern until the user presses an input button (see Fig. 15.6). The LSB was designed for a hospital day school program. The majority of the students in the school have multiple disabilities and restricted physical movement.

SUMMARY OF IMPACT
The LSB was designed specifically for children who have multiple disabilities. The goal was to provide a flexible device to be used in a dynamically changing environment. The teachers noted that because they could record their voices to the LSB they would use it not only as a visual and auditory stimulus tool for the very young children, but also as an educational tool for the older children. One specific example that a teacher illustrated was when objects were placed on the box and the children would answer specific questions by illuminating a certain object.

TECHNICAL DESCRIPTION
The LSB was constructed with four major sub-circuits (see Fig. 15.7): 1) a microcontroller sub-circuit; 2) an audio sub-circuit; 3) an amplification sub-circuit; and 4) a high-voltage sub-circuit. The microcontroller sub-circuit provided the processing of inputs to their corresponding outputs. The audio sub-circuit allowed the recording or playback of sounds from the LSB. The amplification sub-circuit was used to increase the sound output from the audio sub-circuit. The high voltage sub-circuit was used to isolate and control the light outputs from the LSB.

The microcontroller sub-circuit was assigned five inputs and eight outputs via software programmed directly into the microcontroller’s internal PROM (Programmable Read Only Memory). Four of the
five inputs to the microcontroller were assigned as switch input, and the primary interaction with the LSB was through four normally open or normally closed switches. The fifth input was assigned as a record button input and was designated as a normally open momentary switch that, when pressed, would produce an active low input to the microcontroller. Four of the eight outputs of the microcontroller were used to control a switching transistor that would enable a relay attached to the high voltage sub-circuit. The additional four outputs from the microcontroller were used to manage the audio sub-circuit. The microcontroller would handle the recording, skipping, resetting, and playback of voice recordings to the audio device.

The audio sub-circuit was comprised of an ISD1420 voice record/playback IC. It was chosen because it is an inexpensive single chip solution for the recording and playback of telephone quality (f_s=6.4kHz) sounds. Address inputs A6 and A7 were connected to +5 volts to allow the microcontroller to select which message was to be output. The message output was selected by pulsing address bits A0 or A4 with 5 volts, which respectively reset the internal address pointer to memory, address zero, or set the internal address pointer to the beginning of the next recorded message. The recording and playback of sounds to the device was controlled using the /REC and /PLAYE inputs in conjunction with the microcontroller. The additional level-activated play pin, /PLAYL, was connected through a 1kΩ resistor to 5 volts to prevent the LSB from unexpectedly playing a sound. The ANA OUT and ANA IN pins were connected to one another through a series RC circuit recommended by the manufacturer for the best input to output sound ratio results. A capacitive microphone was connected between the MIC and MIC REF pins. Additional microphone conditioning, RC circuitry, was used to filter out unwanted noise from the microphone. The ISD IC provided input pin that was set to amplify the analog input from the microphone to the ISD IC’s internal memory via a parallel RC network that consisted of a 470kΩ resistor and a 6.9µF capacitor. The SP+ output of the audio sub-circuit was connected to the non-inverting input of the amplification sub-circuit.

The amplification sub-circuit consisted of a LM386 low-power audio amplification IC configured as a non-inverting voltage follower with a gain of ~50dB.

![Fig. 15.7. Light and Sound Box Schematic.](image-url)
EASYKIT ENVIRONMENTAL CONTROL DEVICE

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Client Coordinator: Prof. Alan Rux
Supervising Professor: Prof. Charles Maffeo
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University of Massachusetts Lowell
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INTRODUCTION
EasyKit Environmental Control device (EECD) was designed to provide remote control to household appliances for people with physical disabilities, such as visual impairment and quadriplegia. The device uses an IR universal remote to control a TV, VCR, DVD, and stereo. Its functions also include ON/OFF operations of lights, a fan, and an air cleaner. Though the device works as a switch-activated EECD, it was structured to allow a voice option in the future, depending on the clients need. The device is completely modular and portable.

SUMMARY OF IMPACT
The device was designed and built to meet the needs of the client. Due to workplace injury he became sensitive to electromagnetic radiation (EMR) and has poor vision. The large keypad employed in the device enables him to control his household appliances with little or no help. The device emits low power radiation. IR transmission is more directional than RF and reduces his EMR exposure level.

TECHNICAL DESCRIPTION
For simplicity, an existing universal remote was
modified to become EECD (Fig. 15.8). The device also consists of an X-T transmitter to control ON/OFF devices. The circuit board of a universal remote (RCA) is made up of 33 switches. Each of these switches has two contacts: a_i and b_i. In order to activate a function, for example, function 1, a_1 and b_1 are connected or joined. After careful analysis, 7 x 5 matrix arrangements of these contacts were derived. Twelve wires, [7+5] were used to connect the RCA universal remote’s rows and columns matrix to two data selectors, respectively. The data selector is a multiplexer that selects a line at a given input to a common output. The common output of both data selectors were wired together. The power function can be activated by selecting channel two of both multiplexers. All 33 functions of the RCA universal remote are allowed using this set-up.

Three receivers used to turn devices ON/OFF were consolidated into one circuit board and mounted into a 3" x 6" box. Each of the receivers was permanently assigned addresses and was connected to a three-relay circuit. An X-T transmitter was then used to transmit IR signals to the receivers. Each time a signal is detected by the receiver, it checks whether the address matches its local address. When a match occurs, the receiver sends a high or low signal to the relay circuit to turn the device ON or OFF.

A 5x4 large matrix keypad was used to activate a function. This keypad was connected to an 8x8 matrix encoder that generates code on any key pressed on the keypad. An embedded program was written to use the codes generated and assigned inputs to the multiplexer and the X-T transmitter.

The ON/OFF devices required 7 functions, with a total of 40 [33+7] functions. In order to accommodate all these functions, 20 [5x4] keys with two switches (SW1 and SW2) were used. SW1 and SW2 in OFF position represent the first 20 functions. The switch SW1 in OFF position and SW2 in ON position represent the next 20 functions. SW1 ON position serves as the voice option for future improvement of the device. The two switches are connected to the tri-state buffer and the microcontroller. The tri-state buffer allows either the switch or voice inputs to the microcontroller, depending on the position of the switches. The table displayed in Fig. 15.9 summarizes this set-up.

<table>
<thead>
<tr>
<th>SW1</th>
<th>SW2</th>
<th>Function Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>OFF</td>
<td>First 20</td>
</tr>
<tr>
<td>OFF</td>
<td>ON</td>
<td>2nd 20</td>
</tr>
<tr>
<td>ON</td>
<td>ON</td>
<td>Voice Option (future Use)</td>
</tr>
</tbody>
</table>

Fig. 15.9. Summary of Functions.
INTRODUCTION
A client had been using Dragon Naturally Speaking (DNS) 4.0 and different macros, which were designed to facilitate her interaction with the PC for her part-time proofreading job. The current project (see Fig. 15.10) was to update the client’s system to the latest version of the DNS software, while addressing the system requirements for the new PC. Also, when necessary, new macros were written, to substitute for and improve on the ones she previously had, and to further expand the DNS vocabulary.

The final part of the project was to help her make the transition from the old system to the new one. This included copying relevant files from one computer to another, setting up a dial-up connection, importing Outlook folders, and training her to use the new software.

SUMMARY OF IMPACT
This project was custom-designed for the use and needs of the client, who has severe muscle weakness and gets tired very easily. She also has MCS, which makes her allergic to several artificially scented substances and other products. MCS also makes her sensitive to gases expelled by computer parts when they are heated and gases contained in new materials.

TECHNICAL DESCRIPTION
Macros are a series of commands and actions that can be stored and run. These series of commands usually help a user to automate tasks that become time-consuming and are performed regularly. The macros used in the project were limited to the Dragon Edition that the school purchased. This edition did not allow direct scripting of commands and only allowed the creation of plain text or picture macros. This limitation was not a problem since most of the macros needed by the client did not use any of the advanced features of macro scripting. The diagram in Fig. 15.11 shows how macros interface with other software in the system.

The producer of DNS 8.0 guarantees compatibility with most Microsoft products that facilitate the implementation of macros by making them global commands. Most of the macros written for this project have the following scripting format:

```
Sub ListenFullTitle()
  ' ListenFullTitle Macro
  '
  ' Macro created 04/01/2006 by Giovani Seben
  '
  Selection.TypeText Text: ="Listen to Our Stories: Words, Pictures, and Songs by Young People with Disabilities"
```
End Sub

This format can be repeated to create more macros such as the one above. However, if the command is not as long as the title above, an easier and better way to obtain the same result is to add words to Dragon’s vocabulary. In this design, instead of making the words macros, they are added to the vocabulary used by Dragon. Once a new word is added to the Dragon vocabulary, one can train it to be pronounced a certain way. This has the same effect as adding a macro for that command, with the benefit that the text will appear in the text format the user is using.

The cost of parts and materials was approximately $240.

![Fig. 15.11. Macro Block Diagram.](image)
THE MUSIC BOX SOUND RECORDER: A DEVICE THAT PROVIDES BRAIN STIMULATION TO CHILDREN WITH MULTIPLE HANDICAPS

Designers: Huong Ho
Client Coordinator: Lisa Szewczyk, Nashua Center, Nashua, NH
Supervising Professor: Jay Fu

INTRODUCTION
The Music Box Sound Recorder (MBSR) (Fig 15.12) is intended to help students with disabilities develop learning skills.

Development of various skills, such as listening, speaking, and reasoning, is important to allow children with disabilities to be able to actively participate in their communities.

SUMMARY OF IMPACT
The MBSR (Fig. 15.13) is a device that provides brain stimulation for children with disabilities. It is...
designed in such a way that it can be easily used. The MBSR will be an effective tool for children that have difficulties learning. Six songs were recorded on the MBSR before delivery. The children enjoyed the Music Box Sound Recorder. In the future they can record other songs if they desire. The children are learning while they are having fun with the MBSR, because they are associating a particular button with a specific song.

TECHNICAL DESCRIPTION
The voice chip ISD4003_8 was used to record and playback songs of up to eight minutes. Since there are six different songs stored in this chip, each song is recorded to play up to one minute and twenty seconds. The Basic Stamp 2 was used to operate the ISD4003_8 chip because ISD was designed to be used in a microcontroller-based system. Six large jelly-bean buttons were used to play each song. If the MBSR is in play mode, pressing a button will play the corresponding song. If MBSR is in record mode, pressing a button will record the corresponding memory space. A toggle switch was used for playback and record mode. Another toggle switch was used for power on and off. When this switch is toggled to turn the power on, a red Power-LED lights up. When MBSR is in play mode, pressing any jelly-bean button will light up a green Play-LED. When MBSR is in record mode, pressing any jelly-bean button will light up a yellow Record-LED. A push-button was used for the stop function. While a song is playing or recording, a stop switch, when pressed, will stop a song from playing or recording. A microphone was used to receive the sound of the song into ISD4003. A speaker was used to play the sound of the song out of an LM386 amplifier.

An AC adaptor was used to power the MBSR, which requires 6 volts. The Basic Stamp needs a power supply of 6 volts. It has an onboard 5-volt regulator used to power the audio amplifier and an LM317 voltage regulator. The ISD4003 needs 3-volt power, which is supplied by the output voltage of the LM317 voltage regulator.

The cost of parts and materials was approximately $120.

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Fig. 15.13. Client with the Music Box Sound Recorder.
INTRODUCTION
Laser pointers are commonly used in lectures to point to projected information. They can also be used to point to items on a communication board, wall chart, or an input device with laser-controlled optical switches that can control devices such as lights, fans, stereos, TVs, and computers. This laser pointer is specifically designed to be used as an accessing tool for communication. The difference between this laser pointer and regular laser pointers is the safety factor. Regular laser pointers can cause damage to the retina if they are projected directly into someone's eye.

A small laser module was fitted with a neutral density filter to reduce the power to a safe level. This module was then mounted internally to a headband to allow pointing with head movement and for the laser to be controlled by a momentary switch. The optical switch was designed with an array of photocells behind a ground-glass lens and will enable more uses of a laser pointer than those commonly used for communication.

SUMMARY OF IMPACT
Typical use of laser pointers for communication entails pointing at items either on a communication board or in a room. Many users of laser communication devices either cannot afford the high prices, or will opt to use an off-the-shelf high-power laser pointer as result, which is extremely dangerous as these can cause burns to the retina and even blindness. This laser pointer for communication is affordable compared to the purchase price of current communication lasers on the market. The communication laser size is 25 mm x 25 mm, which is smaller than current communication lasers on the market. The safety factor is as safe as GEWA's laser.

The output power is only 0.67mW. The activating switch for the laser is also lighter than the GEWA’s laser, due to three AAA size batteries instead of a battery pack. The optical switch will give more use to a laser pointer used for communicating to others that will help the client during daily activities. These two devices together will contribute to safe and effective communication and environmental control for those with severe communication disorders.

TECHNICAL DESCRIPTION
The laser pointer (see Fig. 15.14) was constructed from a 3mW, 650nm laser module with a size of 17.02mm x 10.44mm manufactured by US-Lasers, Inc. and distributed by Digi-Key Corporation. The laser housing was constructed from a round piece of wood, approximately 25 mm in diameter, an attached absorptive (0.6 optical density), and neutral density filter. The entire module was then glued to a piece of cardboard and inserted inside a headband with only the laser and filter protruding through. The optical switch is inside an enclosure approximately 200 mm x 160 mm. On the sides of the enclosure are two receptacles used to plug in devices that the user can control. Around the lens is a shield made of firm cardboard to prevent ambient light from activating the switch. The lens is approximately 55 mm x 55 mm x 2 mm ground glass. The ground glass is used to spread the beam of the laser, to not reflect any laser light back toward the user, and to prevent ambient light from activating the switch. The active area of the lens is approximately 37 mm x 37 mm. Underneath the lens is a 4x4 matrix of photocells, or photoresistors. These photocells, located approximately 2 inches from the lens, receive the light and report a voltage to a control circuit comprised of a comparator, a zener diode, and a toggle flip-flop. Around the photo resistors is a foil board to reflect oblique angles of incidence back to the photocell network. The power is controlled by a relay, connected to the power supplied from the power cable, and the
receptacles on the sides of the enclosure. Possible design improvements include larger lenses if larger ground glass lenses can be found. If so, a larger photocell network can be created, but increasing the resistance value of the photocells is recommended. In this design, the photocells value was rated at 8000 ohms in full light. Another design improvement would be to cut the neutral density filter to approximately 10 mm.

The cost of parts and materials was approximately $222.

Fig. 15.14. Laser Pointer.
INTRODUCTION
The Video Game Buddy (Fig. 15.15) was designed to enable a person with quadriplegia to play video games. The buttons on the video game controller are pressed or triggered by the user sipping into puff straws mounted on a headset. Head switches attached to a headrest trigger the directional pad. This device was specially designed for a client who has quadriplegia and had enjoyed playing video games prior to his accident.

SUMMARY OF IMPACT
The goal of the Video Game Buddy was to enable hands-free use for the user. The client uses other technology to help him with his everyday life. However, he was limited to turning on the television, talking on the phone, and getting around with a wheelchair. Due to the limited dexterity of his hand, he was not able to play video games in a traditional way with a controller. The Video Game Buddy allows the client to join the fun and experience additional independence. The unit requires minimal assistance to get started.

TECHNICAL DESCRIPTION
The Video Game Buddy is made of two parts: the input box and the switches (see Fig. 15.16). The input box is made of plastic with dimensions of 5 x 2 inches. This box is lightweight and allows enough room for the components needed. The components of the box are a solder board, Basic Stamp 2 module (BS2), a decoder, 3.5 mm jacks, and an Xbox controller by Microsoft™. The outer components of the Video Game Buddy are switches.

The switches used were a quad-puff system and compact head switches, both designed by Enabling Devices™. The quad-puff system was selected because it is an easy method for those with quadriplegia. The puff system was used as four inputs to the input box. Since there are many buttons on the Xbox controller, only nine of the buttons were used. It was designed this way to make the gaming experience less complicated with the four straws. Each straw input has the ability to control two buttons, except for the last straw, which controls three buttons. There are four head switches, used for the directional pad. The head switches are positioned so that the user can easily trigger the switch with slight pressure from the head.

The inputs from the puff straws are processed within the input box with the BS2. The BS2 sends a signal to the decoder, which sends a signal to the appropriate button on the Xbox controller. The inputs from the head switches are directly connected to the controller for real-time movement. When the controller is plugged in, the Microsoft™ Xbox console supplies power.

The cost of parts was approximately $375.

Fig. 15.15. Video Game Buddy.
Fig. 15.16. Video Game Buddy Controller with Input Box.
INTRODUCTION
The main goal of this project is to play different types of music and to blink the light-emitting diode activated by a remote. The entire design depends on the transmitter switching to operate. The circuit that operates the transmitter is a 6-volt DC power supply. The receiver contains a music chip and a versatile flasher that operates on a 5-volt DC power supply. The music and the LED flasher give the client the option of interacting with the device. This device is activated when the switch is on, and deactivated when the switch is turned off (see Fig. 15.17). The music is played via a preprogrammed chip each time the button is touched and the light is flashing. A problem with the versatile flasher was resolved by connecting pin number 9 of the driver ULN2803A to pin number 1 of the capacitor C1 of the crystal resonator. The positive 5-volt DC, which powers the circuit, was then connected to the positive LED number 8, causing the lights to blink.
SUMMARY OF IMPACT
The device provides different means of interaction and encourages movement for children with disabilities in a hospital day school.

TECHNICAL DESCRIPTION
The transmitter device is enclosed in a black plastic box, 6” x 9” x 3”. There are two holes drilled into it with space between them for the buttons, a hole drilled for the antenna, a hole drilled for the light indicator power, and a hole drilled for the on/off switch. The receiver device box is also plastic and is the same size as the transmitter box. There is one hole drilled on the top side of the receiver box for the music button, eight horizontal holes drilled with spacing between them for the versatile flashing lights (LEDs), one hole drilled for the light music indicator, one hole drilled for the antenna, and one hole drilled for the signal light indicator. The actual board is connected via wires. This method of wiring is essential in terms of preventing a cumbersome design because most of the components must be on one board (see Fig. 15.18).

Six-volt DC (4 x 1.5 volts AA batteries) powers the transmitter device. A 5-volt DC adaptor powers the whole receiver circuit. The design has the following parts: two 5-volt relays, one transmitter/receiver/encoder/decoder, ten capacitors, three diodes, 11 LEDs, one programmed music chip, 17 resistors, five transistors, and one switch. This project offers the option of adjusting the frequency of the versatile flashers.

The total cost of parts and materials was approximately $70.
MOTORIZED DYNAMIC STANDER: A SELF-PROPELLED STANDING VEHICLE FOR STUDENTS WHO CANNOT USE TRADITIONAL WHEELCHAIRS

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Supervising Professor: Dr. Donn Clark
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INTRODUCTION
The Motorized Dynamic Stander (MDS) (see Fig 15.19) was developed to provide mobility for students who cannot move around on their own and who lack the skills and strength required to operate manual dynamic standers. The device consists of a foot platform that the student stands on, an upright body pad to lean forward against, drive wheels, and casters for balance. Push-button hand controls are used to operate the power train. The intention is to enable students’ mobility within their school and classroom environments. The MDS also serves to stimulate the students and provide a more interactive educational experience.

SUMMARY OF IMPACT
The design criteria for the MDS were defined by the capabilities of the students who will use it. Because many of the students have limited capabilities, the MDS drive system has been designed to operate at very low speeds. Acceleration has been carefully controlled by software for smooth, safe operation. An RF remote kill switch provides a means for instructors to disable the MDS drive system while supervising their students. The existing Velcro straps have been retained, which allow the instructor to safely secure a student in the MDS.

TECHNICAL DESCRIPTION
The MDS was created by adding an electronic drive system to an existing commercially available manual dynamic stander. The existing manual hand wheels, chains, and drive wheels were removed. In place of the existing drive wheels, a pair of DC hub motors was bolted to the stander frame. The hub motors...
(shown in Fig. 15.20) are 8” wheels with integrated 24V DC motors and gearing.

Two 55Ah 12V sealed lead acid batteries were mounted to the lower frame members in front of the body pad, as close to the center of gravity as possible. These batteries are approximately the size of automotive batteries and weigh 39 lbs each. They are supported by a pair of 1/8” x 2” angle steel brackets that are bolted to the stander frame.

The electronic drive system uses Pulse Width Modulation (PWM) as a means of varying the DC voltage and hence the motor speed. The PWM signals are generated by a PIC microcontroller, which has been programmed to read inputs from the four push-buttons and generate PWM signals accordingly. The PWM signals enable inputs to a pair of H-Bridge motor driver boards. The H-Bridges also have motor direction control inputs, which are also generated by the PIC microcode. Each H-Bridge connects to the 24V battery system and drives one of the hub motors. The H-Bridges were installed in a pair of metal cases, which were mounted to the panel on the front of the body pad frame. The PIC microcontroller board is encased in a black plastic project box, which was also secured to the panel with locking Velcro for easy access. The H-Bridge motor direction control inputs must be set appropriately before the 24V power is applied. A DC solid state relay (SSR) was introduced to isolate the 24V connection from the H-Bridges until the control bits were set to the correct state. The PIC initialization code first sets the control bits correctly, and then sets the input of the SSR to engage the drive system. A rocker switch with an LED indicator mounted on the front of the push-button box activates the MDS. Once the switch is closed, the MDS is ready for use.

The cost of parts and materials was approximately $4200 (including $3300 for the existing manual dynamic stander).
THERAPEUTIC RECLINING WHEELCHAIR

Designer: Jonathan P. Blanchard
Client Coordinator: Lisa Szewczyk, Nashua Center, Nashua, NH
Supervising Professor: Charles Maffeo

INTRODUCTION
The Therapeutic Reclining Wheelchair (see Fig. 15.21) was designed to give a patient with hip and spine deformities the ability to relieve pain independently through the reclining of the wheelchair. The patient had a wheelchair with a reclining mechanism, but her condition did not allow her to use it. She requested a way to easily and independently perform the reclining function.

SUMMARY OF IMPACT
The ability to recline the wheelchair through the activation of a single push-button allows the client to independently relieve pain. This not only increases her quality of life but also provides her with an alternative approach to relieve pain that is not invasive or dangerous.

TECHNICAL DESCRIPTION
The wheelchair’s spring-loaded mechanism for managing the reclining function was removed and replaced with a linear actuator. To control the actuator, a hand-sized push-button was attached to the client’s voice panel. When activated, this push-button sends a signal to a Basic Stamp. The Basic Stamp executes a programmed routine when activated.

When activated, the microcontroller begins by retracting the linear actuator, thereby reclining the wheelchair. The microcontroller then monitors the position of the seat recline via an ADC feedback provided by the linear actuator. Once a preset point is reached, the actuator is told to pause for 1 second and then begin to extend. The extension of the linear actuator causes the seat to incline. This routine is performed three times and then the seat is returned to its original position and is ready to begin again.

The actuator also has a secondary set of controls, which allow for manual control of the actuator. This panel, when activated, overrides the momentary push-button control. It is provided to enable another individual to adjust the chair. This panel provides two push-buttons. The first push-button reclines the wheelchair and the second inclines the wheelchair.

The cost of parts and materials was approximately $1000.
Fig. 15.21. Therapeutic Reclining Wheelchair.
VOICE-ACTIVATED TELEPHONE

Designer: Kristyn Ferro
Client: Evelyn Benson
Supervising Professor: Jay Fu
Electrical and Computer Engineering Department
University Of Massachusetts Lowell
Lowell, MA  01854

INTRODUCTION
The Voice-Activated Telephone (see Fig. 15.22) was designed for an elderly woman with limited vision and moderate arthritis. Voice commands allow the user of this phone to place calls without the need to look up phone numbers or press buttons. The phone can still be used as a normal telephone. This device makes life easier because voice commands do the work of dialing a phone number.

SUMMARY OF IMPACT
The client lives alone and she has trouble making phone calls, as it is difficult for her to read the numbers as well as to press the buttons on her phone. Having the Voice-Activated Telephone will help her feel safer in case of an emergency, because she will be able to contact 911 or family more easily. This system is designed specifically for the client in that telephone numbers of her family, friends, and others are pre-programmed.

TECHNICAL DESCRIPTION
The Voice-Activated Telephone has three parts: 1) a voice recognition circuit, 2) a telephone, and 3) a dialing circuit. The voice recognition circuit is based around the HM2007 voice recognition chip, which can be trained to recognize up to 40 words. The recognized words are stored into RAM memory, which is backed-up by battery to preserve the data. Power is provided to the rest of the circuit with an AC power supply. The system is designed to be user-friendly. For operation, the client only needs to lift the phone handset and speak the name of the person she wishes to contact.

The HM2007 then selects the proper voice command number from the RAM and passes it to the BASIC STAMP 2 SX (BS2sx). The Basic Stamp continually waits for inputs to be received from the HM2007. After receiving the stored word number, the Basic Stamp responds by dialing the phone number associated with the voice command number. If the Basic Stamp receives an invalid command, an error light is displayed on the front of the unit. The Basic Stamp then returns to the beginning of its program and continues waiting for the next voice command.

To dial a number that is pre-programmed into the Basic Stamp, one of the BS2Sx I/O pins generates the appropriate dual-tone multiple frequency (DTMF). A small interface circuit was built to filter out and isolate the digital pin from the analog telephone lines. This circuit is connected directly to the telephone lines, through two relay switches, for hands-free dialing. The relays are normally open, allowing the telephone to be used as a standard phone if needed. The telephone used was a standard telephone that can be connected to any telephone system.

The cost of the materials to make the voice-activated phone was approximately $200, including $59 for the Basic Stamp and $30 for the telephone.
Fig. 15.22. Voice-Activated Telephone System.
INTRODUCTION
The Voice-Activated Universal Remote Control (see Fig. 15.23) was designed to provide an individual with paraplegia the ability to control a television and a cable box by voice. This device is composed of a voice-recognition circuit, an interface circuit, and a universal remote control.

SUMMARY OF IMPACT
The design criteria for the Voice-Activated Universal Remote Control were defined by the capabilities and needs of the client, who wished to control her television with her voice. Instead of always having to ask to have the channel changed or the volume adjusted, it is convenient for her to have complete control of the device. This lets the caretaker focus on other tasks. The design of the device lets the client speak a command, which acts as if a button is being pushed, and another command, which acts as the finger being released from the control. There are eight different voice commands, which include power, TV, cable, volume up, volume down, channel up, channel down and TV/Video.

TECHNICAL DESCRIPTION
The primary component of the Voice-Activated Universal Remote Control is the HM2007 voice-recognition chip (see Fig. 15.24). Combined with an 8K x 8K SRAM, 74LS373 Octal Transparent Latch, matrix keypad, and two TIL311 Hexadecimal displays, a working voice-recognition circuit was built. Training the circuit was the first task to be completed. This was done by entering a two-digit number on the keypad followed by the pound key, and speaking a command into the microphone. After storing all eight commands, the voice-recognition circuit is always “listening.” When the user speaks a command, the circuit processes the command and sends the correct four-bit binary number from the SRAM to the interface circuit.

The interface circuit consists of a 4-16 line decoder, LM555 timers, bi-polar transistors, and solid-state relays. A four-bit binary number from the voice-recognition circuit is fed into the 4-16 line decoder. From there, one of the outputs is selected based upon the input signal. This low output signal is then fed into an LM555 timer, which operates as a “one-shot timer;” it takes the low signal from the 4-16 decoder and triggers the high output. The one-shot timer delays the input signal for a brief instant. From here, the signal is fed into the base of a bi-polar transistor. From this, 5V is output from the emitter into the positive terminal of a solid-state relay. The other side of the relay is connected to two pins coming from the IC in the remote control, making a solid connection between the two, in turn activating the command spoken into the microphone.
Fig. 15.24. HM2007 Voice-Recognition Chip.
ELECTRONICALLY-ADJUSTABLE WORKSPACE

Designer: Matthew Farmer  
Client Coordinator: Jimmy Magiera  
Supervising Professor: Jay Fu  
Electrical Engineering Department  
University of Massachusetts at Lowell

INTRODUCTION
A desk was designed to allow people using chairs of different heights, such as standard desk chairs and wheelchairs, comfortable access to a specially designed computer. It is able to adjust in height to the appropriate level for its user. The desk needs only two positions: low and high. The low position accommodates a standard desk chair with a height of 36 inches from the floor to the top of the desk. The high position allows a wheelchair to go under the desk. The high and low positions are adjustable for use by clients with wheelchairs of varying heights.

SUMMARY OF IMPACT
Superior materials were utilized to create a fully-functional project that looks great and will last for years to come. This desk will be donated to a VA hospital to be used in a computer lab. A highly customized computer will be placed on this desk so that it may be used by those who are able to walk and those who use wheelchairs.

TECHNICAL DESCRIPTION
This project consists of three smaller projects: 1) the legs, 2) the desktop, and 3) the electronics (see Fig. 15.25). The legs enable the desk to change in height. The desktop is comprised of the working area and the housing of all moving components. The electronics use the input from the user and its sensors to control the operation of the desk in a safe manner. A schematic is shown in Fig. 15.26.

The telescoping legs are made from brushed aluminum. From top to bottom there is a gear, a bushing, a bearing, a second bushing, a spacer, a mounting bracket, a top section of the leg, a bottom section of the leg with a nut welded inside, and the footing. There is a threaded rod through the center of these components. The gear is screwed into this rod, allowing the bottom section of the leg to telescope in and out of the upper section of the leg as the screw turns. There is a slot in the upper section of the leg through which a screw slides to ensure that the lower section does not simply spin.

The desktop is a standard size of three by six feet. It is made of two layers of particle board, and is covered by a sheet of Formica. The Formica top is durable and easy to clean. The table edges have all been rounded to minimize any personal injury that could occur by someone wheeling or walking into a corner. It also has a T-molded edge, which both looks nice and is slightly more forgiving than a hard Formica edge.

Below the tabletop is the gear box. This houses the chain, all of the gears attached to each of the legs, a chain tensioner, and the motor’s gear. All of the moving parts are enclosed in this area so there is no chance of an article of clothing getting soiled by grease or ripped by the chain.

This project is powered by standard 110 volt AC wall socket. There is a transformer inside the sealed electronic box, which steps this voltage down to 24V AC for use in the controls and relays. This was done to reduce the user’s interaction with high voltage...
components. There is extremely thick wire housing connecting this electronic box to the motor to eliminate all chance of contact with a high voltage source.

In normal operation the desk starts at either the high or low position. The user then presses the opposite button and the desk moves in that direction. It continues to move until the appropriate limit switch, mounted to the rear left leg, is triggered. Once this limit switch is triggered, the circuit, which keeps the latch in the relay, is broken and the desk stops. If at any time the opposite direction button is pressed, the circuit for the latch in the new direction is enabled. This is all controlled by the combination of the normally-closed and normally-open contacts on the bottom of the palm buttons. If the button corresponding to the current direction is ever pressed while the desk is moving, there is no change.

The emergency stop is comprised of two limit switches, which are placed under the table between the two drawers. There is a panel, to hold the place and keep a constant horizontal line with the bottom of the drawers, and a bottom base which connects to the back of the desk via a hinge. This panel prevents the possibility of injuring the knee on one of the drawers, and serves as an emergency stop if the down button is pressed while there is still something under this area. If this situation were to occur, the desk would start to slide down and once the object, such as a wheelchair or knee, pressed up against this panel, the limit switch would be triggered and the descent would stop. Special care was taken to allow for adjustment of the level of the panel and of the sensitivity of the limit switches.

The cost of parts and materials was approximately $1200.

Fig. 15.26. Schematic of Desk.
MULTIPLE SENSORY LIGHT PROJECTOR

Designer: Michael P. Montagna
Supervising Professor: Alan Rux
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INTRODUCTION
The Multiple Sensory Light Projector (Fig. 15.27) was designed to provide visual and auditory stimulation to children with disabilities. Each of the three outputs from a three-channel audio equalizer trigger one of three display circuits, causing a pattern of lights to appear when a preset magnitude is achieved.

SUMMARY OF IMPACT
The Multiple Sensory Light Projector is to be used in a multiple sensory room, an environment in which an individual can explore and learn through sensory stimulation. This device is meant to supplement auditory and visual experiences.

TECHNICAL DESCRIPTION
The Multiple Sensory Light Projector is basic in construction. Packaging began with a white polymer cutting board, normally sold for culinary purposes, attached securely to a shallow box, which houses the power supply, circuitry, and display elements.

The circuit began with a simple 3-channel audio equalizer. As the audio signal passes through, it is split into three frequency ranges. Each stage of this element has a variable resistor on it to determine the amount of signal allowed to pass through each channel.

The output signal of each channel is then passed on to a vu meter, or level meter. The greater the amplitude of the signal the more outputs are turned on. In this case, because of the IC, five levels were chosen. The signal that comes from the second level of the vu meters activates a relay, which in turn activates the appropriate channel of the display.

The total cost of this project was approximately $80.
Fig. 15.27. Multiple Sensory Light Projector.
INTRODUCTION
The goal of this project was to build a fun and easy-to-use learning tool to help children with developmental language and cognitive challenges independently identify pictures (see Fig. 15.28). The device is a wireless base made up of five primary components: a receiver, a transmitter, a jellybean switch, a monitor, and a Basic Stamp 2.

SUMMARY OF IMPACT
The device provides independent practice in picture recognition and labeling. It allows the children to participate more in the classroom, provides more learning time, and requires less dependence on teachers.

This device was designed to be laid on top of a student desk, allowing it to be used by many users. Its design allows for easy removal (see Fig. 15.28 and 15.29).

TECHNICAL DESCRIPTION
Once the jellybean button is pressed a binary signal is sent to the encoder. The encoder decodes the binary signal, converts it into a square wave signal, and sends it to the transmitter. The transmitter sends a sine wave signal to the receiver. The receiver converts it into a square wave and sends this signal to the decoder. The decoder converts the signal to a binary code, which is then sent to an input pin of the Basic Stamp 2. The Basic Stamp 2 outputs a voltage of 5V to the input of the solid state relay. The relay outputs a voltage of 120V, illuminating the bulb, which is programmed to automatically shut off after 5 seconds. Components and wiring are shown in Fig. 15.30 and 15.31.

The cost of parts and materials was approximately $235.
Fig. 15.30. Learning Tech.

Fig. 15.31. Learning Tech
RADIO-CONTROLLED POWER STRIP INTERFACED BY RS-232 SERIAL

INTRODUCTION
This project is designed to allow remote control of 120V AC electrical outlets using a computer or other serial-capable device as a controller. It consists of two devices, the controller, and the power strip, which are connected wirelessly. The project was created for a man with cerebral palsy who uses a full-body wheelchair and interacts using a specialized computer, called the Vanguard, which is mounted to the chair. It allows him to turn lamps, fans, and other devices on and off at the touch of an on-screen button. Additionally, a nurse call button is implemented, because the client cannot use the standard hospital hand button. Calling a nurse may be accomplished with an on-screen button as well. The project is intended to provide the client with simple switch control of any appliance from his chair.

SUMMARY OF IMPACT
This project increases the client’s independence. Before this project, the client needed an aide to turn appliances on and off in his room. There was no way for the client to call a nurse if he needed one. Now, with these devices, the client can live a more self-sufficient life by controlling his own environment. He is also afforded extra safety, in having a method of calling a nurse from his chair.

TECHNICAL DESCRIPTION
The remote-controlled power strip is designed with flexibility in mind. Rather than anchoring a single unit to the wheelchair and forcing appliances to be located near the chair, the design incorporates radio frequency (RF) communication between two devices, freeing the controlled appliances from the chair. Additionally, rather than hard-wiring appliances to a switching controller, the project uses the interface of 120V AC outlets to support the maximum number of appliances and to allow easy configuration and replacement of the appliances. A block diagram is shown in Fig. 15.32.

The two devices communicate in a master-slave relationship. The master controller is connected to the Vanguard computer mounted on the wheelchair, and accepts commands from the Vanguard over an RS-232 serial connection. It interprets the command, and sends out an equivalent command over a serial RF link. A MAX232 level-converter IC is used to match the +/-12V levels from the serial line to the 5V/0V TTL levels supported by the processor. The master device is powered by an external battery pack of 7.2V at 2 amp-hours, which is internally regulated to 5V by a 7805 regulator IC. The case features two DB-9 serial ports, which allow pass-
through so that the device may be placed in serial between the Vanguard and an external PC (a common mode of operation for the Vanguard).

The slave device receives these commands over RF, and accordingly switches power on or off to one of its outlets or to the nurse call switch. It is built using a six-outlet power strip. The power strip on/off switch controls power to the slave device, which incorporates its own power supply built from a transformer, rectifier, capacitor, and the 7805 regulator. Internally, solid-state relays are used to control power flow to the power strip outlets, and two N2222 power transistors are used to drive the solid-state relays from TTL levels. A magnetic relay is used to control switching of the nurse call switch, which is interfaced with two ¼" mono jacks connected in pass-through configuration so that a traditional hand switch may be used for nurse call as well.

The devices are both built around the PIC16F687 microcontroller IC. The PIC16F687 is used to support asynchronous serial I/O and general purpose, one-bit I/O. In conjunction with the PIC, this project uses the Linx LR series of RF serial transmitter and receiver, and the Linx “Splatch” surface-mount antenna. The RF circuitry requires custom-printed circuit boards, which were drawn and etched by hand. Other circuitry was wired on prototyping boards. Enclosures for the two devices are plastic, to allow maximum transparency to the internal antennas. All components are shown in Fig. 15.33.

The cost of parts and materials for this project was about $200.
SENSORY TOUCH AND SPEAK TOY FOR CHILDREN WITH MULTIPLE DISABILITIES

Designer: Royal Rowland
Client Coordinator: Marrie Haggerty, Shore Collaborative School, Chelsea, MA
Supervising Professor: Donn Clark
Department of Electrical Engineering
University of Massachusetts at Lowell
Lowell, MA

INTRODUCTION
A toy was designed for a multi-purpose educational agency serving students and adults with disabilities (Fig. 15.34).

The goals for the Sensory Touch and Speak game were to create a game that would teach students (ages 5-7) about different weather scenarios, while at the same time increasing dexterity and range of motion. The toy has six buttons, each with a different weather theme (sun, wind, rain, snow, moon, cloud). When a specific button is pushed there is an audio response, such as “cloud.” There are two modes selectable by the teacher, which includes “touch and speak” mode and “button search” mode. “Touch and speak” mode allows the student to press buttons at random and “button search” mode will ask students to find a button and then issue an audio response that tells them they have found the correct button.

SUMMARY OF IMPACT
The design, shown in Fig. 15.34, provides a touch and speak game for children with mild to severe cognitive disorders. The game was designed to be modified to fit any number of circumstances, using removable buttons and replaceable button covers.

TECHNICAL DESCRIPTION
The toy consists of four main components: 1) the box, 2) the “brains,” 3) the “voice,” and 4) the human interface. The internal components are shown in Fig. 15.35. For the project box the Pactec KE-20 series keyboard style project box was chosen. The reasons for this choice were the simplicity of modification, smooth plastic corners (safety), surface area (large buttons), and cost (around $40). For the “brains”, the 16F877 Microcontroller is used because of its versatility and because it requires almost no support circuitry. The controller has over 30 I/O pins and 7 analog inputs. Each I/O pin is controllable on the fly using software. The 16F877 uses flash memory (erasable), which is 8K x 14bits wide. For the “voice”, the Emic Text-to-Speech module was used. The Emic is easily interfaced to any TTL microcontroller that has two serial I/Os. Based on the Winbond WTS701, this device intelligently handles values, sentences, numbers, and common abbreviations using a natural female voice with simple serial string sentences. For the human interface soft touch buttons were used. The soft touch buttons used were supplied by the school. They are 2.2”x 3.2”. Each button contains a different weather picture (i.e. sun, moon, wind, rain, snow, and clouds), and when the student touches the button the game responds with an audio playback message. Each button was mounted so that it could be removed and cleaned.

The cost of parts and materials was about $170.
Fig. 15.35. Interior of Completed Project.
STORY BOX: A DEVICE WHICH USES A JELLYBEAN BUTTON TO RECORD AND PLAY MESSAGES

Designer: Ruvani Nagage
Client Coordinator: Susan Yackolow (Speech Therapy Assistant), New England Pediatric Care, North Billerica, MA
Supervising Professor: Jay Fu

INTRODUCTION
The Story Box was designed for individuals with learning and speech disabilities who also have minimal usage of their hands (Fig. 15.36 and 15.37). There are about six patients (all in their teen years) who will benefit from the project. The Story Box is a plastic box with a jellybean button on the top. There is a reset button, a power switch, and a mode (play/record) switch on one side of the box. It is activated and used by pressing these buttons. The contents of each page of a certain storybook are vocally recorded into the system as separate segments. For this project six segments were chosen with duration of 30 seconds each. Each story chosen...
has six pages. The contents of these six pages are vocally transferred into the Story Box, one segment per page. The jellybean button is pressed to start the story. When that segment is done the jellybean button is pressed again. This activates the segment that has the recording of the content on the second page. By pressing this main key over and over again, the talking box reads aloud from the first page to the last page of the storybook.

**SUMMARY OF IMPACT**

The design criteria for the Story Box were defined by the clients and staff members. The main goal was to design a device that will help individuals with physical and cognitive disabilities, who are not able to handle or read a story book, get satisfaction out of listening to stories being told aloud.

**TECHNICAL DESCRIPTION**

The Story Box consists of a jellybean button, power switch, play/record switch, and reset button. The total recording time for the box is 3 minutes. These 3 minutes are given by two ISD chips (25.120). This time period was divided into 6 segments, 30 seconds each. These segments are controlled by a Basic Stamp 2. The button activates the segments, one after the other. The amplifier increases the volume of the contents being played.

The button is pressed to activate the first segment of the Story Box. This first segment is stored in ISD chip #1. Pressing this button again leads to the second segment, which is also in ISD1. Pressing the button 6 times will progress from segment 1 to segment 6. Segments 1, 2, and 3 are stored in ISD chip #1 and segments 4, 5, and 6 are stored in ISD chip #2. Logic 1 signal is then sent to Basic Stamp 2, which recognizes the voltage and analyzes it through a program. After running through the program this signal is sent to the input pins of the ISD25120 chips. The segment it is on decides which ISD chip to send the signal to. The ISD25120 chip then determines whether the system is in the recording mode or the play mode. If in play mode, the signal is amplified using an LM – 386 Driver Amplifier that goes out through a 16 Ω speaker and an audio output is received.

When the system is in the record mode, a stereo microphone is used to record audible data. When the recording is to be done, the button must be kept pushed down and the above signal cycle occurs through the Basic Stamp and then one of the ISD 25120 chips (depending on what segment is being used).

There is a reset button to take the user back to segment 1 in both the record mode and play mode.

The cost of parts and materials was about $400.

![Fig. 15.37. Story Box (Closed).](image-url)
VOICE RECOGNITION FOR A CAMERA AND INTERCOM SYSTEM

Designer: Samuel Bowden
Supervising Professor: Alan Rux,
Client Coordinator: Fran Williams
Electrical and Computer Engineering
University of Massachusetts Lowell,
Lowell, MA 01854

INTRODUCTION

Voice recognition was added to an intercom and camera system for a woman with quadriplegia. Each system was designed to be positioned at her bedside so that she can view and communicate with anyone in her home. She also has the ability to answer her front door and view her front doorstep. The project consists of two systems that work independently of one another. The camera system uses technology created by X10. The X10 system uses a home’s already existing power lines to send “on” or “off” signals to each camera. The video is sent over a wireless signal to a receiver. Currently, the X10 does not offer a voice activated camera system. The remedy to this problem was the application of Sensory’s VR Stamp in the development of a voice recognition circuit. To create consistency between the camera and intercom systems, another VR Stamp was used in the development of a voice-activated intercom.

SUMMARY OF IMPACT

The client lives alone. Since she lacks the ability to move freely, she cannot check her surroundings for potential threats. The completed camera and intercom systems (Fig. 15.38) alleviate this problem. She can now view each area of her home as well as view any activity at her front door. She can also choose to communicate with anyone she sees in these areas. This results in a safer environment that also allows her to answer the front door and welcome anyone into her home. When her caretaker is present, she also has the ability to communicate with him or report any emergency. An overall increase in quality of life is a great advantage of this project.

TECHNICAL DESCRIPTION

The VR stamp was implemented into the X10 camera system to interface the VR Stamp with a BASIC Stamp and RF transmitter. An applicable C program was written. It calls upon a library of voice recognition sets created using Sensor’s Quick T2SI software. This powerful software allows the designer to create voice sets by simply entering text and then later adjusting the pronunciation of each word. The main task of this project involved learning how to program the sophisticated VR Stamp. A vast array of macros and technical library files had to be created along with specialized functions that served the purpose of the camera and intercom systems. This included integrating error codes into the main program that optimized the recognition of a woman with a potentially frail voice. This program was then compiled and downloaded onto the VR Stamp using a specialized programming circuit board. Once the VR Stamp was set to issue signals by voice command, the BASIC Stamp then read those signals and handled the camera addressing by determining which device had to be activated and issued the corresponding command code to the RF transmitter. Following the

Fig. 15.38. Intercom with VR Circuit Suspended in the Middle (Microphone in Upper Left).
X10 transceiver’s protocol, the BASIC Stamp was programmed using the PBASIC language. The cameras are then controlled by X10’s transceiver, which reads the RF transmission and sends the appropriate signal to each camera over a home’s already installed electrical wiring. The camera system circuit is shown in Fig. 15.39.

A second VR Stamp was then embedded in a set of wireless home intercoms. Using the intercom’s own DC power to power the VR Stamp, a network stemming from the VR Stamp’s IO lines are then used to trigger the intercom’s paging functions. As with the camera system, a voice recognition set was created, called upon and manipulated by a C program, and then compiled and downloaded on to the chip.

Each system met its voltage requirements using AC to DC adaptors and LM317 voltage regulators. The sensitivity of each microphone was adjusted to remain consistent with the frequency response generated by a human voice at arm’s length.

The total cost for parts and materials was $673.
SOUND ACTIVATED BUBBLE

Designer: Sergi Valme
Client Coordinator: Bonnie Paulino, Kennedy Day School Program
Department of Electrical and Computer Engineering
University of Massachusetts Lowell
Lowell, MA 01854

INTRODUCTION
A sound activated device was designed to entertain children by generating bubbles whenever it is activated by a sound. The circuit operates on a 12-volt DC power supply. The activated switch turns on, either by clapping hands, or by any sound. It turns off after a time delay. The sound is picked up by the microphone, which feeds it to the amplifier. The amplified signal is fed to the two diodes, which function as half-wave voltage doublers to produce 12-volts at the output. A potentiometer could dramatically reduce the sensitivity. The device is shown in Fig. 15.40.

SUMMARY OF IMPACT
The goal of this project were to entertain and demonstrate cause and effect.

TECHNICAL DESCRIPTION
The box (see Fig. 15.41) is made of wood with clear polish. Components include: the sound activated switch, the music generator, the color-changing bubble light, the power surge protector, and all the wiring connections, all on the same board.

CONCLUSION
A 12-volt DC adapter powers the overall circuit. The bubble tube is made of a clear plastic. A strong base, which is made of wood, supports it and it is

almost impossible to flip over. The voice activation is suitable for the project, and it includes the option of adjusting the sensitivity of the sound.

The cost of parts and materials was about $180.
Fig. 15.41. Box.
HANDS-FREE BALLOON INFLATOR SYSTEM

Designers: Wen Lu  
Client Coordinator: Lisa Szewczyk, Nashua Center, NH  
Supervising Professor: Prof. Alan Rux  
Electrical Engineering Department  
University of Massachusetts at Lowell, Lowell, MA

INTRODUCTION
The Hands-free Balloon Inflation System (HBIS) is an automated balloon inflation system designed to help people with disabilities to easily inflate balloons (see Fig. 15.42 and 15.44).

This automated balloon inflation machine starts to fill helium by simply one push of a button. When it detects that the balloon has been filled with enough gas, it immediately stops the process by shutting down the valve. The HBIS can automatically save and load the helium filling time pre-set by the user for different balloon types (volumes).

Upon completion, the HBIS was presented to a person with a disability who owns a balloon business but cannot handle typical balloon filling tools. This project will help him conduct his business more independently and enhance his self-confidence.

SUMMARY OF IMPACT
The user of this system is a person with a disability, and it is difficult for him to operate a complicated machine and quickly respond to the upcoming state change. The balloon inflation uses a swift gas flow from a high-pressure helium tank. The gas flow must be shut off immediately when the balloon has been inflated to an appropriate volume, otherwise the balloon will be overfilled and explode. The device automatically stops the gas when inflation is complete. The system saves and recalls the inflation time length for different balloon types, so that the user does not have to figure out the inflation time for a different balloon again when a new type (volume) of balloon is to be inflated.

The elapsing inflation time is shown on the screen to tell the user how many seconds are still left to inflate the balloon. The user can interrupt the inflation process any time by pushing a button. This function is useful in an emergency state, or when the user is trying to inflate a new type of balloon and does not know how long the inflation should be.

TECHNICAL DESCRIPTION
Fundamentally, HBIS has an integrated structure with electrical and pneumatic subsystems (see Fig. 15.43). It runs the application program written in PBASIC language on the Parallax Basic Stamp 2e microchip, receives the user input through 4X4 Matrix Keypad, as well as on-board and wired buttons, and outputs system internal states (inflation seconds countdown, etc.) and messages (error, input, prompt, etc.) to the user through a 2X16 Parallel LCD display. It starts the balloon inflation process by driving a relay to energize the solenoid valves, which let the helium gas flow through and fill the balloon.

The electrical subsystem is composed of the Basic Stamp 2e-IC and Super Carrier Board, 4X4 Matrix Keypad, a 74C922 encoder, 2X16 parallel LCD display, a relay driving power regulator, and peripheral circuits. The pneumatic subsystem has two solenoid valves and brass tubes, corners and valve fittings. The Basic Stamp 2e-IC and 74C922...
encoder, power regulator, relay, and LCD input resistance arrays are located on one board, and the amplifier circuit to drive the relay, the relay itself, and solenoid valve power supply connections are on the peripheral board. The LCD and keypad are fixed on the front panel of the machine, while the start button, valve select button and reset buttons are also on the front panel. The pneumatic assembly is installed at the rear of the box with a tube outlet passing through to connect to the helium gas supply.

The Basic Stamp microchip (BS2e-IC) is the kernel of the entire system. The four data output lines and data available line of keypad encoder 74C922 are connected to the 4 input ports of BS2e-IC and they are scanned when data available input is high, to get the key code (0 to 15) pressed. BS2e-IC has 4 output lines to send the high and low character to be displayed on the LCD, and also controls the LCD instruction or text mode read/write. BS2e-IC outputs a digital high signal to the input of the amplifier circuit, which is used to drive a relay to connect the 12 volt DC power supply to one of the two solenoid valves. There is a valve selector switch to enable one valve (for latex or foil balloon) at a time. A big round start button is used to issue a pulse signal to tell the BS2e-IC program that the user is starting the inflation.

There is also an emergency reset button located on the front panel connected to the reset input of the BS2e-IC, which is used to reset the software program. When the program resets, all output is pulled down to low level voltage, stopping the relay and power to the solenoid valve thus restoring it to a normal closed state so that the helium gas flow is shut down.

The cost of parts and materials was about $262.
WIRELESS PITCHING MACHINE

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Supervising Professor: Alan Rux
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INTRODUCTION
The Wireless Pitching Machine (Fig. 15.45) was designed to provide sensory stimulation and social interaction for children with limited motor skills. This device is a modification of a commercially available pitching machine. A wireless controller, featuring large, easy-to-use buttons, was designed for the operator to pitch various types of pitches (curveball, fastball, etc.) to the batter. Upon completion, the pitching machine was presented to a client with poor motor skills who enjoys sporting events. With the help of this machine the child can pitch baseballs to his brother and participate in a league for children with special needs.

SUMMARY OF IMPACT
The design criteria for the pitching machine were defined by the capabilities of the client. He and his family desired a device that would allow the client to pitch baseballs to other family members.

TECHNICAL DESCRIPTION

The Wireless Controller
A plastic box was used as the housing for the wireless controller. The box was painted black to disguise the electric wiring inside. Velcro was used to hold the battery pack in place, yet provide accessibility to change the battery in the future. Holes were drilled into the box to screw the jellybean buttons down and to allow the cords to run back inside the box. Metal standoffs were then screwed into the box to secure the circuit board. Finally, a hole for the transmitter antenna was made while a nut fastened it in place.

A battery pack containing four AA batteries provided the power for the wireless controller. The 12V setup featured an ON/OFF switch to conserve power when the machine was not in use. This battery pack was chosen because it uses standard AA batteries that can be easily replaced. Since the circuit consumed less than 70mA, this setup was more than adequate. To distribute the power, a 5V voltage regulator was used to provide the correct voltage values for the logic circuitry.

A four-input encoder (HT-12E) was used to select the motor speed via an antenna (TWS-434). When the red button was pressed, the motor changed to speed 1, and a left curve was thrown by the machine. When the yellow button was pressed, the motor changed to speed 2, and a fastball was thrown.

The Pitching Machine
The pitching machine had to be modified. The plastic box for the motor control had to be raised up 4 inches to allow room for a new circuit board. This was done by cutting four pieces of metal tubing 4 inches in length and using them as spacers between the plastic motor control box and the machine itself. Four long screws were then run through the tubing to reattach the box to the machine. To cover the open space left by the spacers, four pieces of heavy duty black cardboard were cut to the appropriate shape and glued into place. Black was chosen to match the rest of the machine. Finally, a hole for the receiving antenna was made on the top of the box while a nut fastened it in place.

A 12V deep cycle battery was used to power the pitching machine. This type of battery could be discharged completely and recharged many times without damaging the battery. Also, these batteries have a higher rating, meaning that the machine can run for a few hours before needing a recharge. To distribute the power, a 5V voltage regulator was used to provide the correct voltage values for the logic circuitry.

To change speed, the antenna (RWS-434) received a signal from the wireless control box and output the signal to the decoder (HT-12D). If the signal was
valid the LED would momentarily light. This light was used to verify that an RF signal was being transmitted.

The motor control chip was originally controlled by a mechanical knob. The connections to the knob were broken so that the decoder would control the motor speed instead.

The decoder was also used to tell the carousel when to spin, allowing a baseball to be rotated into the launch chamber of the machine. A timing circuit is triggered by the decoder every time a valid signal is received from the antenna. However, the timing circuit must be triggered by a logic 0 when pin 17 outputs a logic 1. To invert this signal, a multiplexer was recruited.

To rotate a baseball into the launch chamber, a 555 timing circuit was used. This circuit is activated when a valid signal is sent to the decoder and inverted by the multiplexer. A TIP31 transistor then provides the power to rotate the carousel motor to spin for about eight seconds, enough time for one baseball to rotate into the launch chamber.

The cost of parts and materials was about $750.

Fig. 15.45. Pitching Machine.
HANDITALK COMMUNICATION DEVICE.

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Client Coordinator: Jimmy, Edith Nourse Rogers Memorial Veterans Hospital, Bedford, MA
Supervising Professor: Dr. Jesse M. Heines, Alan Rux
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INTRODUCTION
HandiTalk was designed to be a communication and typing program for individuals with speech and physical impairments. One of its main features is ease of use. HandiTalk is a two-part system. The first part allows the user to type on a computer with look-ahead word selection features, or select preprogrammed messages from pictures (Fig. 15.47). The second part allows the user to have the computer speak the typed text or the requested message of the pictures for better communication.

SUMMARY OF IMPACT
The client can generate speech via HandiTalk. The product takes less than five minutes to learn to operate. It is easy and efficient for most patients with speech impairments to learn and use.

TECHNICAL DESCRIPTION
The input device is made from a momentary switch button. It is connected to a RS232 cable. HandiTalk software monitors the state change of the host computer RS232 port. Every time the button is pressed down, the highlighted item on the screen is selected. The computer then generates speech corresponding to that item.

The software has interfaces for the patient and the administrator. The administrator has the ability to control what the patient sees. The patient interface contains the Pictures and the Letters section. The Pictures section enables the patient to select from a table of pictures. The Letters section lets the patient spell out words to construct a sentence. The user can then choose to have the computer generate speech.

The hardware, cost of parts, and materials was about $21.
Fig. 15.47. HandiTalk Displays.
CHAPTER 16
UNIVERSITY OF NORTH CAROLINA AT
CHAPEL HILL

Department of Biomedical Engineering
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Principal Investigator:
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SUPINE LEG EXERCISER

Designers: Joy Kasaaian and Sevan Abashian
Client Coordinators: Anne Kelly OTR/L and Pat Cox PT, Duke University Medical Center
Supervising Professor: Dr. Richard Goldberg
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INTRODUCTION

Individuals in an intensive care unit may have to stay in bed for extended periods of time (weeks or more). A lack of leg movement can lead to muscular atrophy and poor circulation to lower extremities. The Supine Leg Exerciser was developed to provide a way for patients to exercise from their hospital bed.

SUMMARY OF IMPACT

The client coordinators said, “It is very difficult to aerobically condition patients [who are confined to a hospital bed for extended periods], due to the tubes, multiple IVs, and other hospital equipment. A device that allows us to strengthen and aerobically condition the patient who is debilitated and limited to bed rest is a great tool. This device is portable for ICU nurses to manage safely in patient rooms. We are currently performing trials using the device on patients. The impact we are looking for is a decreased length of stay, decreased time on the ventilator, and increased functional and aerobic capacity.”

TECHNICAL DESCRIPTION

Fig. 16.1 and Fig. 16.2 show photos of the device. The hospital staff positions the device at the foot of the bed and places the user’s feet in the pedals. The user can then move his or her feet back and forth independently, which makes the pedals slide along a track. As the user gains strength in the legs, the staff can adjust a valve to provide more resistance. The hospital staff can easily clean the device before using it with a new patient.

The device is composed of two tracks with pedals that glide along them. Each pedal has a heel cup for support. Inside of each track is a pneumatic cylinder that is connected to a series of valves to provide adjustable resistance. The tracks sit on a wheeled aluminum frame. The patient is able to make a flexion/extension motion along the tracks to get low resistance aerobic exercise and help build leg muscle.

The frame is three feet tall and on wheels so that the hospital staff can easily move it. It is constructed of T slotted framing aluminum (8020, Columbia City IN). The horizontal portion of the frame can be adjusted to any angle from 0 (horizontal) to 90 degrees (vertical for storage). Typically, a 15-30 degree angle with the bed is optimal in order to utilize gravity to help the user pull back on the pedals. There are two sets of 20 inch drawer slides that are connected to the frame, rated at 100 lbs/pair. The gliders are made of rectangular aluminum tubing with ¼ inch wall thickness. Two rods protrude from the glider box (with another rod going across them) and connect the bottom of the pedal to the glider. The pedals were created using molded Kydex.
A bicycle pump provides resistance as the user pushes. The pumps are connected to the back side of the gliders, with the pump's "handle" section facing the patient and the air hose facing away. The air hose is connected to a series of valves that will allow hospital staff to adjust the amount of pressure that the patient pushes against. When the valve is entirely open, there is little resistance. The device also includes a pair of counters so that clinicians can keep track of the number of repetitions. They are triggered mechanically when the user completely extends a leg. The pedal has slots for Velcro straps and a heel cup.

In total, the device cost about $600.
MOTIVATIONAL SYSTEM TO BUILD UPPER BODY STRENGTH IN CHILDREN

Designers: Erica Lee and Siroberto Scerbo  
Client Coordinator: Marcia Rollings  
Supervising Professor: Dr. Richard Goldberg  
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INTRODUCTION

A device was developed to help babies and toddlers build upper body strength. The device is placed adjacent to a child lying on his or her stomach. It helps to motivate the child to raise his or her head or upper body. When the child raises his or her head and shoulders, the device provides a stimulus such as music, bright lights, or vibration. This encourages the child to keep lifting the head and shoulders, which builds upper body strength, a precursor to crawling.

SUMMARY OF IMPACT

The client coordinator described the first time she used this device on a client: The client’s “PT would love to see him on a wedge bearing more weight on his hands and using his hands [to build upper body strength]. He tolerates being on the floor on his tummy for short amounts of time, but does not tolerate being on the wedge. The first time we tried this device, he lifted his head and the device started playing, ‘Who, Who, Who let the dogs out?’ His grin went from ear to ear. Then he continued to lift his head through the next rap song. Before we knew it, [the client] had been happily on the wedge for 15 minutes.”

TECHNICAL DESIGN

To fulfill the design criteria, an infrared beam, similar to what is used in a burglary alarm system, was used. The completed device (see Fig. 16.3 and Fig. 16.4) looks like a walker with wheels. It has the infrared transmitter/detector unit and battery case mounted on the left, speakers mounted on the crossbeam and an MP3 player with its controller on the right side. The therapist can change the height of the infrared unit (Radio Shack) so that it shines a beam just above the client, who lies face down in the middle of the device. When the client pushes up, he or she blocks the infrared beam, which acts as a switch to trigger either a switch-activated toy or the built-in MP3 player. The infrared unit is mounted to a vertical shaft and secured by a quick release collar. This allows up or down adjustment of the device, depending on the height of the child when prone or on a wedge.

The stimulus can include music or recorded sounds to motivate the child. This is accomplished with a programmable MP3 player (Rogue Robotics, Toronto) that uses an SD flash memory card to store songs. Using any computer, the teacher or parent can add different songs as well as record family members’ voices to the SD card.

The controller interface has an LCD, volume control, stereo plug, and two switches. The first switch controls the different musical tracks and the second controls a delay. The brain of the controller, which
makes all this possible, is a Basic Stamp II microcontroller (Parallax, Rocklin CA). It processes the signal from the infrared device, manages the switches, sends the text to the LCD, and tells the MP3 Player which song to play from the SD card.

The total cost was approximately $350.
INTRODUCTION
A girl with a traumatic brain injury has difficulty isolating lines and reading small fonts. Her injury also affects her motor control and she has spastic movements. A mechanical reading aid was developed that isolates one to two lines of text and allow her to easily scroll through the page.

SUMMARY OF IMPACT
The client’s mother says, “The reading aid has made it possible for our daughter to read independently because it isolates and magnifies one line of text at a time, and she can move to the next line of text fairly easily. Before, someone needed to hold the book and isolate the text with a piece of paper…. The reading aid is so sturdy that she can move from one line to the next with little effort.”

TECHNICAL DESCRIPTION
The reading aid consists of a rotating cylinder that is mounted on a stand. A ratchet is attached to the cylinder. The client pushes on an acrylic platform, which pushes the ratchet handle and rotates the cylinder to the next line. A black piece of acrylic

Fig. 16.5. Client Using Reading Aid.
shields the rotating cylinder so that it is not a distraction to the client. There is a rectangular window in the acrylic, which reveals one to two lines on the page at a time. A Fresnel lens is mounted to the window to magnify the text.

The cylinder consists of a PVC pipe of radius 1 3/4 inches. Two PVC caps with holes at the center are attached to the ends of the pipe. The length of the pipe and caps is about 15 inches. Copper pipe goes through the center to form an axle. The PVC pipe and exposed parts of the copper axle are painted black.

The side supports and base of the reading aid are made of Lexan, a strong and durable polymer. All of the Lexan pieces are removable so that the device can be easily assembled and disassembled for portability. The different Lexan shapes were milled and cut from a 4’ by 2’ sheet that is 0.5” thick. The rough edges and surface scratches of the Lexan were blowtorched for smoothness.

The client advances the text using a ratcheting mechanism. The ratchet converts motion in a linear direction to a rotation of the cylinder, and it also allows for rotation in both clockwise and counterclockwise directions. The ratchet allows the reading aid to be rotated in the direction of interest. Once there, the reading aid remains motionless while the ratchet is rotated back to its starting position. To rotate in the opposite direction, the switch on the ratchet is turned reversing the ratcheting direction. The ratchet is a standard commercial ratchet with a 12” handle. The copper axle is soldered to a standard ratchet socket and this socket snaps into the ratchet.

The total cost of this device was approximately $440.

Fig. 16.6. Comfort Reader Device with Acrylic Screen, Fresnel Lens, and Ratcheting Mechanism.
EMOD: ELECTRONIC MEDICATION ORGANIZER AND DISPENSER

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INTRODUCTION
EMOD (Fig. 16.7) is a custom pill dispenser designed to give people with disabilities independence when managing complicated pill schedules. It is designed to reduce the risk of incorrect dosage. The primary objectives were to create a dependable device that is easy to use, dispenses variable medication doses, reminds clients of their medication schedules, safely halves pills when necessary, and eliminates medication loading errors. The device also had to be functional when used by a person with one arm, able to withstand tremors, and require minimal strength during usage.

SUMMARY OF IMPACT
The EMOD allows clients the ability to manage complicated medication schedules with little or no help. They are easily able to load their own pills using the Pill Loader, which helps prevent errors in setting up their medication schedule. Cutting pills is safe because there is no exposed blade. Once the pills are loaded and the alarms are set, the pills are dispensed at the appropriate times, with an audible reminder.

TECHNICAL DESCRIPTION
Overall operation:
The heart of the device is the Medtime XL motorized 28 compartment tray (made by Careousel, Sweden, and purchased from epill.com). The existing electronics were removed, and custom electronics as well as new mechanical features were added to make it accessible to people with disabilities. The device is fully automated; the user enters the time of day, and sets up to four alarms when medication is to be taken. Then, the user loads the pills using the clear acrylic loading tray, which provides full visual and motor control over which pills go into each compartment of the pill dispenser tray. Once loaded, the dispenser is placed upside down into the mounting stand.

When an alarm goes off, EMOD automatically advances the dispenser to the next compartment, dumps the desired pills into a small cup, and sounds an audible alert. The cup is replaced by the client after every dose. Appropriate placement of the cup is aided by a marked red area beneath the pill dispenser.

Pill Dispenser:
The pill dispenser has four operational modes: Loading, Set Current Time, Set Alarms, and Run. The interface for the pill dispenser consists of three buttons, an LCD, LEDs and a switch to turn off the verbal commands. The left button cycles between the pill dispenser’s operational modes. The middle button changes the hours and the right button changes the minutes. The LCD displays the current operational mode and gives instructions to the user.
For those users who have difficulty reading the LCD, the device also provides prerecorded verbal commands. The user can toggle a switch to turn those verbal commands on or off.

For loading and run modes, a DC motor advances the dispenser tray in a clockwise motion. There are tabs on the bottom of each compartment and an infrared detector and emitter detect the passing of the tabs. When the tray advances to the next tab, the system stops the motor.

The custom circuitry consists of a PIC 16F877 microcontroller (Microchip, Inc., Chandler AZ) programmed in C-language, an ISD33120 voice recorder chip (Winbond, San Jose CA), an LM386 amplifier and a MAX232 driver.

**Pill Loader:**
A pill loading tray (Fig. 16.8) was developed to facilitate the loading process. Since the user will typically take the same medication during a certain time of day (morning, noon, evening, and bedtime), the tray was designed so that the user first loads all morning pills for the week. The upper loading tray has holes for every fourth compartment so that the user can load these pills in the appropriate places. Initially, the pills sit below the upper loading tray, but on top of the lower tray. This allows for easy correction in case of any loading mistakes. Once the user confirms that all of the pills are placed properly, then he or she slides a lever on the lower tray to drop them simultaneously into the compartments below. They repeat this process for the noon, evening, and bedtime pills.

The upper tray loader was constructed of 0.177” thick clear acrylic. Using a laser cutter, seven large thumb-print sized holes were cut over every fourth compartment of the pill dispenser. The lower tray loader was cut out using 0.08” clear acrylic but was modified to include an extra piece as a handle. To prevent pills from falling over the outer edge, 0.177” thick white acrylic was used to create a ring barrier on the outermost edge of the top piece.

**Pill Cutter:**
The custom Pill Cutter is designed with safety guards and a sliding loading tray that protect the user from the sharp blade. The blade guards and limited opening angle prevent the blade from being exposed. A stop bar limits the opening angle, which prevents the blade from being exposed.

The total cost of the project was $384.
SWITCH RELAY

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INTRODUCTION
The Switch Relay was designed to give clients control over two different switch-activated devices using only one switch. Pressing and releasing the switch directly controls the first device. However, when the client presses the switch for a preset minimum duration of time, “hold time,” the device toggles its state to control a second device. An example of this is shown in Fig. 16.9, where one switch controls both a computer and a communication device. A knob allows the client to adjust the minimum pressing duration from 0.5 to eight seconds, in one-second increments to set the “hold time”. Subsequent switch presses that are longer than the minimum duration will toggle control of the Switch Relay between the two devices. An LED readout shows which device is being controlled at a given time.

SUMMARY OF IMPACT
Allowing operation of multiple devices with one switch increases the user’s independence. The use of only one switch to operate a pair of devices minimizes confusion for the user.

Because of the adjustable “hold time,” devices with Fig. 16.9. Switch Relay Device Attached to a PC and a Communication Device.
different activation times can be operated; therefore, almost any switch-activated device can be controlled with the Switch Relay. The coordinator stated that "the device will enable people with limited physical ability to independently operate multiple devices."

**TECHNICAL DESCRIPTION**

The Switch Relay circuit (Fig. 16.10) is based on a PIC microcontroller (Microchip, Inc., Chandler AZ), which detects the activation of the user’s switch. The PIC can determine the amount of time the switch is held, and then either change devices or continue to operate the current device. Latching SPDT relay switches (Omron G6EK-134P) were used to isolate electronically the output devices from each other and the input switch. The use of latching switches allows for reduced power consumption, because they require a pulse for activation rather than a continuously applied voltage. Transistors (2N222A) were used to apply sufficient current to the relays.

The adjustable “hold time” is set using a potentiometer, which is read by the A/D converter of the PIC. LEDs indicate which device is under the control of the switch. An additional LED light bar indicates the length of the “hold time.”

The electronics are housed in a 3.5” x 7.0” plastic project box. Two mono 1/8” audio cables are attached to connect to the devices. A standard 1/8” mono audio jack is used as the input terminal, to which the switch is attached. The device is powered by a 9V battery with a regulator controlling the voltage applied to the circuitry.

The total cost of the device was approximately $40.

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**Fig. 16.10. Switch Relay Circuit Diagram.**
ACCESSIBLE GARDEN BED AND ADJUSTABLE HANGING BASKET

Designers: Tejan Diwanji, Michael Murray
Client Coordinator: Allison Darwin, OT Carolina Meadows
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INTRODUCTION
A multifunctional living community provides housing and recreational facilities for elderly people. The community offers a range from totally independent-living houses and apartments to intensive care facilities. The goal was to improve a garden area at this facility to allow for easier access for the residents. A previous raised garden bed was difficult to access for residents in wheelchairs.

The hanging planter and birdfeeder operate with a pulley and winch system, which allows for residents to adjust the height so that they can attend to these items. They can water plants, clip dead leaves or refill the birdfeeder with seeds. The garden bed and the hanging basket help the residents to engage in everyday activities to exercise, maintain mobility, and retain a sense of independence.

SUMMARY OF IMPACT
The client coordinator stated, “The wheelchair accessible raised garden bed will allow residents to actively engage in gardening activities, regardless of physical ability. Prior to the construction of this bed, residents who use wheelchairs did not have an adequate way to functionally and naturally participate in gardening activities due to the inability to get close enough to a garden bed to interact with the soil and plants. We hope that this addition to our existing courtyard will enhance activities for residents and enrich overall quality of life for these older adults.”

TECHNICAL DESCRIPTION
The garden bed is shown in Fig. 16.11. It is made of five sheets of ¾” x 4” x 8” pressure treated plywood supported in the corners by 2” x 2” lumber and across the top by 2” x 4” lumber. The structure is held together by 2” galvanized deck screws. It consists of three main pieces: two boxes measuring about 17” x 33” x 35” for the bases and a third piece spanning the gap between the bases. The third piece allows for about 6” of soil to be placed on top of it. Space was allowed within the two bases for the resident to be able to pull his or her wheelchair under it. Space in this area is about 29” from side to side and roughly 27” from bottom to top.

Two drawers were built into the bed for tool storage. Within these drawers, tools are easily accessible to an individual at the garden bed. They were constructed using pressure treated plywood, 1 ¼” stainless steal screws, and two sets of drawer slides. A drawer box was connected to the base and the top piece on the inner right side for support. The drawer boxes were constructed with pressure treated plywood and 2” galvanized screws.

For the pulley system, about 24’ of 1/8” plastic coated steel cable was used. The cable is held up by two steel pulleys, each with the capability of holding over 55 lbs. To allow for easy movement of the
hanging item (Fig. 16.12) a two-way boat winch was used. The load can be raised and lowered easily and without slipping.

Construction was done in the facility’s woodshop. One of the residents of the facility helped with construction and installation.

Total cost was about $400.
NSF 2006 Engineering Senior Design Projects to Aid Persons with Disabilities
CHAPTER 17
UNIVERSITY OF TOLEDO

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TRANSFER LIFT SYSTEM

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INTRODUCTION
This project was designed to enable a 21-year-old man with cerebral palsy to transfer himself from his motorized wheelchair to his bed with no outside assistance. This young man has control of his extremities. He only has intact fine motor control of his right hand. Once in an upright position the client has the ability to maneuver himself with his legs, as long as his legs are not bearing any of his body weight. The lift is designed to limit the user’s muscle force input, in order to make the lift easily operable. The lift system is shown in Fig. 17.1. The user support system includes an under-arm support that is placed under the arms to minimize the force input from the user. The frame of the lift is designed to maximize stability and lift motion. As the client has a small bedroom, the lift system was designed to utilize as little floor space as possible. It slides partially beneath the client’s bed, leaving enough space for the client to maneuver his wheelchair under the lift into position.

SUMMARY OF IMPACT
Prior to the completion of this project the client had to be physically lifted out of his wheelchair and placed into his bed by one of his parents. This project provides Alex with a system that allows him to achieve more independence in his
daily life.

**TECHNICAL DESCRIPTION**

The lift system includes three main components: a main supporting frame to mount the lift system, a user support system, and a lifting mechanism.

Several methods to mount the system were considered, including a wheelchair-mounted lift, a bed-mounted lift, a ceiling-mounted lift, and a floor-supported lift. A wheelchair-mounted system would allow the lift to be powered by the power supply of the wheelchair, thus eliminating the need for an external power source. It would also allow for the lift system to be confined entirely to the wheelchair, which would keep the room floor clear of obstructions. Finally, it would allow for the wheelchair to be used as a counterbalance for the lifting action, eliminating the need for the system to be bolted to a wall or bed. However, this design had several problems. First, the client and his parents did not want anything added to the chair. Also, the wheelchair is already large. If the lift increased the overall width of the wheelchair, it would not fit through the doorways of the house. A bed-mounted system is simplistic, inexpensive and it would use up virtually none of the floor space. However, such a system would require reinforcement and the modification of the bed frame. A ceiling mounted system would allow for the lift to be completely set out of the way, and it would also not take up any floor space. However, this system could be prohibitively expensive, costing approximately $5,000-$6000. Floor-based systems allow for repositioning of the lifting system should the room be rearranged. The cost of a floor-based system is also substantially less than other configurations. However, floor-based systems require a large amount of floor space for the apparatus to support itself. A hybrid floor-and ceiling-based support system was finally selected. Figure 17.2 shows the bedroom layout. The system was thus designed to be placed up against the user’s bed to minimize the space used in the room.
Several methods were also considered for the user support system, including: a sling, a harness, SureHands body support system, and an underarm system. The sling support system is most commonly used in hospitals, nursing homes, and personal homes. However, it requires the user to be placed into a sling before lifting, which eliminates the possibility of an independent transfer. A harness would be equipped with rings that could be attached to the lift and allow for a balanced independent transfer. While the user would be able to operate these clips independently, he would have to wear the harness all day, and it could be uncomfortable to wear for extended periods of time. The SureHands Body Support System is a lifting mechanism designed and manufactured by the SureHands Company. The support system acts as a set of pinchers and grasps the patient. This system would allow for a completely independent transfer as well as being safe. However, this system is proprietary and the company would not donate or sell without selling the complete lifting system, which costs at least $4,000. The underarm support system is similar to the SureHands Body Support System; however, it does not physically grab the patient. In contrast, it simply lifts the patient with two supports that would be positioned under the armpits. This lifting style would provide independent, simplistic, and relatively safe user support. This design was not without drawbacks.

Should the arms not be padded correctly, the support arms could be uncomfortable and potentially cause bodily injury. This drawback was ruled out as the patient is very light and the arms were to be more than adequately padded.

Finally, several methods were also considered for the lifting mechanism to bear the weight of the user and control the up and down movement including hydraulic, pneumatic, mechanical and electrical lifting systems. Hydraulic systems are strong and able to support the body weight of nearly any individual. However these systems are not cost effective, and tend to require maintenance. Pneumatic lifts are usually clean, effective, and fairly inexpensive when compared to hydraulics. However, these systems are complex to create due to the electronic integration
needed for control; a compressor unit would also be needed to provide the air inside the pneumatic piston. Mechanical systems such as springs, gears or counterweights are less expensive. However, it is hard to control the amount of force exerted at any one particular instance when springs are used. Furthermore, springs and gears have pinch points and could provide safety hazards to the user. Using of counterweights also involves safety hazards. An electric lifting system was thus used to control the user’s movement.

The electric lifting mechanism was donated by the Ability Center of Greater Toledo and is depicted in Fig. 17.3. The unit was obtained from a wall-mounted patient lift, the Multi-Lift, manufactured by Access Unlimited. The lift has a 275-pound patient capacity; this is more than adequate, as the client weighs less than 100 pounds. The lift also has a maximum vertical lift of 18 inches in its current setup; however, it has adjustable lift arms that can extend another 10 inches outward to achieve more vertical displacement. The lift is also compact; it is less than two feet long. This was optimal for the design as space is at a premium. It is easily operated by a control that has two buttons, one for up and one for down. The lift is a type of screw drive that forces a piston upward to perform the lifting action. It uses a 12V DC motor, which is not compatible with a standard household wall plug. An electrical analysis was conducted to determine the appropriate converter for the lift. Its schematic is shown in Appendix A. The lift was determined to draw approximately 3 amps when there is a load on it. As a safety factor, the maximum current drawn is increased by a factor of 1.5 or 2. The power source, therefore, can convert 5 to 6 amps. The problem
with building a power supply is that it would not have been UL rated for safety reasons. It was found that a small computer power source stripped from an old computer would provide the necessary power to the lift without overload. It was taken from an older computer because current computers use ATX power sources that use the motherboard and power switch of the whole computer to turn it on. The power source used has its own power button.

The frame of the lifting system was constructed of steel UniStrut channels, shown in Fig. 17.4. This framing system allowed for easy assembly, for the frame of the lift to be modular and easily moveable, and for maximum adjustability. UniStrut systems are also strong. Two Unistrut channels were used in parallel across the top of the structure, each having a load capacity of approximately 560 lbs for a 72-inch span.

A trolley system was designed and constructed to allow the lift to move horizontally along the track. Six trolleys were used to connect the lift to the overhead rails with three in each Unistrut channel. The trolleys were also made of Unistruts and are shown with their dimensions and placement in the Unistrut channels in Figures 17.5a and 17.5b, respectively. Each trolley can hold 100 pounds. The trolleys fit snugly into the Unistrut channel, which allows them to take a tensile or compressive load.

To connect the lift to the trolleys, a brace was constructed of 11 gauge steel square tubing as shown in Fig. 17.6. The lift brace hangs from the trolleys and holds the electric lift unit. The lift brace’s triangular shape allows for the load to be distributed across the six pulleys. Bolts were used to hold the lift to the lift brace using aluminum shims.

The four vertical legs of the main supporting frame were constructed of another Unistrut material, Telestrut. The Telestrut is a telescoping frame that allows the lift to be adjusted from five feet tall to nine feet. This would allow for the lift to be adjusted to any new bed or bedroom. Calculations were based on a structure height of 6 feet. The Telestrut material used for the frame is shown in Fig. 17.7.

The final component of the transfer lift system is the patient support system. It was made of tubular stainless steel. Figure 17.8 illustrates a conceptual rendering of the underarm support system mounted on the electric lift unit, which is attached to the lift brace. The support arms were designed to fit under the client’s arms. They were made of steel to maximize strength and minimize deflection. Padding was required to make them safer. Without proper padding, it was determined that pain, discomfort or even damage...
to the nerves and arteries under the arms could occur. The pads used are the type utilized for exercise equipment to reduce stresses on the body under extreme weights. The arms were ergonomically designed. Figure 17.9 depicts the final patient support system.

Figure 17.10 shows a conceptual rendering of the complete transfer lift system. All relevant analyses to ensure structural stability and safety have been performed. I-DEASIM (Integrated Design Engineering Analysis Software) 10, a finite element analysis software package, was used to perform the structural analysis of every component. All components were found to be well within the desired safety limits for the given loads.

The total cost of all parts was $430 as many components were donated to the project by Unistrut Toledo, the Ability Center of Greater Toledo, Fischer Tool and Die Corporation, and Rolled Alloys, Inc.

Appendix A
PORTABLE MOUNT TO ACCESS CRUTCHES

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Client Coordinator: Ms. Kim Dittman
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INTRODUCTION
A portable mount was designed to allow a client to attach a set of two-bar aluminum crutches to a tabletop surface or the back of a chair, therefore allowing her crutches to be stored next to her yet out of the way. The unit includes a uniquely designed clamp, a ball and socket joint, and a connector that links the joint to a clip. The clamp allows the portable mount to be attached to any tabletop surface. One of the crutches is then attached to the portable mount’s clip, and the crutches are attached together using a double clip as shown in Fig. 17.11.

SUMMARY OF IMPACT
The portable mount eliminates the practice of laying the crutches on the ground, against the wall, or having someone take them to an appropriate spot. This will allow the client to deal with her crutches in an everyday environment by holding, stabilizing, and keeping them conveniently available. Using this device,

Fig. 17.11: Pair of Crutches Secured to Table Using Portable Mount.
the client will be able to go to restaurants and other public places and not worry about her crutches being in the way and becoming a hazard.

**TECHNICAL DESCRIPTION**

The portable mount unit includes a specially designed clamping device, shown in Fig. 17.12a. The device consists of a “C” shaped aluminum body and an integrated steel moveable clamping plate. A compression spring provides the clamping force to the plate. The C-clamp is 3.315” tall, 2.126” and 1.575” deep.

A ball and socket joint was used to provide a limited range of motion between the crutches and the clamp. The ball portion of the joint was threaded into the back of the C-portion of the clamp. The socket portion of the ball joint was then threaded into a custom-made connector. On the other side of this connector is a clip that allows connection to one of the two crutches.

The fixture shown in Fig. 17.12b was manufactured by attaching two clips to a spacer block. These clips allow the two crutches to be connected together as shown in Fig. 17.12c, therefore only requiring one crutch to connect to the table. These clips were selected because of their ability to snap on and off of the crutches easily.

The two components of the clamping device, the C shaped portion of the clamp and the clamping plate, were modeled using SolidWorks®, as illustrated in Fig. 17.13. The two parts were then analyzed using COSMOSWorks Designer, which is design validation software fully embedded inside the SolidWorks interface. Stresses, strains and displacement analyses were thus conducted for both parts. Both had very high factors of safety and low deflection.

The total cost of all parts used to build this unit was $100.

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![Image of clamping device](image1.png)

(a) Clamping Device  (b) Clipping Fixture  (c) Two Crutches Connected Together Using the Clipping Fixture.

![Image of model](image2.png)

Fig. 17.12: (a) Clamping Device (b) Clipping Fixture (c) Two Crutches Connected Together Using the Clipping Fixture.

![Image of model](image3.png)

Fig. 17.13: Model for Two Parts of Clamping Device Generated Using SolidWorks®.
ADAPTIVE HAND TOOL TO PROMOTE INDEPENDENT LIVING

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INTRODUCTION
The goal of this project was to develop a device that would allow an individual with cerebral palsy to hold fragile food items without damaging them. The client desires a discrete and portable device that will allow her to pick up food items and hold onto them as they are being eaten. The design is based on a set of barbecue tongs with a fulcrum at one end of the handle and the gripping area at the other end of the handle. The device is made of plastic to fulfill the portability requirement. Figure 17.14 shows two views of the adaptive device. Fig. 17.15 shows the device being used by the client to hold a cheeseburger.

SUMMARY OF IMPACT
A junior in high school with cerebral palsy has difficulty controlling the strength of her grip. She has a tendency to hold onto soft food items too tightly, crushing them. The client is reaching an age where she desires more independence and would like to have the ability to eat any type of food without a feeling of self-consciousness. She desires a portable, discrete device that will allow her to hold onto soft food items. She tested the device on a variety of foods and found it easy to use.

TECHNICAL DESCRIPTION
Given that this device must reflect the needs of the client, she was involved in each stage of the design. Anthropometric measurements of the client’s hand include the physical dimensions of her left (preferred) hand as well as the strength of her grip. She has average length digits with an abnormally small palm (less than 5th percentile of women). This would limit the maximum grip surface contact area, which means that the area where the tool is gripped by the hand is smaller than one designed for an average population. A mold of the client’s hand was taken as a reference. Based on the physical measurements, it was determined that the device requires a handle approximately 3 inches long and no more than 2.5 inches in height.

The strength measurements of the client’s hand, taken using a hydraulic dynamometer, revealed that her grip strength is below the average for her age range. Using 1.6”, 2.0”, and 2.5” grip diameters, it was found that the average grip strength for her left hand was 28.6 lbs, 37.4 lbs., and 23.0 lbs., respectively. The average grip strength of a non-athletic female of the client’s age is reported to be 52.5 lbs.

The dimensions of the gripping area were based on the average size of a small sample of differently sized sandwiches. The average sandwich size was found to be approximately 4” in diameter and not more than 3” in height. The gripping area of the device had to be large enough to hold the item securely, yet small enough to not restrict the amount of food that can be consumed. The dimensions of the gripping area were selected to be 2 7/8” by 3”.

Fig. 17.14: Two Views of the Adaptive Device.
A material that is rigid enough to withstand everyday use and lightweight enough to easily transport was needed. Metals are capable of fulfilling the rigidity required, but are not lightweight. A plastic, high-impact polystyrene (HIP) was selected. HIP provides the rigidity that the device demands and is lightweight enough to transport easily. HIP is also easy to machine and thermoform.

After the product design was finished it was subjected to a final analysis. The drawings were made into solid models, which were then imported into FEMLAB 3.1, an interactive environment for modeling and solving scientific and engineering problems based on partial differential equations (PDEs). When solving the PDEs that describe a model, FEMLAB applies the finite element method. The load on the device was based upon the grip strength measurements. This load was input as 50 psi on the top surface. Based on the structural analysis using FEMLAB, the design was found to be sound and suitable.

The device was machined out of a flat sheet of HIP. The device was then sent to Allied Plastics of Toledo, Inc. where it was formed into its final shape out of the pre-cut blanks. Three prototypes were manufactured to provide a variety of devices to the client. Several parallel grooves, 1/32” deep, were machined on both of the food-bearing surfaces to assist with retention of the food. Note in Figure 17.15 (a) that the food is in a relatively awkward position yet maintains its position and provides easy access for eating. In Figure 17.15 (b) the client is shown utilizing a different grip that is also comfortable to her. This grip gives her greater control over the size of the opening that holds the food. This grip is also useful on the smallest food items.

GE Polymershapes of Maumee, Ohio donated a sheet of HIP from which the prototypes were machined free of charge. The only costs incurred were $180 for forming.

![Fig. 17.15: Client Demonstrating How She Holds a Double Cheeseburger with Device.](image-url)
POKER CHIP DISPENSER

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INTRODUCTION
An individual with Cerebral Palsy loves to play Poker. However, impairment of his motor skills makes it difficult to handle small objects. When playing poker, he has trouble gathering, stacking and dispensing poker chips, thus making him feel like he is holding up or interrupting the game. The purpose of this project was to design and construct a poker chip dispenser that eases the stacking and dispersion of chips. The unit has a capacity of holding 240 chips. It also incorporates slide ramp technology. The unit includes a ramp to assist gathering the chips and a rack that pivots to allow stacking and presentation to other players. Figure 17.16 shows the unit from two different views.

SUMMARY OF IMPACT
The unit has a potential to make it easier, and hopefully more enjoyable, for the client to play poker. A review of poker tournament rules has revealed no limitations to using such a device during regulation play. This was reaffirmed by corresponding with a columnist from Card Player Magazine.

TECHNICAL DESCRIPTION
Design constraints required the unit to be mobile and functional. The user wanted a device that he could take with him to different tournaments. It must fit within his table space of 1.5’ x 1.5’. Design goals were to: (1) to minimize moving parts to ensure function and durability; (2) develop a compact unit to assist in mobility and to free up table space; and (3) use lightweight materials while maintaining robustness.

The unit includes left and right mounts, a chip holder, a holder area, and a ramp. The mounts hold the unit together and provide travel slots for the chip holder, which dispenses and holds chips. The holder area is used to hold chips for dispersion into the chip holder. The ramp is used to slide the chips up and to disperse them down. Figure 17.17 shows a conceptual rendering of the unit as the chip holder is lifted up from the stacking position (Fig. 17.17a) and rotated to the dispersing position (Fig. 17.17c).

There are six holes in the chip holder; each can

Fig. 17.16: Poker Chip Dispenser from Two Different Views.
hold up to 40 chips. The holes were equally spaced out with 0.5-inch spacing. Slots were cut on the face of the holder along the length of the chip holes. When the chip holder is in the dispersing position the user can easily slide the desired chips in the slots and dispense the chips from the top of the chip holder. The slots are also used to show the opposing players how many chips the client possesses. The slots had to be big enough to fit the client's fingers but not too big that the chips would not fall out the sides.

On the sides of the chip holder there are 3/8-inch holes that have pins pressed in them. These aluminum pins slide in the slots of two side mounts, which were designed to hold the top holder area and the ramp, and to house guides for the chip holder. Horizontal and angled slots were milled out of the side mounts to hold 3/8-inch boards forming the top holding area and the ramp. All corners were filleted to make the structure more durable and easier to manufacture.

To determine the optimum ramp angle, an experiment was conducted to determine the static coefficient of friction of a poker chip on a smooth surface and a poker chip stacked on another poker chip. The angle at which the poker chip began to slide on the flat surface was 25°. An angle of 20° was found for the stacked chip. Based on these data, the poker chip dispenser was designed with a ramp angle of 33°.

The unit is made of oak. Felt was applied to the surface of the ramp, and all wood was stained and varnished to improve the look of the unit. Handles were fastened to the poker chip holder so the user could easily move the holder from the stacking position to the dispersing position. A detachable shoulder strap was mounted to the sides of the unit for ease of transport.

Integrated Design Engineering Analysis Software 10 (I-DEASTM), a finite element analysis software package, was used to perform the structural analysis of all the components of the unit.

The total cost of all parts was $50.

Fig. 17.17: Chip Holder as it Moves From a Stacking Position to a Dispensing Position.
ALL TERRAIN WHEELCHAIR FOR METROPARKS – SECOND GENERATION

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INTRODUCTION

The park system has a wheelchair that is made available to park visitors for use on trails. This wheelchair, shown in Fig. 17.18a, was developed by a previous group of engineering students as their senior design project. However, some problematic issues had to be addressed. Access was the primary problematic issue. Figure 17.18a shows how the seat location and footrest configuration impede access. It takes two attendants to assist the user into the wheelchair. Other issues included: 1) having a brake only on one rear wheel; 2) having a short brake handle that tilts away from the user; 3) having reduced spacing between the grip ring and tire causing the users not to be able to avoid rubbing the inside of their wrists on the tire when driving the rear wheels; 4) having a seat that is short from front to back; and 5) having narrow and fixed armrests that are located close to the top of the tires, forcing the user to keep his or her arms to the inside of the armrests to avoid contact with the rotating tires.

The wheelchair that was developed is shown in Fig. 17.18b and features a seat assembly that slides forward, as shown in Fig. 17.19a, to clear the rear wheels and pivots to the side, as shown in Fig. 17.19b, such that a more able-bodied user is able to transfer into it independently without the need of an attendant. The seat of the new All-Terrain Wheelchair also has flip-up armrests that are positioned higher above the rear tires in comparison to the existing wheelchair. Braking can be applied to each of the two rear drive wheels using two easily accessible handles.

SUMMARY OF IMPACT

The park system operates 11 scenic parks and two recreational trails. The largest attractions of these parks are its various trails, which allow people to walk through and enjoy the outdoors on their own. However, wheelchair users are limited in this activity due to the rough terrain on the trails. An all-terrain wheelchair was designed and built to allow individuals with disabilities to access these trails.

TECHNICAL DESCRIPTION

The design involved adding a slider system to the frame and seat assembly. The seat slides forward to clear the rear wheels and then pivots 90 degrees, allowing the user to be close to the seat. Once the user is seated in the wheelchair, he or she can pivot the seat back 90 degrees and slide the seat back to its original position. A more able-bodied user may be able to access the wheelchair without the assistance of an attendant. A telescoping slider mechanism for the seat assembly was selected because it is capable of supporting human weight. The telescoping sliders were purchased from General Devices Company, Inc., Indianapolis, IN. These sliders can handle heavy loads and are manufactured.
using 14-gauge work-hardened, cold-rolled steel having yield strength of 60 ksi.

The wheelchair includes a seat platform that slides forward and backward within the frame as shown in Fig. 17.19a and Fig. 17.19b. The platform and the frame were made from 2-inch-square 6061-T6511 aluminum tubing with a wall thickness of ¼ inch. The sliders were mounted to the frame using 8-32 bolts. A support was also added to the platform. The support was located such that it is positioned under the midpoint of the front edge of the seat when it is pivoted to the side. A roller was mounted to the top of the support such that the bottom of the seat moves freely on and off of the support.

The overall frame dimensions are 52” L x 22” W x 6” H. Impact testing on the frame was simulated using ANSYS (a general purpose finite element analysis software package). This testing was performed following the guidelines of the American National Standards Institute’s (ANSI) and the Rehabilitation Engineering Society of North America (RESNA) for Wheelchairs, Section 8. These guidelines specify that during the frame impact test, an impact pendulum, one meter in length, and with a mass of 10 kilograms at its end, strikes the frame at its furthest forward point. The rear of the frame is blocked for this test. This test is to be done with the angle of impact along the longitudinal axis of the wheelchair and also along a line at 20 degrees to each side of the longitudinal axis. To simulate this test, the force with which the impact pendulum would strike the frame was calculated to be 443 pounds.

The new All-Terrain Wheelchair is supported by three wheels (one at the front and two at the rear) with pneumatic tires. The front tire is a wide balloon type tire and the rear tires have an aggressive tread pattern to provide the necessary traction to maneuver the wheelchair. These tires reduce the tendency of the wheelchair to become stuck in loose dirt and sand. The seat has flip-up padded armrests positioned higher above the rear tires in comparison to the previous wheelchair. Both rear drive wheels feature brakes with new, easily accessible handles. A storage box has been added for the user to carry the required cell phone and first aid kit.

The cost of material and most components was $800.

![Fig. 17.19: (a) Seat Extended to Clear Rear Wheels. (b) Seat Pivoted to Side.](image)
CHAPTER 18
UNIVERSITY OF WYOMING

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INTRODUCTION
The primary goal for this project was to modify an existing quad-cycle that had been designed for school-yard use. The original school-yard design was intended for use on flat paved surfaces by multiple clients. The quad-cycle was changed to be used on city streets by an individual with special needs.

SUMMARY OF IMPACT
The quad-cycle was a source of joy and interaction for the client. Modifications made to the cycle enhanced his safety. Using the cycle encouraged him to pedal and increase his motor skills.

TECHNICAL DESCRIPTION
The modification of the leg powered Quad-cycle for use on city streets required a different approach to safety concerns than those encountered on a playground. The original design had called for two riders on a level playground surface. City street surfaces are much different. The design goals were to improve stability and safety while on the streets. Also problems that had been encountered in the steering and mobility were addressed.

The criteria for design modifications are presented in the prioritized list below:

1. Mitigate sharp edges;
2. Replace rusted fasteners;
3. Replace fasteners that are too long or too short;
4. Add castor to the front wheels;
5. Install an SMV placard (requested by client);
6. Install a flag/whip (requested by client);
7. Install larger profile tires (easier to inflate and providing better ride and control);
8. Create a front suspension that will allow the cycle to navigate an eight-inch curb without becoming unstable;
9. Redesign the linkage so that the wheels turn at appropriate angles;
10. Provide a turning radius of 12 feet;
11. Redesign corners to remove sharp edges;
12. Provide a means to engage the pedals on the passenger side so that they turn with the rolling motion of the cycle rather than freewheel;
13. Improve stability; and

The first item addressed was the front axle. An axle was designed and built to allow floatation on uneven surfaces. This was done by attaching the axle on a center pivot such that it could move vertically independent of the rest of the cycle. To protect the axle from damage, a bumper was designed. The bumper incorporated a bolted coupling for the frame.

After the axle, the steering was modified to provide proper angles to each wheel, a more precise turning radius, and more travel in the steering wheel. The front wheels were given 20 degrees of reverse castor to help maintain traction in turns. Further, the steering linkage was strengthened. Next, the passenger steering arm was shortened to mitigate a sharp edge posed by the rod. A support was added behind the passenger seat and provision made to attach a three-point passenger restraint. The passenger pedals were changed to clip-type pedals.
and a clutch was designed to engage the passenger side pedals.

The open ends of aluminum tubing were closed with caps and ground smooth to remove sharp edges. Fasteners that were rusted or of improper length were replaced as needed. The braking system was slightly modified and adjusted. The attachment points of the seatbelts were modified to provide better operation. The tires were replaced with larger-profile tires to facilitate riding comfort, turning and ease of adding air. Finally, a hitch was constructed to tow a baby carrier and the SMV placard and flag were installed.

The function of the new design was superior to the original design given the new use criteria. All foreseeable safety issues were mitigated. Other concerns of the client family and supervisor were addressed and superior handling, ride and steering were achieved. In addition all other issues concerning fasteners and sharp edges were mitigated.
Fig. 18.2. Client and His Brother.
Fig. 18.3 (a and b). Tyler and Jared taking the improved Quad Cycle out for a test drive.
CHESS AUTOMATION BOARD (CAB)

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INTRODUCTION
The goal of this project was to create an automated chess game for a client with limited mobility. To provide for a more interactive feel the design uses physical pieces that move, making it more realistic than a video game design. Both players face each other and play over a real chess board. The CAB can perform all the moves, set up the pieces on the board, and provide rule checking to ensure only valid movements can take place. A block diagram of the entire system is shown in Fig. 18.4.

SUMMARY OF IMPACT
The board game controller allows a client with limited mobility to enjoy the game of chess. It also allows other games to be played since the control mechanism can be adapted easily to a wide variety of board games.

TECHNICAL DESCRIPTION
An XY Plotter (Fig 18.5) with an electromagnet mounted on its pen carriage is used to move the pieces. Input from the user is provided through six push-button controllers: four directional buttons as well as a select and cancel button. Output to the players is provided through light-emitting diodes (LEDs) and a liquid crystal display (LCD). The LEDs display the current vertical and horizontal position during each player's turn by lighting up. The position is changed with the up, down, left, and right buttons. A microcontroller is at the heart of the system, controlling the different systems in the CAB.

Three printed circuit boards (PCBs) are used as drivers to interface the subsystems of the CAB to the microcontroller. One is used to drive the LEDs and the on/off switch of the electromagnet. Both the vertical and horizontal LEDs use a 3x8 decoder and a buffer. The 3x8 decoder is used to transition the lights through all possible states and the buffer is used as a current drain to preserve the integrity of the microcontroller’s logic. The on/off switch of the electromagnet was implemented using a MOSFET and a reverse bias rectifying diode. The diode is used to collapse the hysteresis loop caused by the shutting off of the electromagnet.

![Microcontroller Diagram](image-url)
Another PCB driver board is used to control the push-button controller and to split the LCD control lines to the LCD screens of both controllers. The push-button controller circuitry uses 10kΩ resistors that drop the voltage from the power supply as the buttons are pressed. This drop in voltage is detected by the microcontroller as a logic 0, or an active low signal. The LCD control lines from the microcontroller are routed directly to both LCDs. A potentiometer is used as a voltage divider to provide for contrast control.

The final PCB driving board is used to control the XY Plotter and to provide 36 volts through a variable voltage regulator. The XY Plotter is controlled through four electronic switches. These switches control the up, down, left, and right movement of the plotter. By turning on these switches for the required amount of time, the XY Plotter can be placed anywhere under the Chess board.

The completed device is fully automated and user friendly. It has a resume feature that allows the user to stop in the middle of a game and resume the game at a later time. The squares are big and pieces are small to avoid collisions between pieces. The rules of chess are implemented and checked against every move. The hardware can be used with different game boards and different codes so that the user may play games other than chess.
INTRODUCTION
The primary goal for this project was to create a telephone that can be operated hands-free (Fig 18.6). The phone uses speech recognition technology. This allows persons with limited use, or no use of their hand or arm, the ability to use a standard analog telephone.

SUMMARY OF IMPACT
The system allows navigation through a simple voice-driven menu. The user is able to place a call by listing digits, redial a previous number, call and navigate through a voicemail system, and answer incoming calls without using his or her hands. While this telephone was initially intended for people with limited hand or arm movement it could be useful for nearly everyone.

TECHNICAL DESCRIPTION
This telephone operates on any standard Public Switch Telephone Network (PSTN) landline.

Since the primary user may not have the ability to easily toggle switches or plug and unplug wires, the telephone setup requires only four connections:

1) A telephone Line;
2) Speech recognition; and
3) Audio amplification.

The PSTN interface had to comply with FCC Part 68 regulations. Xecom Inc.'s XE0092 Data Access Arrangement module (DAA) was used. A block diagram of the module is shown in Fig. 18.7. This device includes a hook switch controller, a 2-to-4 wire converter, and a network isolation unit. It is basically an analog telephone on a 1”x 1” circuit. Given a voltage supply, tip and ring telephone connections, and an active low signal on the OH pin, the XE0092 presents a dial tone on the Rx lines. Any amplified audio (dual tone multiple frequency signals or user speech) on the Tx lines is transmitted over the telephone line. Speech recognition is accomplished using the Sensory Inc’s RSC4128 microcontroller. It has built-in speech recognition and synthesis capabilities. The speech recognition capabilities also provide for trigger word wakeup and subcommand menu navigation via programmable speech libraries. The RSC4128 was also used to provide the logic signals to control the On/Off Hook status of the XE0092.

Audio amplification is accomplished using a single microphone and a single speaker for the input and output on both the XE0092 and RSC4128. Since both devices function with different volume amplitudes we made use of an LM324 op-amp package to amplify the respective audio signals and sum them together. The device setup takes less than one minute to complete and operates on any standard analog telephone line. No training is required to use the device. A voicemail number and password can be permanently stored in ROM, allowing the user to access voicemail with two simple commands. The touchtone feature allows the user to transmit DTMF frequencies on command during a phone call. The device fits in a small box: 6.4” x 3.4” x 1.1”. The user may place outgoing calls and accept incoming calls, navigate any voicemail system, and use any other touch-tone operated telephone systems.
Fig. 18.6. Speech-Recognition Telephone.

XE0092 BLOCK DIAGRAM

Fig. 18.7. XE0092 DAA Layout (XE0092 data sheet, www.xecom.com)
MECHANICAL LIFT FOR A DISABLED TEENAGER

Student Designers: Mike Nelson, Branden Wagner,
Brian Barritt and Jordan Cuthbertson
Project Supervisor: Scott Morton
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INTRODUCTION
Our client requested a device for lifting her son, who has physical disabilities, from the floor to a standing position. He cannot get up by himself and has become too heavy for one person to lift. The device was to be easy for one person to use, and safe for the operator and child. The device proposed uses a hand winch and cable hoisting from a pulley mounted on the inside of a collapsible tripod.

SUMMARY OF IMPACT
From the collapsed position the lift stands on its feet. The transport strap is removed and the legs are pulled out to full extension. If the individual to be lifted is not under the center of the lift, the lift can be moved to the individual. This is accomplished by lifting one leg a small distance off the ground and pulling. Once the individual to be lifted is under the center of the lift, the winch lock is released and the sling is pulled down to an acceptable height. One side of the sling is then released from the carabiner, wrapped around the individual under the arms, and then connected back to the carabiner. When the winch lock is re-engaged the individual can be lifted to the desired height.

TECHNICAL DESCRIPTION
The tripod design consists of three two-inch aluminum tubular legs, each with a steel hinge insert affixed with a 5/8-inch by three-inch UNC bolt and nylon lock nut to a central brace made from ¼-inch mild steel. For safety and ease of use, the range of motion of the legs is limited by a hinge at the top of the leg. The lifting mechanism consists of a hand-powered 3.1:1 gear reduction winch, which pulls a rope from the sling around the individual to be lifted, through a pulley, and into the winch drum. The pulley is secured to the central steel brace by a locking carabiner. The locking carabiner is connected to a steel ring which is welded to the central brace. The rope and sling are connected by a loop in the rope, made by a figure-eight knot, and a spring-locking carabiner. The spring-locking carabiner is connected through both loops in the ends of the sling and the loop in the end of the rope. The final product is shown in Fig. 18.8. The device has a lift capacity of 320 pounds, although this was not tested to failure. Off axis operation is 22.8 degrees. The lift force of the wrench is 15 pounds.
Fig. 18.8 (a, b, and c). The Mechanical Lift.
CRANIAL CONTROL (WHEEL) CHAIR

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INTRODUCTION
The Cranial Control Chair was designed to meet the needs of users with limited use of their arms and legs. By monitoring ocular bio-electrical signals, this system allows the user to steer the chair using only eye movements. A “Sip and Puff Unit” is used for overall control of the system, allowing the user to change modes of operating using only his or her breath. Finally, an ultra-sonic rangefinder is added to provide an extra measure of safety, alerting the user to sudden changes in grade. The rear view of the project is shown in Fig. 18.9 and in full view in 18.10.

SUMMARY OF IMPACT
This device allows completely hands-free control of the wheelchair, providing more freedom and independence to the user. A safety system protects users from injury by not allowing the chair to reverse over steep inclines. The self-contained design means that all systems are housed in a control box (17x13x4”) attached to the back of the chair, and the chair is powered by four 7.2 volt Radio Controlled (RC) car batteries (in a box). The user can select different control systems. He or she may switch from using a joystick to EOG control and back by flipping a switch.

TECHNICAL DESCRIPTION
within the design include: function control (using a “sip and puff” unit); steering (using EOG signals); safety measures (using ultrasonic sensors); an interface with the wheelchair itself; and a microcontroller.

The steering mechanism is based on EOG electrodes and measurements of eye movement. When connected to an instrumentation amplifier and a filter, the electrodes provide a simple DC signal. The voltage increases when the user looks left, and decreases when the user looks right. The system interprets this signal using the Motorola HC12’s
ATD system, and uses it to control the direction of the pivot or turn.

The “sip and puff” unit is used for function control. It uses a simple pneumatic switch to close a contact on a separate line for each “sip” or “puff”. A common circuit is used to “pull up” the switched lines. A five-volt source is connected to the switch, a port on the microcontroller, and an AND gate. When the switch is open, both inputs to the AND gate are logic high, leaving the IRQ pin of the microcontroller high. When one of the switches is closed, the IRQ drop low, triggering an interrupt. The interrupt service routine (ISR) for the IRQ polls the connected port to decipher which signal was asserted, and then changes the function of the systems accordingly. Because the control system is designed for users whose heads have a limited range of movement, safety measures for hazards that lie behind the user must be included. Potential dangers include collision with objects and steep drops that may be life threatening. An ultrasonic sensor monitors the distance from the sensor to the ground. The SR-04 is controlled by a simple 10µs pulse. Once the sensor package receives this pulse, it emits an ultrasonic signal, and waits for an echo. The length of the output pulse is proportional to the distance between the sensor and the object. If the microcontroller detects a pulse that is too long (indicating an abnormally long distance to the ground), it will restrict movement in the reverse direction.

The wheelchair is controlled via a joystick and electronics contained in a box attached to the side of the chair. The joystick was removed and tested to mimic the control signals. This allowed use of the existing H-bridge and electronics. Only the signals corresponding to the X and Y axes are intercepted. The joystick is still connected to the wheelchair electronics, and a switch allows the user to choose between the joystick control system and the EOG system. Digital to analog (DTA) converters produce similar analog control signals.

The EOG system requires repeated calibration, especially for different users. The low-pass filter causes integration of signals such that the system centers itself to one side if eyes linger for too long. This could be corrected by removing low-pass filtering stage (if the circuit could handle the additional noise), and adding electronic switches to short-circuit capacitors once the desired level has been reached. An indicator of state would be helpful. It is sometimes difficult to tell what mode it is in (e.g., still, pivot, forward, backward). An LED display would be sufficient and simple to implement.
MOBILE WHEELCHAIR LIFT

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University of Wyoming

INTRODUCTION
A lift was designed to raise and lower a wheelchair and its occupant. It also rotates 360 degrees using low voltage electric actuators. It attaches to a wheelchair and makes access to healthcare procedures more convenient for individuals using wheelchairs and their physicians. It lifts, lowers and rotates while supporting a load of up to 300 pounds. Weight and size exceed the initial design specifications. Upon testing of the prototype, TACT determined that the prototype’s size and weight are acceptable but could always be reduced.

SUMMARY OF IMPACT
Persons with disabilities require access to many forms of health care, including dental procedures, health checkups, and diagnostic procedures. Frequently, persons with disabilities must physically be moved into position for these procedures. This may be uncomfortable for the individuals and strenuous for those assisting. A device to aid in accessing medical procedures is in high demand by individuals with disabilities and medical communities. It allows the user to remain in his or her wheelchair and to control movement of the chair.

TECHNICAL DESCRIPTION
The device lifts the occupied wheelchair zero to nine inches off the ground and then rotates anywhere in a 360° horizontal range (see Fig. 18.11). Lifting is accomplished using an electronic Atwood tongue jack, which is attached to the wheelchair using a mount designed by the student team. This mount, to which the jack attaches, fastens to the wheelchair behind the occupant seat. The foot of the jack connects to a base, designed by the team, which is raised and lowered with the jack. Upon lowering the base to a height just above the ground, a series of mechanical booms are deployed, extending outward from the wheelchair. When the booms are in their fully extended position, the jack continues to lower and the wheelchair and occupant are lifted. To the end of each boom is attached to a motorized caster, designed by the team. The casters allow the entire wheelchair, occupant, and lift apparatus to rotate within a 360° horizontal range as one body. Upon the completion of health-related procedures, the lifting procedure is reversed. The wheelchair and occupant are lowered, the booms are retracted, and the base is lifted, so that normal wheelchair use may be resumed.

The original design consisted of an H-shaped base with motorized casters attached to each extremity. The lifting mechanism was a camper tongue jack and was attached to the base by a mounting foot. Since the H-shaped base protruded out 10 inches on either side of the wheelchair, it could not get through doorways. The base then evolved to a rectangular main base with extending and collapsing boom arms. These arms were extended and collapsed using two linear actuators. The motorized casters were of the same design and still attached to the end of each arm. The tongue jack was still used and mounted to the wheelchair through the use of a flat plate and steel tubing.

Many items in the design were improved or changed. The caster assemblies were redesigned to make them easier to fabricate. The motors, which operated the caster wheels, were mounted such that they fit inside the boom arms, helping to protect them and prevent physical or weather damage. The base was redesigned to help reduce weight, and reduce the number of total parts.

The final design concept has a triangle shape with one telescopic and two extending and collapsing boom arms. These open simultaneously through the use of one linear actuator. The tongue jack is still used as the lifting device and is attached to the base by a triangular jack foot. Most of the pieces on the base were fabricated of 1020 steel. Steel was chosen because rigidity was of utmost concern. Instead of using a flat plate and round tubing for the jack mount, the final design consists of one main circular tube and rectangular square members that are mounted to the wheelchair itself. The electrical
controls consist of limit switches and relays to automate the system.

Fig. 18.11 (a and b). Lift Assembly (i.e. Wheelchair, Lift Prototype, and Occupant). Shown in Lowered Position (a) and in Raised Position (b). Mount Shown in Red, Jack in Grey, Base in Blue, and Casters in Green.
VOICE MACHINE

Supervisor: Dr. Steven F. Barrett, Ph.D., P.E.
Michael Stephens, Erica Weber
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University of Wyoming

INTRODUCTION
A device was designed to provide cues to a nonverbal child as he uses a computerized speech device.

SUMMARY OF IMPACT
The device includes a liquid crystal display (LCD), a voice chip and a microcontroller. It is packaged to be used as a lanyard. The device provides the child visual cues about what message he is selecting to be spoken.

TECHNICAL DESCRIPTION
The design incorporates a picture frame type LCD. This did not require much additional programming for the microcontroller as the LCD is standalone, addressing image generation. A Spectare Keypix LCD was chosen because of its small size. The entire device is 1.5” square. The screen itself is small (96 pixels wide by 64 pixels high). The device contains its own resident memory and is battery operated.

The LCD was dismantled to make it fit inside the case and to allow other modifications. The case was removed to expose the support circuit board and the actual screen. Wires were soldered on to the switches. The battery was removed as the final device is powered by the main battery. The USB cable was also dismantled as these wires are routed to the PC Board.

The microcontroller sends simple pulses to the buttons to simulate a person pressing them. Care was taken in timing of these pulses. It is possible that if the skip button is pressed on the microcontroller three times quickly, that the LCD will ignore most of these instructions while it is trying to render the first new image. For this reason optimized wait functions were built into the program so that the microcontroller will ignore input from the user until the LCD is finished displaying the next image. This is necessary so that the internal index of the microcontroller matches the LCD index.

A Winbond ISD 4003 series voice chip was chosen because it can hold from two to eight minutes of recorded voice. The ISD 4003 takes input directly from a microphone via few resistors and capacitors. The ISD 4003 then stores that info and plays it back from flash memory. For this application the four-minute chip was chosen. The four-minute chip has mid-quality recording clarity and is long enough to accommodate 51 messages that are 4.6 seconds long.

The microcontroller is the “brains” behind the device. It takes user input and outputs data to the LCD and/or the voice chip. An Atmel AT90S8515 chip is adequate for the simple task of taking inputs from buttons and controlling the LCD and the voice chip. The chip was removed from a STK500 board and programmed through the In System Programming (ISP) port. This was done to ensure that a properly working completely standalone prototype could be constructed.

The microcontroller was programmed in C. An Image Craft compiler was used to compile the code. The compiler then used the STK500 to download the compiled code to the chip. The program is short and does nothing more than take inputs, make a decision, and then pulse the appropriate outputs. The data flow for this device can be seen in Fig. 18.12. The microcontroller is digital and the voice chip creates an analog signal.

Internal components can be seen in Fig. 18.13.
Fig. 18.12. Diagram of Voice Machine.

Fig. 18.13. Voice Machine.
“CYCLOPS II”: MOBILITY AID DEVICE FOR THE BLIND

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INTRODUCTION
Cyclops II is a new design to aid mobility for individuals who are blind or visually impaired. The goal was to design an effective mobility aid that would be easy to operate and affordable. This design incorporates an HCS12 based Minidragon+ MC9S12DP256B microcontroller evaluation board (Wytec Inc). It is a continuation of a previously designed project called Cyclops I, which was based on a XILINX CPLD using Verilog HDL.

The design of Cyclops II is based on ultrasound technology. Ultrasound helps the user detect nearby obstacles for safety during movement.

SUMMARY OF IMPACT
As shown in Fig. 18.14, this project can be worn by the user on a headband. It provides audible feedback on the range of obstructions. The user gets information from the device to gauge the distance to nearby obstacles.

TECHNICAL DESCRIPTION
The Cyclops II design is based on three compact features: the transducer, one or two headphones, and the controller.

An ultrasonic transducer the SRF04 (Acroname Inc.) was used and controlled by a HCS12 microcontroller (Minidragon+). The microcontroller triggers the transducer to generate a pulse. The SRF04 emits this pulse. When this sound pulse hits a nearby object it bounces back to a receiving unit on the transducer. The microcontroller then captures this pulse and uses it for distance calculation. The time from the start of the pulse until it returns to the transducer is used for distance calculation. When the time is calculated using the program, the information is processed by the microcontroller and the Minidragon generates subsequent frequencies to a sound emitter (which can be a speaker or one or two headphones). Depending on the pitch of the frequency emitted by the earpiece the person using the device is able to understand how far the nearby obstacle is and easily avoid it. The higher the frequency is, the closer the object.

The SRF04 transducer used in Cyclops II is a compact transducer, has very minimal operating voltage requirements and has a useful range-finding capability. The MC9S12DP256 Minidragon+ evaluation board hosts a powerful microcontroller. It is a 16-bit device with a 16-bit central processing unit, 256K bytes of Flash EEPROM, 12K bytes of RAM, and 29 discrete digital I/O channels. It is operable using a 9VDC source. The device is battery operated, compact and easy to carry around. The device is cost effective and affordable. It performs a 180° scope of the user’s surroundings to detect obstacles from as close as 3 cm to a maximum of 3m. It requires minimal training. Its unique ability to detect overhanging objects especially enhances mobility.
Pulse emitted by SRF04 form a cone
Shaped range of spectrum with min
Distance of 3 cm to maximum
Distance of 3 m

SRF04 transmit pulses, after pulse
Hits obstacle, receiving unit captures
Pulse and is sent to a microcontroller
to process data

Earpiece emits different
Frequencies depending on
the proximity of the
obstacle

SRF04 transducer
worn on forehead
attached to a
headband

Minidragon microcontroller
worn on a carrying case
clipped on to a waist belt

Fig. 18.14. Illustration of Cyclops II.
“LIFE’S A SWITCH”: PROJECT UPDATE

Designers: Jennifer R. Barnes and Stephanie A. Popp
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INTRODUCTION
This project is a workshop and a 55-page teaching manual entitled “Life’s a Switch – A Guide for Building Assistive Technology Switches.” The workshop provides assistive technology professionals guidance on how to build their own cost-effective assistive switches. It teaches them to use readily available, low-cost electronic parts and supplies.

SUMMARY OF IMPACT
Assistive technology includes any product that enhances a person’s quality of life by improving the individual’s mobility, ability to perform daily activities, communication, or participation in education, vocational activities and recreation. A goal of assistive technology is to provide opportunities for children with disabilities to explore, play, learn, and communicate with others. Switches are essential tools used to provide these opportunities.

TECHNICAL DESCRIPTION
The workshop provides instruction in basic electrical theory, safety, and use of equipment. It culminates with each participant adapting an off-the-shelf toy into an assistive technology teaching aid. The workshop has been taught annually since 2002 on campus and at another location within the state. One participant at our Summer 2005 workshop was a middle school student who wanted to build assistive devices for his brother. A picture of his project is provided in the figure below. Workshop materials are available upon request.

Fig. 18.15. An assistive technology switch developed by a workshop participant for his brother.
CHAPTER 19
WAYNE STATE UNIVERSITY

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INTRODUCTION
Our design is for a small business that employs people with disabilities. The business produces a product line of hand painted tools with wooden handles, including kitchen and garden tools, hammers, and screw drivers. A screwdriver is shown in Fig. 19.1. The tools are distributed worldwide through gift stores and as promotional items for companies.

Unfinished inventory is sent to special education vocational classes for sanding and priming of the wooden handles. The prepared tools are then sent back for artists to paint. The finished products are packaged for shipment. Packaging involves: 1) folding cardboard frames and supports that hold the tools in place; 2) affixing a tool to the holding supports; and 3) inserting the cardboard frame into a stiff plastic sleeve. It is important that the plastic sleeve not be scratched or deformed so that the product is nicely displayed.

Previously, there was no standardization of the production process or quality control at the different schools involved. Also, the method of shipping unfinished tools and materials to schools and back was not cost effective and tools were often marred or ruined. The first goal of the project was to design fixtures to standardize the fabrication and packaging processes. The second goal was to design a shipping kit to standardize the shipping process as a way to prevent damage to the tools.

SUMMARY OF IMPACT
A kit was designed for shipping all materials and inventory required by the special education classes. Fixtures were created for improving the sanding and paint priming process. Fixtures were also created for improving cardboard folding and insertion of cartons into plastic sleeves. After training with the kits, the students were able to independently and efficiently unpack the shipping materials and organize them. They were also able to repack their finished products to be sent back. Students with physical and cognitive disabilities were able to perform the associated tasks faster and with fewer errors. Based on the initial success of the fixtures provided, the client company has built ten more fixtures like them. They use some at their facility and have shipped others to the participating schools.
TECHNICAL DESCRIPTION
A team of student engineers and occupational therapists worked with special education teachers at a vocational training school to design a collection of jigs to help improve the productivity and quality of participating students. A prototype shipping kit was also designed and is being field tested.

Fig. 19.2 shows an unfinished screwdriver handle (steel portion removed) on a jig that can hold four handles for the sanding and priming operations. Fig. 19.3 shows a folding jig for the shipping/display boxes.

Fig. 19.4 shows a packaging jig to aid in error-proofing, quality control and productivity. The jig is a wedge-shaped block of wood with metal clamps on the end. The clamps are stiff enough to hold the box while the wedge is inverted and pushed through the plastic cover. The rectangular shape of the wooden jig forces the plastic cover to open to the correct shape as the box is inserted.

The estimated cost of all the materials is $140.
FACILITIES ANALYSIS AND WORKSTATION DESIGN

Designers: Stephanie J. Hayes, Virginia Lingham, Ryan DeLoye, Jonathan Rice
Client Coordinator: Lisa Knoop-Reed, President, Art For A Cause
Supervising Professors: Dr. Darin Ellis, Dr. Robert F. Erlandson, Dr. Donald Falkenburg
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INTRODUCTION
A client business produces a product line of hand-painted decorative tools, as described in the previous project report. The business is experiencing a rapid growth phase in terms of increasing orders and expanding business opportunities. The business required operations and facilities that can accommodate this growth. The goals of this project were to: 1) conduct an analysis of facilities requirements; 2) make recommendations for improvements; and 3) design a prototype workstation to serve as a standard workstation for the facility. The work area was overcrowded. There

Fig. 19.5. Redesigned Shipping Area.
were materials stored on the floor in a receiving area, a shipping area that doubled as the packing area, and donated furniture and shelving spread about the facility. Workers in wheelchairs could not access most of the work area. Workers with mobility or balance problems had trouble negotiating the work area. Material flow and handling were inefficient and limited because of worker’s navigation difficulties.

**SUMMARY OF IMPACT**

A detailed facilities analysis was performed and several alternative scenarios were presented to personnel. Discussion among the design team, participating faculty, and staff resulted in a consensus strategy. Additional space was rented adjacent to its current facilities. The team set up shelving, established new shipping and receiving areas, and created an organized storage area. A new mobile wheelchair-accessible workstation was designed and built. The work area was reorganized into U-shaped work cells with defined tasks in each cell, i.e., sanding in one, priming in another, and final decorative painting in another.

As a result of these changes the entire work area became more accessible. Workers in wheelchairs and those with mobility or balance issues can now safely navigate the work area, allowing these workers to assume more responsibilities for material handling, stocking and inventory control.

**TECHNICAL DESCRIPTION**

The first step was to conduct an analysis of storage space, shipping areas, material handling practices, work areas, and task analyses. Brainstorming with owners and staff led to more clearly defined business and operational objectives. Based on these a 5S program was implemented. The 5Ss are: sort, set in order, shine, standardize, and sustain. AutoCad was used to display the original facilities layout as well as alternative layout strategies. BlocPlan was used to analyze facilities layout options. A more organized inventory system using the A-B-C approach was designed and implemented. Fig. 19.5 shows the new shipping area.

A prototype version of a mobile workstation was designed based on agile assembly principles. The workstation was built from Creform, a pipe and joint technology used extensively in manufacturing and assembly. There is a pegboard top and a pegboard divider extending up from the center of the workstation table. Hangers can be attached to the pegboard to hold freshly painted tools. The pegboard serves as a holder for many of the tools. They are simply inserted in the holes and securely positioned for priming, decorative painting, or a final protective coating of varnish.

The estimated cost for the mobile workstation is $350.
MATCHING CORRESPONDENCE COUNTER:
COUNTING AND PACKAGING

Designers: Purav Dagli, Gurmanjyot Sandhu, Rainier Monteiro, Satnam Bansal
Client Coordinator: Jane Resutek, Occupational Therapist, Warren Woods Tower High School
Supervising Professor: Dr. Robert F. Erlandson
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INTRODUCTION
A special education vocational training class has a mini-business that supplies teachers throughout the local school district with a variety of decorative paper cutouts. The Matching Correspondence Counter (MCC) was developed to help special education students count and package paper cutouts that have been ordered by teachers throughout the district. The MCC consists of 10 instrumented bins communicating with a control PC. It communicates to the PC the status of the bins (empty or containing an object) via an indicator light.

SUMMARY OF IMPACT
The MCC is ideal for counting light paper cutouts because of the sensing bin structure. It turns the counting task into a pattern recognition task with system monitoring and multi-modal feedback to the students. The MCC enables students who cannot count to engage in the packaging activity.

TECHNICAL DESCRIPTION
The program is written in Visual Basic 6. It uses the MSCOMM control variable in Visual Basic to communicate with the MCC. Fig. 19.7 shows the splash screen that appears when the program starts. Fig. 19.8 shows the system configuration screen. The teacher can specify a prompt time. The prompt time is the amount of time the system will wait for a user response before issuing a voice or sound message. The teacher can record a customized prompt message and can add new pictures to the display. The pictures are of the paper cutouts to be counted. Fig. 19.9 shows the job set-up screen. Here the teacher selects the cutout to be counted and the number of pieces to be counted. These are displayed on the screen. Fig. 19.10 shows the counting screen. As the cutouts are added or removed, an image is added or removed to keep track of the MCC bin contents.
Fig. 19.9. Job Setup Screen for Selection of Cutout and Number of Pieces to be Counted.

Fig. 19.10. Counting Screen Reflecting Number of Items in the MCC Bins.
MATCHING CORRESPONDENCE COUNTER:
MATHORAMA MATH GAME

Designers: Nandana Doddapuneni, Simon Rayes
Client Coordinator: Kathy Kittleson, Pre-School Teacher, Hillcrest Preschool, Dearborn Heights.
Supervising Professor: Dr. Robert F. Erlandson
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INTRODUCTION
A universal design approach was used in creating a game for pre-school, kindergarten and early elementary students and those with comparable cognitive abilities. It is a manipulative activity that makes use of the Matching Correspondence Counter (MCC). The MCC consists of ten instrumented bins communicating with a control PC. The MCC can be programmed to perform a variety of tasks. The MathORama game involves users adding objects to and removing them from the bins, guided by visual and voice prompts from a PC. The activity has two levels, a practice level (level zero) and a grading level (level one).

The practice level prompts the user to fill the bins until all of them are full and then prompts him or her to remove the cards from the bins until all of them are empty. In the grading level game the student is given ten questions and is graded on a ten-point scale. The questions can be addition, subtraction or a combination of both. The teacher is given an option to select a category. Scores are shown in percentages on a graph. The prompt time, the duration for which the system waits without a user response before presenting another auditory prompt, can be set by the teacher according to each student’s ability.

SUMMARY OF IMPACT
Students with cognitive disabilities can benefit from this educational activity.

TECHNICAL DESCRIPTION
The game was developed using Visual Basic 6.0 with a PIC 16F876 microcontroller on the MCC to provide the communications interface between the PC and the MCC sensing and display elements.

Fig. 19.11. Splash Screen of MathORama Activity.

The backbone of the MCC program is the Visual Basic MSCOMM control, version 6.0.81. This control integrates both hardware (RS232 port) and the MathORama software to produce an integrated gaming activity that interfaces smoothly with the MCC and user responses. The MSCOMM control accomplishes this communication utilizing OnCommEvent, RThreshold, and InBufferCount. The OnCommEvent, for example, invokes the PC and updates it with user movements or interactions. As the user fills the bins or removes items from the bins, the microcontroller polls the bins and detects the status of the bins via the sensors. The microcontroller then sends the data to the PC. The OnCommEvent receives the data and signals the PC, which then reacts accordingly.

Fig. 19.11, 19.12, and 19.13 provide sample screen images. Fig. 19.11 shows the splash screen, which is present as the program starts. Fig. 19.12 shows the teacher set-up screen wherein she can select the game level (1 or 2) and enter the player’s name. When the game starts the player is prompted both
verbally and visually. Fig. 19.13 shows an addition example where the player is asked to add three and six together to get nine. The player places objects one at a time into the MCC bins. With each placement the player receives a prompt. A prompt also indicates when the sum number is reached (three in this case) and then provides another verbal and visual prompt to add six more. When that is done the prompt provides a reward message stating the answer, nine in this case. A voice recording utility is provided so that teachers can create their own customized prompt message.
ACCUCUT MANUAL DIE MACHINE CONVERSION TO SWITCH OPERATED

Designers: Purav Dagli, Gurmanjyot Sandhu, Rainier Monterio, Satnam Bansal
Client Coordinator: Jane Resutek, Occupational Therapist, Warren Woods Tower High School
Supervising Professor: Dr. Robert F. Erlandson
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INTRODUCTION
The staff at a high school special education vocational training program uses a mini-business model for vocational activities. A goal of the program is to engage as many students as possible in work activities. One successful mini-business produces paper cutout decorations for classrooms throughout the school district. Teachers place orders for decorative cutouts, e.g., 25 hearts for Valentine’s Day, 12 flowers for spring, etc. The students are using manual AccuCut Die cutting machines to create the cutouts. Fig. 19.14 illustrates use of the manual device. The physical demands of this task preclude use by students with poor upper extremity functioning.

The goal of this project was to design and build a switch-controlled version of the AccuCut Die machine. The staff requested that this device be mounted on a wheelchair-accessible mobile workstation with enough storage space for all the materials necessary for the job.

SUMMARY OF IMPACT
The staff was pleased with the final design and eager to start using the system.

TECHNICAL DESCRIPTION
Conversion of the manually operated device to a switch-operated device required that the manual crank be removed and an electric motor coupled to the shaft. The manual device was inherently safe in that it was impossible for a student to turn the crank and get his or her fingers into the die press rollers. With switch control, safety is a primary concern.

Fig. 19.15 shows the completed system. The AccuCut is positioned on a custom-designed Creform workstation. Creform is a pipe and joint technology ideally suited to rapid prototyping yet durable enough to be used as the final product. The workstation is wheelchair accessible and has storage units for the job’s required materials.

First, the dies must be placed into the movable tray. Then the tray must be positioned so that an edge of the tray and the cushion material are engaged with the press rollers. It does not matter on which side the tray starts, as system sensors detect the position and move the tray accordingly. One or more sheets of paper are then placed over the dies and the start switch is pressed. The press rollers pull the tray through. The roller pressure pushes the paper into a metal cutting blade in the die. As the tray moves through the rollers the paper cutouts are produced. Sensors detect when the dies have passed through the rollers and the device stops. A worker can then remove the cutouts and the residual scrap paper, place new paper on the dies, and push the start switch. The tray then moves through the press rollers in the opposite direction, completing the cycle.
Fig. 19.16 shows the various safety mechanisms. The stop bars block fingers or larger objects from entering the rollers. If the bars are engaged and move toward the rollers they activate a limit switch, which stops the rollers. Two switches must be sequentially pressed to restart the device. The rollers move the tray away from the press section when activated again. This clears the object from the safety bars. Multiple limit switches and a timer add redundant safety measures.

The cost of the system was about $1,500.
CHAPTER 20
WRIGHT STATE UNIVERSITY

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INTERACTIVE OBJECT MOBILE WITH LIGHT AND SOUND

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INTRODUCTION
A client coordinator desired a sensory device for a child with cerebral palsy. One aim of the project was to assist the child in muscle control and coordination by engaging multiple senses with a toy. The toy creates a feedback system that engages the child’s interest and encourages further interaction. Another aim was to improve the child’s optical tracking ability by engaging her with a moving light stimulus on the toys. The device had to be accessible to the child while lying down, and take into account the client’s fine motor control abilities. The client coordinator desired that the device stand independently and have multiple toys, each emitting sound and light when struck. The height of the device had to be adjustable to enable use by other children in a classroom environment. The Interactive Object Mobile with Light and Sound met all the requirements defined by the client coordinator.

SUMMARY OF IMPACT
The client coordinator indicated that the device is simple to set up, and instructions are easy to follow. In the future, more toys can be added. Although songs can be selected by changing the address of the toys, additional songs may also be programmed at any time. Currently, the toys are set up to respond with lights, but any sort of device may be attached to the LED pin of the toys provided they draw less than 800 mA. All of these techniques may be used to increase the long term appeal of the device. The client showed interest in the device and was engaged by the various toys and stimuli (Fig. 20.1).

TECHNICAL DESCRIPTION
The design is a modified T-Frame seen in Fig. 20.2. The benefits of a simple T-Frame include that it is lightweight, simple, and compact. Modification of the T-Frame included adding an additional vertical and horizontal bar, and a top panel to house the electronics. This two-bar design allows the structure to achieve stability in both horizontal axes. Although stable, this design is subject to stresses at the joints. For example, the stability of the design to shearing forces, such as a force that moves the base and top in opposite directions, is dependent on the strength of the joints between the members. Strong joints were made using two 2.5” screws to fasten each leg to its base. These types of forces are also reduced by the addition of a cross bar on each side of the legs. SolidWorks models were constructed and analyzed to determine weak points and maximum stresses.

To meet the demand of compact storage the device is divided into three parts: two legs and a top. The top features a collapsible structure that is three feet long when collapsed and can span a four-foot mat when expanded. The legs are foldable so they can be stored in the provided space. Height adjustability is implemented using a pin and sleeve system. The system consists of equidistant holes drilled into the legs into which 3/8” steel pins are inserted. The top

Fig. 20.1. Client Using Interactive Object Mobile with Light and Sound.
rests on the pins and is secured by inserting an additional pin.

To provide interaction, and demonstrate cause and effect relationships to the user, the device must generate sound and light responses that are tied to a specific action. The light control circuit is shown in Fig. 20.4. In order to meet these specifications a microcomputer-controlled system was implemented. Communication from the toys to the microprocessor is handled through auxiliary circuitry. The microcontroller used in this device is the Freescale MC9S08GB60, as part of the M68DEMO908GB60 Demonstration Board. It features 60KB Flash Memory, 4KB RAM, 56 Input or output (I/O) pins, hardware interrupt (IRQ), keyboard interrupt (KBI), real time interrupt (RTI), serial communication interface (SCI), and a preinstalled serial monitor program. Programming of this controller was done using CodeWarrior v3.1 by MetroWerks, primarily in C programming language.

Toys are mounted on the structure at four locations. They communicate with the microcontroller, which is responsible for each toy’s response. This design required two lines for the power supply and ground connections because lights are mounted on the toys. However, since the light response is controlled centrally, there is an additional line to handle the light signal. Each toy also indicates whether it has been hit or pulled, requiring two additional lines. Finally, all of the toys send a unique identifier, in the form of a four-bit binary address, to the controller. Without this address, it is impossible to make each action unique to the toy. Due to the limitations of binary scale imposed by the number of bits, it was determined that four bit addressing was the most appropriate. This level of addressing enables development of up to 16 unique toys, providing a balance between flexibility and complexity. A total of nine lines connecting the toy to the central system were required. The pulling indicator is separate from the toy because the signaling mechanism is mounted in the structure.

To detect the address of each toy, digital comparison circuitry is used to compare the address of the toy to an address being broadcast by the microcontroller. When the two addresses match, a flag triggers and indicates the location at which the match occurs. This flag is read and stored by the microprocessor and is required in order to send responses to the appropriate location. Initialization procurement occurs at power-up to detect all of the toys, and is not needed again unless the device is powered down, or toy locations are changed. A power reset circuit is used to send a short, low logic pulse to the microcontroller at power-up. Upon detecting this pulse, the microcontroller broadcasts addresses from one to 15, and then polls the input pins for locations one to four in order to detect response. When a response occurs, the microcontroller associates the toy address to the location that responds.

To detect a pulling response, a simple limit switch, tied to a spring mechanism, was used. When the toy is pulled, the shaft to which the spring is attached travels down. A protrusion, placed on the end of the shaft, is used to trigger a limit switch. When the toy is released, the spring simply causes the shaft to return to its original place, thus deactivating the limit switch.

To detect impact, a piezoelectric transducer was used. The impact detection circuit is shown in Fig. 20.3. The transducer responds to vibrations and deflections. It then generates a decaying, sinusoidal voltage in proportion to deflection, which can be caused by vibration or bending. These voltages range from less than 50 mV for a light vibration to almost 7 V for a severe deflection. Although sufficiently high voltages were generated, there was not enough current to allow signal processing from the transducer. It was determined that an analog
A comparator performs well with high impedance, an easily controlled threshold voltage, and a digital output. A voltage divider is used to set the reference voltage to the non-inverting input of the op-amp, and the transducer is connected to the inverting input. When this is tied into a monostable 555 timer, it creates a "high" voltage for approximately 300 ms.

All communication to and from the microprocessor is controlled through circuitry embedded in a custom-printed circuit board. Because of the complexity of the circuit it was decided that the auxiliary circuitry would best be implemented on a PCB. The circuitry uses 6 volts, and level conversion circuitry is used to convert the 6 volt logic into 3 volt logic. A zener diode is used to regulate the voltage at 3 volts. Also, because the KBI on the microcontroller is an active low input, the outputs from the pulling and hitting responses were inverted. To achieve both level conversion and inversion, a HEF4049 IC is used. The impact detection circuitry amplifies and cleans the output from the piezoelectric transducer. Once it reaches the 4049 inverter, the active high pulse is converted into an active low pulse, which is fed into the KBI port of the microcontroller. When the microprocessor detects this pulse, it enters into a service routine to determine which toy, and what type of input (hitting or pulling), has been activated.

Output for the lights is controlled by both the microcontroller and external circuitry. The microcontroller generates an enable or disable signal to control the status of the lights. Blink rate is determined by an external oscillator running at approximately two to three Hz. Light intensity control is implemented using a pulse width modulation (PWM) that varies duty cycle, and runs at approximately 60 Hz. Output from the three subsystems (microcontroller, light flasher, and PWM) is passed through a logical AND, resulting in the final output. To handle the current demands of the LEDs, this output is fed into a transistor to provide appropriate gain.

The total electrical system implemented on the printed circuit board consists of four impact detection blocks for digital comparators, light flashing circuitry, DB9 connectors for toys, a DB-25 connector for the microcontroller, level converters, and four transistors.

The device features a low battery indicator, designed to illuminate an LED when the battery voltage drops below a certain threshold. The circuit uses an op-amp as an analog comparator. The input to the non-inverting input of the op-amp is tied to the battery voltage through a voltage divider. A zener diode is used to set a reference voltage at the inverting input. Normally, the battery voltage is above the reference voltage, which causes the op-amp to saturate to +V. However, when the battery voltage drops below the reference voltage, the op-amp output goes to ground, triggering the LED.

Fig. 20.3. Impact Detection Circuit.
determine the trigger voltage for the circuit, the different components of the PCB mentioned above were tested. It was determined that a voltage of 4.5V was ideal.

To address the need of volume control, a computer speaker was removed from its casing and was used for audio output. There is a volume control built on the speaker. The audio signal comes from 8 pins on the microcontroller as a digital signal and then runs through an 8-bit digital-to-analog converter that outputs to the computer speaker. Sound generation is done within the microprocessor using a variable frequency amplitude output. The output generates points on a sine wave through the digital to analog converter, resulting in an audio format similar to that of MIDI.

The total cost of parts and labor was $665.
ADAPTATION OF THE 7-LEVEL COMMUNICATION BUILDER

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INTRODUCTION
Augmentative communication devices promote independent use while also stimulating the cognitive thought process of a child. In a classroom setting it is desirable that they be inexpensive, durable, and lightweight. The 7-Level Communication Builder (7-LCB; Enabling Devices, Inc., Hastings-on-Hudson, NY), met all the required features of a classroom communicator, with the exception of promoting independent use. The 7-LCB was modified so that the client may use the device without any extraneous aid.

SUMMARY OF IMPACT
All of the required design specifications were met by the final prototype. The client supervisor indicated that the device could be successfully used by the intended clients during the upcoming school year. The design project gives clients the ability to use the communicator independently, thus promoting the advancement of their communication abilities.

TECHNICAL DESCRIPTION
The final design of the Adapted 7-Level Communication Builder has the same general physical configuration as the original model. The most noticeable outward change is the addition of sub-surface photoreflectors that lie below the top cover of the device. The central photoreflector is aligned with the center of the device; the two peripheral photoreflectors are separated from the central photoreflector at a distance of 6.5 cm. The axial line containing all three photoreflectors lies 1 cm below the recessed edge of the top cover.

The mechanical knob on the back of the device that changes the level setting is no longer functional. To lessen the amount of mechanical modification that had to be made to the device casing, the knob itself was left in its original location.

The modified device uses a binary barcode system to indicate the setting level. A binary barcode system decreases the number of photoreflectors needed to implement the project when compared to a discrete barcode system. Three photoreflectors are used to read the barcodes corresponding to the 7 levels of the 7-LCB. Photoreflectors are a type of integrated circuit that detect reflection or absorption of infrared light to give either a high or a low output, respectively. Different combinations of three black and white surfaces can be used to represent a maximum of eight outcomes. These barcode configurations represent the corresponding seven levels. The first level is represented as the lowest logic of “0” and the seventh level is represented as the highest logic of “6”. For such a barcode system, the black surface represents logic low or 0, and the white surface represents logic high or 1. Experimentation was used to determine the optimal
distance for placing a surface to reflect the IR back to the photoreflector. It was determined that an optimal range for the reflection of the IR would be 4mm to 6mm.

Fig. 20.6 shows the circuit design used in the project. The three photoreflector circuits on the top left read the barcode on the rear of the overlay and produce a corresponding high or low output. The output from the three photoreflector circuits is the binary input of the circuit. This binary input is fed to a binary-to-decimal decoder, CMOS 4028. The CMOS outputs 5V through the pin that corresponds to the level matching the binary input to the CMOS. Each output pin on the CMOS is connected to a relay circuit through an NPN transistor. The pin with the high output forward bias corresponding to the transistor and current starts flowing through the coil of the relay. This closes the switch connecting the corresponding level to the common. The common is a high output of 5V from the microprocessor board on the actual 7-LCB. The level leads are inputs to the microprocessor in the 7-LCB. Closing the switch through the relay and connecting the level to the common lead signals the appropriate level to the microprocessor. An outside DC power supply was used initially to supply the voltage to the circuit. The amount of current being drained by the circuit was 90mA. Assuming that AA batteries have 1200mAh, the device has a total of approximately 13 hours of continuous operation time. The adapted 7-LCB will operate according to the original operating parameters of the device. The final project is shown in Fig. 20.5.

The total cost of parts and labor was $855.
INTRODUCTION
The Sensory Vest was designed to provide musical and tactile stimulation for a child with cerebral palsy and blindness. He is also nonverbal and therefore cannot effectively communicate his need for stimulation. The vest is a garment worn by the user, who is able to control the various stimuli. Currently, there are a variety of similar systems available for tactile stimulation. However, most of these devices are tabletop units that are not easily portable. The Sensory Vest is a battery-operated sensory stimulating system that can be worn by the user and is self-contained.

SUMMARY OF IMPACT
The Sensory Vest provides auditory and tactile stimulation. These stimuli can be altered by a caregiver in order to provide new stimuli for the client. The client expressed his satisfaction with the design with a big smile as he used the vest. He required only a brief amount of time to learn how to control the different types of stimulation.

TECHNICAL DESCRIPTION
The inside and outside layers of the vest are made of a durable lightweight denim. These layers encase up to one inch of easily compressible foam. Embedded in the foam are the circuit components, wiring, switches, and speakers. Three buckle closures are attached to the backside of the vest for easy donning and doffing as well as maintaining adjustability. Because the vest is intended for a young child, it measures only 16 inches wide by 17 inches tall. Lying flat, the thickness of the vest measures 1.5 inches. The arm hole circumference is 16 inches. The opening for the neck and head has a 25 inch circumference.

Raised rigid musical notes adorn each shoulder. The center of the chest holds a large circular foamy texture and is flanked on either side by two strips of Velcro. The Velcro strips allow for the interchanging of four different textures: bumpy, soft and fuzzy, beaded, and hanging pom-poms. An oversized pocket near the bottom of the vest is lined with thick fur. At any time, the client can access any of the different textures. The interchangeable patches can be changed by a supervisor.

To hear music the client presses the switch located under the raised rigid musical note on the right shoulder. A 15 to 30 second children’s melody plays after the button is pressed. The speakers for the sound element are located just above the music notes on each shoulder. If the switch is pressed a second time, while the first tune is playing the circuit will automatically switch to the next song on
its play list. A total of 12 songs will cycle through after each pressing of the switch.

The motor generating the vibration is housed in the chest region of the vest, directly beneath the soft foam circle. To activate this stimulator, the user must press the switch located at the bottom of the foam circle. The control circuit is designed to create pulsing vibrations for each press of the switch. Each pulse is around 2.5 seconds followed by 2.5 seconds of no vibration. This process repeats four times before stopping.

One circuit used in the design is a 12-tone melody generator circuit (shown in Fig. 20.8). The output of the circuit required an impedance of 8 ohms, which was satisfied by using two 16 ohm speakers wired in parallel. A potentiometer incorporated into the circuit regulates the current flow through the speakers to control the volume. Two AA batteries produce the voltage and current necessary for operation. Because of their long life and cost effectiveness rechargeable batteries were selected. Two rechargeable AA batteries, wired in series, provide 2.8 volts and have a current capacity of 1800 milliamp hours.

A second circuit was designed to create a sequence for the vibration. This circuit is composed of a bistable 555 timer, a 555 clock timer and a 4017 decade counter as well as other basic circuit elements. The output from the 4017 controls a relay that operates a small DC motor spinning an unbalanced weight. This circuit is controlled by a lever switch and nine-volt battery. The clock pulse drives the 4017 decade counter. Every other output of the decade counter is connected through a diode to a transistor-controlled relay. Once the relay is turned on, 2.8 volts is sent to the motor, producing vibration.

The total cost of parts and labor was $660.

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Fig. 20.8. Twelve-Tone Melody Generator Circuit.
CANDY SORTER

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INTRODUCTION

The Candy Sorter (Fig. 20.9) enables a user to sort individually wrapped pieces of candy by color. These pieces of candy are used to make wreaths, which are then sold. The client has limited fine motor skills with both hands, and uses an electric wheelchair. The Sorter assists the client in performing the sorting task, which allows him or her to earn an income.

This project is a redesign of a candy sorting system. The original design sorted gumballs of various colors into containers, under the supervision of the operator. The old design was unable to handle wrapped pieces of candy. The new Candy Sorter design is capable of sorting many different kinds of...
piece of candy from a bag of mixed candy. The mechanical design accomplishes this. Using this device creates employment opportunities for the client. The new design is simpler than the original device, with fewer moving parts. This was accomplished by eliminating the conveyor belt system and by the use of potential and kinetic energies to move the candy. However, the design is not fully automated and is not controlled by single-button operation due to the constraints placed on the project. The available funds and time were insufficient to fully achieve an optimal solution. In this respect, the design is a compromised solution. Despite this complication the client supervisor was satisfied with the final design.

TECHNICAL DESCRIPTION

The hopper is a rotating drum with a spiral fin inside of the drum, similar to a cement truck. Candy that is to be sorted is placed into the hopper. The hopper sits approximately 5° upward from back to front. It rotates and dispenses a controlled amount of candy, one to five pieces, onto a slide. Using a momentary contact switch, the motor (controlled by the client) rotates the hopper.

The candy comes down the slide, aligned against the right edge. The slide is angled from left to right, facing the device, at 22.5°. There is a 20° downward angle from back to front on the slide. Two rollers at the end of the slide rotate to dispense a single piece of candy into a holding area. The holding area is also angled downward at 20°. The rollers are manually operated to dispense the candy into a holding area. The sorting slide rotates to the corresponding color bin for each different colored piece. The sorting slide is rotated by a motor using a toggle switch until the correct position is reached. The gate opens to release the candy down the sorting slide and into the bin. The release of the gate is manually controlled and the gate is held closed by magnets.

The supporting structure was made completely of wood. The motor mounts were constructed from PVC Expanded Foam Board and assembled using various length deck screws, machine screws and nuts, and Liquid Nails adhesive.

The structure was then coated with Krylon Semi-Flat Latex Paint. Its overall dimensions are 30” length x 17” width x 34” height. The drum was constructed from Fiberglas. It is attached to the motor by bolts and the adapter is mounted to the motor. The drum is coated with shellac inside and outside. Its dimensions are 10” diameter, with a 10 ¾” depth. The slide pieces are made of PVC Expanded Foam Board. They were attached using PVC cement, Liquid Nails adhesive, and deck screws. Their dimensions are: 1) Slide: 9” width under drum, 12” length, 1 ¾” width opening at end of slide, 2) Holding Area: 5 ¼” length, 2 ½” width, 3) Gate: 2” width, 2” height, and 4) Selector Slide: 7 ¼” length, 3” diameter semi-circle at top, 2 ½” width opening at bottom. The rollers are 2 foam paint rollers, with a 1” diameter and 4” width.

A physics analysis of the slide system was performed to effectively design a gravity-fed system without having the candy stop sliding due to friction. At an angle of 20 degrees, the force of friction was overcome by the force of gravity exerted on the candy. This angle was then applied to all slide pieces to assure smooth motion of the candy through the system.

The device is powered by a 120V power source. The motor that rotates the drum had to be separately controlled through a DC to PWC. This was necessary to control the speed of the motor and allow for future adjustment. The current to the motor had to be reduced due to the power supply voltage being 13.77V. Using Ohm’s Law, V=IR, and power equations, P=VI, the output voltage of the PWC was modified to obtain the necessary speed and torque from the motor.

The total cost of parts and labor was $725.
INTRODUCTION
The Tactile Board is a sensory-stimulating apparatus that is used in a classroom setting. It includes sounds, textures, and lights. The client is an eight-year-old girl with autism. She loves music and enjoys textures; the presence of such stimuli engages the client and reduces incidents of destructive behavior. The client coordinator attempted to stimulate the client’s senses by gluing a piece of carpet and a string of beads to a desk in the classroom and playing music from time to time. The Tactile Board incorporates similar stimuli into a small board that can fit on a desk or tabletop, and is controlled by the client. By allowing the client to control the stimuli, cause and effect relationships are demonstrated.

SUMMARY OF IMPACT
The client coordinator was satisfied with the final design. The client was able to use each different part. Fig. 20.10 shows the client using the Tactile Board. She danced around to the music as it played and appeared fascinated by the other sensations the board created. By successfully engaging the client’s senses, the Tactile Board may help to improve her motor skills and understanding of cause and effect relationships. It may also reduce incidents of self-harm and destructive behavior.

TECHNICAL DESCRIPTION
There are six main stimuli areas on the board: 1) vibration area, 2) abacus, 3) noisy wheel, 4) lights, 5) texture slides, and 6) music. To use the vibrating area the client presses on the vibrating pillow and the pillow continues to vibrate until she releases it. The abacus acts as a touch and audio sense stimulating area. A client will be able to run her hand across the beads and knock them together, causing loud clicking noises. The noisy wheel is essentially an audio stimulating area. The lights portion of the board stimulates the visual sense. There are five LEDs inside of small domes arranged in a semi-circle. At the center of it is a switch that can be pressed to make the lights flash around the semi-circle until the switch is released. The texture slides stimulate the client’s touch sense when she runs her hands across them. The client coordinator was given seven extra slides that may be swapped on the board periodically.

The last part of the board is the sound area. There are four different switches from which the client can choose to play four different nursery rhymes. Each of the buttons play a song for approximately 20 seconds and a new song cannot be chosen until the present song is finished.

The body of the board is constructed from royal blue PVC foam. The bottom of the board is 1.5’ by 2’. The vibrator is comprised of the components from a pressure-touch massager from a retail store. The materials for the pillow and the vibrator are held in black fleece and cotton or wool stuffing. The abacus
is comprised of four rows of multicolored wooden balls on stainless steel rods. The noisy wheel is made up of a PVC pipe with small pieces of PVC foam glued randomly to the inside of the piping. Loose beads were placed inside this piping. The ends of the piping are sealed with two circular pieces of the same PVC foam used for the body of the board. The noisy wheel was spray-painted red. It spins on a rod of stainless steel. The light circuit comes from a chip, approximately \( \frac{3}{4} \)" in diameter. The small LEDs that came on the chip were removed and replaced with brighter LEDs with longer leads. This allows the LEDs to reach each of the light holes. The switches for the lights and for the sound are normally-open momentary switches. The texture slides are made of carpet, fleece, noisy paper, and other random textures affixed by glue or staples to a 4" by 5" slide. These slides are held in place with 4 mm screws and wing nuts. To remove the texture slides the user simply removes the wing nuts and takes the current slide off. A new slide is placed on the board and affixed with the four screws and wing nuts.

The sound circuit that is connected to the four switches in the sound area is a Sound Pro Board from Blue Point Engineering. The board runs on rechargeable batteries. The batteries must be charged after approximately five hours of use. The user may simply connect the battery pack hook-up that is sticking out of the board to the wall charger that was provided and allow the batteries to charge overnight. A diagram of the on and off switch and the terminal board are shown in Fig. 20.11.

The total cost of parts and labor was $990.

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**Fig. 20.11. Circuit Diagram of On/Off Switch and Terminal Board**
INTRODUCTION
The Sound and Light Dome uses sounds and lights to help calm agitated students. Researchers have shown that color and light modifications are correlated to diminishing aggressive behavior and decreasing blood pressure. In classroom settings, sometimes students display agitated behavior that cannot be controlled easily. In that case a “relaxation room” can help. The “relaxation room” is usually somewhat small, comfortable and dimly lit with blinking lights, and soothing music. With insight on how colors can affect mood, the client coordinator proposed designing a sound and light dome for use as a means of calming children with disabilities.

Only one similar product has been patented and commercially sold. However, this product only adapts to the recognition of the user’s voice pitch and can only be placed on the ceiling. The client supervisor requested a device that is wall mountable and that responds not only to pitch and volume of a student’s voice, but also to musical tone variance. The new design meets these criteria.

SUMMARY OF IMPACT
The client coordinator was pleased with the final product. The dome was mounted on the wall. A student was brought in to interact with the dome and observe the changing lights to the radio. The user sat quietly while watching (Fig. 20.12). Ideally, the device will facilitate calming of agitated students, which will help to improve the overall classroom environment.

TECHNICAL DESCRIPTION
Stereo input or the subject’s voice can trigger the light display. This device displays a certain color based on the frequency and volume of the input signal. The device operates on 120 VAC and houses a color organ that powers four LED bulbs. The color organ has four frequency channels (low, mid-low, mid-high, high) and a sensitivity channel to adjust the intensity of the sound input to the circuit. The dome is wall- mountable. It is constructed from a wooden box frame (23 x 23 x 5 inches) with a reflective dome (18 inches in diameter) that projects LED bulbs onto an outer acrylic plastic dome (20 inches in diameter) and is equipped with speaker jacks, intensity adjustment and microphone.

This product is operable by plugging the device into a wall socket and connecting speaker wire to the outer two speaker jacks. When the switch is activated (the white dot is pressed down) the device will emit lights. The lights illuminate when the user speaks into the microphone or when music is played. The microphone can only pick up a signal within 6 feet of the Sound/Light Dome. Most of the lights operate at around the same starting frequencies but have different ending frequencies.

In order to achieve optimal lighting onto the dome, a reflective base dome was added to reflect most of the LED light (Fig. 20.13). Most of the components in
the dome are easily replaceable; the LED bulbs can simply be replaced and the speaker jacks are attached on the outside of the product.

Since this product runs on wall voltage, certain safety precautions were taken. The circuit itself was placed in a grounding box with grommets used to secure all wires going into and out of the box. Also, all wires connecting the lights to the circuit were shrink-wrapped and covered as to not expose any wire that carries the wall voltage supply. Lastly, a lock has been placed on the device itself so only the teacher can operate and replace any parts inside the device as needed. This product has a long shelf life and will be reliable for up to 100,000 hours of operation if used properly.

The total cost of parts and labor was $770.

Fig. 20.13. LEDs and Reflector Dome.
ACCESSIBLE WHEELCHAIR TRAY

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INTRODUCTION
The Accessible Wheelchair Tray was designed to assist a client who is in a wheelchair. The client has spastic Cerebral Palsy (CP). Spastic CP is characterized by muscle stiffness and movement difficulty. Because of limited motor control, the client has difficulties looking at objects that are on a flat table; he needs his learning material at eye height. A tray was designed that can tilt up and down so that his teacher can adjust the angle steepness depending on what he is doing.

The client uses a switch-operated device to speak; it is sometimes knocked down by spastic movements. A place for that device was created on the tray surface so that the client, with the help of his teacher, can operate it efficiently. An attachment to hold papers is provided on the tray surface so that when the client draws or paints, the paper can stay in place while the teacher helps the user with his hand movement.

SUMMARY OF IMPACT
The client supervisor said that she liked the design ideas that were implemented, such as: the personalized painting, rounded edges for safety, padded arms, lightweight material, and the indentation in the tray for the switch. The client was able to start using the tray immediately (Fig. 20.14). The various features of the tray enable the client to work more independently.

TECHNICAL DESCRIPTION
Polyvinyl chloride (PVC) expanded foam was used as the main material in this design. PVC foam was chosen because of its various characteristics and applications. The characteristics include: 1) lightweight, 2) high strength, 3) ease of cleaning and 4) ease of fabrication. The support rods were made from aluminum alloy. The dimensions of the tray were based on the dimensions of the client’s wheelchair. The dimensions of the parts are as follows: 1) tray top is 16”x22”x1”; 2) tray arms are 8”x4”x1”; 3) side beams are 14”x2”x1/2”; 4) aluminum rods are 11.36”x1”; and 5) support beam is 1”x21”x1”.

Large clamps are used to affix the tray to the arms of the wheelchair (Fig. 20.15). Large thumb screws can be tightened to hold the support arms in place at the desired angle for the tray tilt. Hinges hold the main tray piece to the arm structures. A paper clamp is screwed into the main tray piece for holding paper. Various pins and screws hold the other pieces of the structure together. Padding covers the arms of the structure. The tray can be adjusted to accommodate different wheelchair widths. The tray was given a custom paint job.

The total cost of parts and labor was $630.

Fig. 20.14. Client Using the Accessible Wheelchair Tray.
Fig. 20.15. Clamps That Attach Tray to Wheelchair.
TOUCH SCREEN FOR COMPUTER AND INTERACTIVE DISPLAY

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INTRODUCTION

The users of a computer in an elementary school are primarily children with cerebral palsy, autism and conditions involving motor impairment. To interface with different learning programs, they use a TouchWindow® (Riverdeep Interactive Learning, Edmark Corporation) in place of a standard mouse. The TouchWindow® functions as a mouse, so that rather than moving the cursor to a desired position clients can touch the screen where they would like for the cursor to go.

The users would sometimes knock the window off the monitor. This prevented the children from using the equipment and also created risk of injury or potential damage to the computer in use. Due to these concerns, the client coordinator requested a new method of attaching the TouchWindow® to the monitor. The clients also have difficulty interacting with the original software that the TouchWindow® uses. The client coordinator requested new software for the children to learn with and enjoy while using the TouchWindow®.

Three solutions were created. First, a steel frame was fabricated and attached to a 17” monitor. The TouchWindow® sits in the frame while in use. An interactive program that helps the students learn colors, shapes and cartoons was written. Also, a wireless keyboard and mouse were purchased for each classroom to reduce the clutter around the computer station and facilitate efficient removal when the TouchWindow® is in use.

SUMMARY OF IMPACT

The client coordinator expressed satisfaction with the way in which the TouchWindow® was secured to the monitor. The interactive software program provides a tool that the students can use to learn and have fun. The software is easily navigated by the students and keeps their attention when the teacher is attempting to assist other students. The inclusion of a wireless keyboard and mouse simplified the area around the computer workstation. The client coordinator is able to remove the keyboard and mouse from the immediate workspace when a child is using the computer, but is still able to use them at a distance to help children complete tasks if they encounter difficulties.

TECHNICAL DESCRIPTION

The final project is shown in Fig. 20.16. The frame is constructed of steel because of its relative light weight, cost (free - donated from National Machinery Company), and ability to be welded. The dimensions of the TouchWindow® were used to design the dimensions of the frame. The frame is 12.75” tall, 14.75” wide, and 1.875” thick. The bottom portion is 1.875” tall, 14.75” wide, and 1.875” thick. It has a 0.787” x 9.45” rectangle cut out to ensure the buttons on the monitor are available for use when the frame is in place. The frame is coated...
with a black oxide to prevent corrosion, smooth the surface and improve its aesthetic appeal. Industrial strength Velcro was used to affix the steel frame to the computer monitor. Based on grip strength, the only individuals able to remove the structure are the teachers.

The software was written using the Visual Basic programming language and was programmed using Microsoft Visual Studio .Net 2003. The source code creates an executable file that may be run on the school’s computers (which use Windows XP Pro). To use the program, the student simply double-clicks on the icon from the computer’s desktop, and from there the child is able to navigate through the program learning about colors or shapes or playing with cartoons (Fig 20.17). The software is reliable in that the student can loop through the program as many times as he or she likes without the program having errors or malfunctions.

The total cost of parts and labor was $755.

![Fig. 20.17. Front Interface of Interactive Program.](image)
CHAPTER 21
INDEX

5
555, 72, 297
555 Timer, 72

A
Aerobic, 302
Alarm, 101, 171, 189, 304, 308
Amplifier, 15, 88, 89, 97, 167, 263, 289, 292, 295, 309, 342
Antenna, 167, 212, 214, 269, 285, 296, 297
Armrests, 65, 82, 123, 127, 128, 328, 329
Arthritis, 274
Audio, 72, 73, 76, 77, 81, 88, 97, 100, 101, 118, 212, 213, 256, 257, 263, 280, 286, 289, 311, 338
AutoCad, 355

B
Backpack, 76, 77
Battery, 35, 72, 73, 76, 81, 86, 92, 93, 110, 118, 121, 141, 165, 174, 212, 213, 214, 235, 242, 264, 271, 274, 284, 296, 304, 311, 346, 348
Bed, 54, 82, 90, 109, 134, 190, 198, 302, 312, 316, 317, 320
Bicycle, 128, 136, 156, 157, 180, 187, 303
Blind, 1, 9, 94, 106, 114, 348
Board, 1, 2, 10, 11, 17, 19, 21, 22, 24, 25, 37, 72, 73, 86, 89, 107, 138, 141, 145, 151, 189, 210, 213, 244, 259, 264, 266, 269, 271, 278, 280, 290, 292, 294, 296, 336, 337, 346, 348
Brace, 48, 49, 320, 340
Brain Injury, 306

C
CAD, 10, 11, 182, 186, 193, 195, 196, 226
Camera, 81, 290, 291
Cantilever, 44, 182
Car, 156, 166, 167, 176, 190, 212, 216, 217, 1342
Cart, 196
Cause and Effect, 60, 61, 64, 250, 292
Cause-Effect, 3
Cerebral Palsy, 31, 66, 80, 96, 208, 210, 222, 232, 234, 236, 284, 316, 324, 326
Chair, 42, 54, 68, 74, 75, 82, 110, 128, 134, 138, 152, 153, 154, 158, 162, 184, 192, 194, 196, 202, 206, 207, 210, 224, 234, 240, 241, 252, 253, 272, 278, 284, 317, 322, 342, 343, 344
Chassis, 4, 253
Child, 31, 64, 76, 77, 82, 83, 186, 190, 193, 216, 222, 224, 296, 304, 340, 346
Children, xi, 1, 44, 60, 61, 64, 76, 77, 82, 88, 96, 186, 190, 192, 220, 222, 256, 262, 264, 269, 280, 282, 286, 292, 296, 350
Clutch, 105, 110, 333
Communication, xi, 7, 11, 12, 13, 14, 16, 19, 20, 25, 32, 36, 39, 95, 120, 214, 264, 284, 298, 310, 350, 358
Communicator, 212
Comparator, 264
Converters, 97, 105, 343
Crawling, 304

D
Database, 3, 12, 220, 221
Deaf, 36
Decoder, 254, 266, 269, 276, 282, 296, 297, 336
Dental, 344
Desk, 114, 138, 210, 278, 279, 282
Diabetes, 198
Diabetic, 170
Diode, 264, 268, 336
Dispensers, 86, 170
Door Opener, 37
Driving, 42, 127, 180, 195, 196, 294, 328, 337

383
Chapter 21: Index

385

Radio Shack, 304
RAM, 74, 274, 348
Receiver, 1, 15, 105, 166, 213, 214, 254, 259, 268, 269, 282, 285, 290
Recreation, 36, 37, 39, 68, 350
Regulator, 76, 263, 284, 285, 294, 311, 337
Rehabilitation, viii, 2, 9, 10, 33, 34, 39, 50, 51, 53, 127, 182, 224, 226, 315, 329
Remote, 20, 105, 110, 123, 166, 167, 212, 213, 254, 258, 268, 270, 276, 284
Remote Control, 105, 110, 166, 167, 254, 258, 276, 284
RF, 258, 270, 284, 285, 290, 297
ROM, 7, 10, 20, 138, 158, 338, 342

Safety Factor, 264, 319
Scanner, 11
Screws, 68, 72, 352, 353
Sensor, 52, 92, 94, 95, 105, 109, 140, 141, 174, 175, 290, 343
Sensory Stimulation, 96, 240, 242, 256, 280, 296
Servo, 164, 165
Ski, 35
Social Interaction, 296
Speech, xi, 1, 7, 11, 12, 212, 213, 286, 288, 298, 338, 346
Springs, 158, 208, 247, 248, 319
Stabilizers, 244, 245
Standing, 44, 74, 110, 158, 192, 193, 224, 252, 270, 340
Steering, 82, 128, 136, 156, 157, 176, 196, 332, 333, 342
Sporination, 46
Support, xi, 1, 8, 9, 11, 12, 13, 14, 20, 27, 35, 36, 44, 68, 70, 72, 74, 82, 90, 109, 110, 112, 143, 146, 154, 168, 169, 182, 188, 190, 192, 193, 198, 203, 204, 206, 207, 208, 222, 224, 232, 233, 247, 284, 285, 286, 302, 312, 316, 317, 318, 320, 329, 332, 346
Swing, 64, 105, 238

T
Table, 110, 111, 138, 154, 198, 210, 222, 236, 246, 247, 248, 259, 278, 279, 298, 323, 326, 355
Telephone, 1, 12, 100, 101, 167, 257, 274, 338
Time Delay, 292
Timer, 72, 276, 361
Toilet, 194, 195
Toys, 61
Train, 99, 261, 270
Trainer, 98, 99
Transducer, 42, 174, 348
Transmission, 137, 212, 213, 258, 291
Transmitter, 72, 105, 212, 213, 214, 254, 259, 268, 269, 282, 285, 290, 296
Transportation, 82, 136, 180, 217
Tray, 64, 65, 70, 87, 112, 113, 188, 189, 222, 234, 235, 308, 309, 360, 361
Tricycle, 136, 137, 157

U
Ultrasonic, 342, 343, 348
Ultrasound, 348
Utensil, 210

V
Velcro, 66, 71, 130, 207, 208, 210, 221, 233, 235, 270, 271, 296, 303
Visual Impairment, 106, 114, 258
Voltage Regulator, 81, 105, 243, 263, 291, 296, 337

W
Walker, 202, 203, 204, 212, 214, 304
Wheel, 75, 82, 127, 128, 136, 156, 157, 162, 180, 184, 185, 192, 224, 234, 253, 328, 332, 342
Wheelchair Access, 132, 204, 312, 360
Wheelchair Lift, 134, 144, 344
Work Station, 354