NATIONAL SCIENCE FOUNDATION
1996
ENGINEERING SENIOR DESIGN PROJECTS TO AID PERSONS WITH DISABILITIES

Edited By

John D. Enderle

Brooke Hallowell

NATIONAL SCIENCE FOUNDATION 1996 ENGINEERING SENIOR DESIGN PROJECTS TO AID PERSONS WITH DISABILITIES

Edited By
John D. Enderle
Brooke Hallowell

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

PUBLICATION POLICY

Enderle, John Denis
National Science Foundation 1996 Engineering Senior Design Projects To Aid Persons With Disabilities / John D. Enderle, Brooke Hallowell
Includes index
ISBN 0-936386-77-0

P.O. Box 320
Mansfield Center, Connecticut 06250

Printed in the United States of America

CONTENTS

CONTRIBUTING AUTHORS

Richard Culver, Mechanical Engineering, The Watson School, SUNY Binghamton, Binghamton, NY 13902-6000

John Enderle, Electrical & Systems Engineering, University of Connecticut, Storrs, CT 06269

Marvin G. Fifield, Mechanical & Aerospace Engineering, Utah State University, Logan, Utah 84322-4130

Bertram N. Ezenwa, Department of Mechanical Engineering, School of Medicine, Department of Physical Medicine and Rehabilitation, Wayne State University 261 Mack Blvd Detroit MI 48201

Jerome A. Gilbert, Agricultural and Biological Engineering, Mississippi State University, Mississippi State, Mississippi 39762-5465

Daniel W. Haines, Dept. of Mechanical Engineering, Manhattan College, 4513 Manhattan College Parkway, Bronx, NY 10471

Brooke Hallowell, School of Hearing and Speech Sciences, Lindley Hall 208, Ohio University, Athens, OH 45701

Mohamed Samir Hefzy, Department of Mechanical Engineering, University Of Toledo, Toledo, Ohio, 43606

William Hyman, Bioengineering Program, Texas A&M University, College Station, TX 77843
Richard K. Irey, Department of Mechanical Engineering, University Of Toledo, Toledo, Ohio, 43606

Joseph C. Mollendorf, Mechanical and Aerospace Engineering, State University of New York at Buffalo, Buffalo, NY 14260

Chandler Phillips, Biomedical and Human Factors Engineering, Wright State University, Dayton, OH 45435

Jonathan W. Pote, Agricultural and Biological Engineering, Mississippi State University, Mississippi State, Mississippi 39762-5465

Frank Redd, Mechanical & Aerospace Engineering, Utah State University, Logan, Utah 84322-4130

Thomas Swiontek, Electrical Engineering & Computer Science, Milwaukee School of Engineering, 1025 North Broadway, Milwaukee, WI 53202-3109

Dick Wilkins, Mechanical Engineering, University of Delaware, Newark, DE 19716

Gary Yamaguchi, Chemical, Bio, & Materials Engineering, Arizona State University, Tempe, AZ 85287-6006

FOREWORD

Welcome to the eighth annual issue of the National Science Foundation Engineering Senior Design Projects to Aid Persons with Disabilities. Started 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 disabled individuals. Through the Bioengineering and Research to Aid the Disabled (BRAD) program of the Emerging Engineering Technologies Division of NSF[1], funds were awarded competitively to sixteen 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, reporting on the projects that were funded during the first year of this effort.

The BRAD program of the Emerging Engineering Technologies Division of NSF increased the number of universities funded to twenty-two in 1989. Following completion of the design projects funded under this initiative during the academic year 1989-90, a second book was published in 1990 describing these projects, entitled, *NSF 1990 Engineering Senior Design Projects to Aid the Disabled*.

In 1991, NDSU Press published a third issue of the *NSF 1991 Engineering Senior Design Projects to Aid the Disabled*. This book described the almost 150 projects carried out by students at twenty universities across the United States during the academic year 1990-91.

NDSU Press published the fourth issue of the *NSF 1992 Engineering Senior Design Projects to Aid the Disabled* in 1993. This book described the almost 150 projects carried out by students at twenty-one universities across the United States during the academic year 1991-92.

[1] In January of 1994, the Directorate for Engineering (ENG) was restructured. This program is now in the Division of Bioengineering and Environmental Systems, Biomedical Engineering & Research Aiding Persons with Disabilities Program.

NDSU Press published the fifth issue of the *NSF 1993 Engineering Senior Design Projects to Aid the Disabled* in 1994. This book described ninety-one projects carried out by students at twenty-one universities across the United States during the academic year 1992-93.

Creative Learning Press Inc. published the sixth issue of the *NSF 1994 Engineering Senior Design Projects to Aid the Disabled* in 1997. This book described ninety-four projects carried out by students at nineteen universities across the United States during the academic year 1993-94.

In 1998, Creative Learning Press Inc. published the seventh issue of the *NSF 1995 Engineering Senior Design Projects to Aid the Disabled* in 1998. This book described one hundred and twenty-four projects carried out by students at nineteen universities across the United States during the academic year 1994-95.

This manuscript, funded by the NSF, describes and documents the NSF supported senior design projects during the eighth year of this effort during the academic year 1995-96. As before, the purpose of this manuscript is to report on the engineering senior design projects developed and implemented through participating schools in this NSF program. Each chapter describes the activity at a single university and, except for the introduction, was written by the principal investigator(s) at that university, and revised by the editors of this publication. Individuals wishing more information on a particular design should contact the designated supervising principal investigator. Additionally, an index is provided so that projects may be easily identified by topic.

It is hoped that this manuscript will enhance the overall quality of future senior design projects directed toward persons with disabilities by providing examples of previous projects, and by motivating other universities to participate because of the potential benefits to the student, school, and community. Moreover, the new technologies used in these projects will provide examples in a broad range of applications for new engineers. The ultimate goal of both this publication and all the projects that were built under this initiative is to assist disabled individuals in reaching toward their maximum potential for enjoyable and productive lives.

It should be evident from reviewing this manuscript that this NSF program has brought together individuals with widely varied backgrounds. Through the richness of these interests, a wide variety of projects was completed, and are in use. A number of different technologies were incorporated in the design projects, to maximize the impact of the device on the individual.

For the most part, a two-page project description format is used in this text. Each project is described with a nontechnical description, followed by a summary of impact that illustrates the effect of the project on the disabled person's life. A detailed technical description then follows. Photographs of the devices and other important components are incorporated throughout the manuscript. Some of the projects are described with a much more extensive description covering many pages; these projects are typically the first or last project in the chapter.

It should be noted that none of the faculty received financial remuneration supervising the building of devices or writing software for the disabled in this program. Each participating university typically has made a five-year commitment to the program.

Sincere thanks are extended to Dr. Allen Zelman, a former Program Director of the NSF BRAD program, for being the prime mover behind this initiative. Additionally, thanks are extended to Drs. Peter G. Katona, Karen M. Mudry, Fred Bowman 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 wish to 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. We also wish to acknowledge and thank William Pruehsner for drawing the technical illustrations used throughout the book and Amy Martin for editorial assistance.

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 the disabled. The NSF and the editors make no representations or warranties of any kind with respect to these senior design projects, and specifically disclaim any liability for any incidental or consequential damages arising from the use of this publication. The projects presented here have been implemented in the eighth year of this initiative; they have a wide range of depth and usefulness. 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 Enderle moved from North Dakota State University to the University of Connecticut in 1995. With that move, the publication also moved from NDSU Press to Creative Learning Press Inc. in 1997. During 1994, Enderle also served as NSF Program Director for the Biomedical Engineering & Research Aiding Persons with Disabilities Program while on a leave-of-absence from NDSU.

New to this edition is co-editor, Dr. Brooke Hallowell, faculty member in the School of Hearing and Speech Science at Ohio University. Dr. Hallowell's background is in neurogenic communication disorders.

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/

John D. Enderle, Editor
Department of Electrical & Systems Engineering
260 Glenbrook Road, U-157
University of Connecticut
Storrs, Connecticut 06269-2157
Voice: (860) 486-5521
FAX: (860) 486-2447
E-mail: jenderle@bme.uconn.edu

Brooke Hallowell, Co-Editor
School of Hearing and Speech Sciences
Lindley Hall 208
Ohio University
Athens, OH 45701
Voice: (740) 593-1356
FAX: (740) 593-0287
E-mail: hallowel@oak.cats.ohiou.edu

February 1999

NATIONAL SCIENCE FOUNDATION
1996
ENGINEERING SENIOR DESIGN PROJECTS TO AID PERSONS WITH DISABILITIES

CHAPTER 1
INTRODUCTION

Devices and software to aid persons with disabilities often need custom modification, are prohibitively expensive, or nonexistent. Much of the disabled community does not have access to custom modification of available devices and other benefits of current technology. Moreover, when available, engineering and support salaries make the cost of any custom modifications beyond the reach of the disabled.

It has been reported that over 35 million people in the United States have disabling conditions. More than 9 million Americans have significant mental or physical conditions that prevent them from being able to carry out the major activity of their age group (that is, play, attend school, work, or maintain a household). These numbers are rapidly increasing due to advances in medicine that extend life expectancy. Today, the average American spends approximately 12 years of his or her life as a person with disabilities. Besides the enormous suffering experienced by the disabled community, disability imposes an enormous cost to the nation, totaling 6.5% of the gross national product (greater than $170 billion).

Aside from the economic cost to the United States due to disabilities, there is the vitally important consequence of the disability to the individual. Every American has either a disability or direct contact with a person with disabilities (that is, a family member or close friend). Disability ranks as America's greatest health problem in terms of the number of individuals affected and the economic impact.

In 1988, the National Science Foundation (NSF) provided a mechanism, through the Bioengineering and Research to Aid the Disabled program of the Emerging Engineering Technologies Division of NSF, whereby student engineers at universities throughout the United States designed and built devices for persons with disabilities. This NSF program has enhanced the educational opportunities for students and improved the quality of life for disabled individuals. Students and university faculty provided, through their normal Accreditation Board for Engineering and Technology (ABET) accredited senior design class, engineering time to design and build the device or software, and the NSF provided funds, competitively awarded to universities for supplies, equipment and fabrication costs for the design projects.

This book describes the NSF supported senior design projects during the eighth year of this effort during the academic year 1995-96. The introduction provides some background material on this book, elements of design, and illustrative engineering design experiences at two universities that participated in this effort.

After the introduction, twelve chapters follow, with each chapter devoted to one participating school. The chapters begin by completely identifying the school and the principal investigator(s). Following the chapter introduction for the school, each senior design project description is written using the following format. On page one, the individuals involved with the project are identified, including the student(s), the professor(s) who supervised the project, and the many professionals involved in the daily lives and education of the disabled individual. A brief nontechnical description of the project follows with a summary of the impact on how the project has improved the quality of life of the disabled person. A photograph of the device or the device modification is usually included. Following this, a technical description of the device or device modification is given, with parts specified only if they are of such a special nature that the project could not be fabricated without knowing the exact identity of the part. An approximate cost of the project is provided, excluding personnel costs.

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

The purpose of this publication is twofold. One obvious purpose 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 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 serves to motivate both students and graduate engineers and others to work more actively in rehabilitation, leading to an increased technology and knowledge base to effectively address the needs of persons with disabilities. In the past, students were typically involved in design projects that enabled students to improve the quality of their lives, for instance, by designing and constructing a stereo receiver. Under this NSF program, engineering students at participating universities are involved with designs that result in an original device or a custom modification of a device that improves the quality of life for a person with disabilities. The engineering design students are provided an opportunity for practical and creative problem solving to address a well-defined need, and the disabled person receives the product of that process. There is no financial cost incurred by disabled persons participating in this NSF program; upon completion, the finished project becomes the property of the individual for whom it was designed.

Under faculty supervision, students developed specific projects, through their senior design classes, to address the identified needs of particular disabled individuals. Local school districts and hospitals participated in the effort by referring interested individuals to the program. A single student or a team of students specifically designs each project for a disabled individual or a group of disabled individuals with a similar need.

The emphasis of the program is to:

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

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

Some projects built in years past include a laser-pointing device for people who cannot use their hands, a speech aid, a behavior modification device, a hands-free automatic answering and hang-up telephone system, and an infrared beacon to help a blind person move around a room. The students participating in this project have been singularly rewarded through their activity with the disabled, and justly have experienced a unique sense of purpose and pride in their accomplishment.

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 bring together concepts and principles that students learn in their field of study — it involves the integration and extension of material learned in their major toward a specific project. Most often, the student is exposed to system-wide analysis, critique and evaluation for the first time. Design is an iterative, decision making process in which the student optimally applies previously learned material to meet a stated objective.

There are two 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 neglects the interactions that take place between the components. The traditional approach usually involves a sequential, iterative approach to the system or problem, and emphasizes simple cause-effect relationship.

Another approach to engineering design adheres to treating the problem from a holistic viewpoint. This approach is much easier today with the availability of powerful computers and engineering software packages, and the use of systems theory that addresses interrelationships within the system. Rather than partitioning a project based on discipline-defined components, the holistic view partitions the project according to the emergent properties of the problem.

Design is not a course substitute for the deficiencies that exist in a department's curriculum. It is an approach to problem solving for 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

Project Selection

In a typical NSF design project for a person with disabilities, the student meets with the client (a disabled person and/or their client coordinator) to assess the needs of the disabled person and to help identify a useful project. Often, the student meets with many clients before finding a project of interest that suits his or her background.

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.

The team approach is similar to that of an individual student. One or more members of the 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 carries out many 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 to aid the disabled 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 manufactures and is available from:

http://www.abledata.com
or
(800) 227-0216

Specifications

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

Prior to the design of a project, a statement as to how the device will function is required based on operational specifications. These specifications determine the problem to be solved. The operational specifications completely describe and define the project. Specifications are defined such that any competent engineer is able to design a device that will perform a given function. 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. Specifications determine the device to be built, but do not provide any information about how the device is built. No manufacturer's name or components are stated in specifications. For example, specifications do not list electronic components or even a microprocessor since use of these components implies that a design choice has been made.

If the design project involves modifying an existing device, the device should be fully described in as much detail as possible in the specifications. In this case, it is desired to describe the device by discussing specific components, such as the microprocessor, LEDs, and electronic components. This level of detail in describing the existing device is appropriate because it defines the environment to which the design project must interface. However, the specifications for the modification should not provide any 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 the disabled person. It is also important to provide motivation for carrying out the project in the specifications. The following issues are also addressed in the specifications:

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

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

Electrical Parameters

interfaces
voltages
impedances
gains
power output
power input
ranges
current capabilities
harmonic distortion
stability
accuracy
precision
power consumption

Mechanical

size
weight
durability
accuracy
precision
vibration

Environmental

location
temperature range
moisture
dust

Paper Design and Analysis

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

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

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 analysis problems. Other situations require a potential design project solution be partially constructed or breadboarded for analysis and evaluation. After analysis of all possible solutions, the optimal design selected is the one that meets the specifications most closely.

Construction and Evaluation of the Device

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

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

After the project has undergone laboratory testing, it is then tested in the field with the client. After the field test, modifications are made to the project, and then the project is given to the disabled person. Ideally, the design project in use by the disabled person should be periodically evaluated for performance and usefulness after the project. Evaluation typically occurs, however, when the device no longer performs adequately for the disabled person, and is returned to the university for repair or modification. If the repair or modification is simple, a university technician will handle the problem. If the repair or modification is more extensive, another design student is assigned to the project to handle the problem as part of their design course requirements.

Documentation

Throughout the design process, the student is required to document the optimal or best solution to the problem through a series of required written assignments. For the final report, documenting the design project involves integrating each of the required reports into a single final document. While this should be a simple exercise, it is usually 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 also require the final report be professionally prepared using desktop publishing software. This requires that all circuit diagrams and mechanical drawings be professionally drawn. Illustrations are usually drawn with computer software, such as OrCAD or AutoCAD.

The two-page reports within this publication are not representative of the final reports submitted for design course credit, and in fact, are a summary of the final report. A typical final report for a design project is approximately 30 pages in length, and includes extensive analysis supporting the operation of the design project. Usually, photographs of the device are not included in the final report since mechanical and electrical diagrams are more useful to the engineer to document the device.

The next two sections illustrate two different approaches to the design course experience. 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.

Texas A&M University Engineering Design Experiences

The objective of the NSF program at Texas A&M University is to provide senior bioengineering students an experience in the design and development of rehabilitation devices and equipment to meet explicit client needs identified at several off campus rehabilitation and education facilities. Texas A&M has participated in the NSF program for five years. The students meet with therapists and/or special education teachers for problem definition under the supervision of the faculty. The type of design experience offered in this program provides very significant "real world" design experiences, emphasizing completion of a finished product. Moreover, the program brings needed technical expertise to the not-for-profit rehabilitation service providers that would otherwise not be available to them. Additional benefits to the participating students involve their development of an appreciation of the problems of disabled persons, 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.

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

The faculty at Texas A&M University involved with the rehabilitation design course have worked in collaboration with the local school districts, community rehabilitation centers, residential units of the Texas Department of Mental Health and Mental Retardation (MHMR), community outreach programs of Texas MHMR, and individual clients of the Texas Rehabilitation Commission and Texas Commission for the Blind.

Appropriate design projects are identified in group meetings between the staff of the collaborating agency, the faculty, and the participating undergraduate students enrolled in the design class. In addition, one student is employed in the design laboratory during the summer to provide logistical support, as well as pursue his or her own project. Each student is required to participate in the project definition session, which adds to the overall design experience. The meetings take place at the beginning of each semester, and periodically thereafter as projects are completed and new ones identified.

Faculty feel the needs expressed by the collaborating agencies often result in projects of varying complexity and corresponding time to completion. To meet the broad spectrum of needs, simpler projects are accommodated by requiring their rapid completion, at which point the students move on to another project. More difficult projects involve one or more semesters, or even a year's effort; these projects are the ones that typically require more substantial quantitative and related engineering analysis. Projects are carried out by individual students or a team of two.

Following the project definition, the students proceed through the formal design process of brainstorming, clarification of specifications, preliminary design, review with the collaborating agency, design execution and safety analysis, documentation, prerelease design review, and delivery and implementation in the field. The execution phase of the design includes identifying and purchasing necessary components and materials, arranging for any fabrication services that may be necessary, and obtaining photography for their project reports. Throughout each phase of the project, the faculty supervises the work, as well as the teaching assistants assigned to the rehabilitation engineering laboratory. These teaching assistants are paid with university funds. The students also have continued access to the agency staffs for clarification or revision of project definitions, and review of preliminary designs. The latter is an important aspect of meeting real needs with useful devices. In addition to individual and team progress, the rehabilitation engineering group meets as a group to discuss design ideas and project progress, and to plan further visits to the agencies.

One challenging aspect of having students responsible for projects that are eagerly anticipated by the intended recipient is the sometimes 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 the requirement that the project be revised and reworked until it meets approval by the faculty.

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

Feedback from participating students is gathered each semester using the Texas A&M University student oppinionaire form as well as personal discussion. The objective of the reviews has been to obtain the student's 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 Engineering Design Experience

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

During the early stages of NDSU's participation in projects to aid the disabled, a major effort was undertaken to develop a complete and workable interface between the NDSU electrical engineering department and the disabled community to identify possible projects to aid the disabled. These organizations are the Fargo Public School System, NDSU Student Services and the Anne Carlson School. Mechanisms are in place so that NDSU students visit disabled individuals 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 disabled 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 a disabled individual. Each report consists of an introduction to the project establishing the need for the project. The body of the report describes the device; a complete and detailed engineering analysis is included to establish that the device has the potential to work. Almost all of the NDSU projects involve an electronic circuit. Typically, devices that involve an electrical circuit are analyzed using PSpice, or another software analysis program. Extensive testing is undertaken on subsystem components using breadboard circuit layouts to ensure a reasonable degree of success before writing the report. Circuits are drawn for the report using OrCAD, a CAD program. The OrCAD drawings are also used in the second phase of design, which allows the students to bring a circuit from the schematic to a printed circuit board with relative ease.

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

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

Design facilities are provided in three separate laboratories for analysis, prototyping, testing, printed circuit board layout, fabrication, and redesign/development. The first laboratory is a room for team meetings during the initial stages of the design. Data books and other resources are available in this room.

There are also twelve workstations available for teams to test their design, and verify that the design parameters have been meet. These workstations consist of a power supply, waveform generator, oscilloscope, breadboard, and a collection of hand tools.

The second laboratory contains Intel computers for analysis, desktop publishing and microprocessor testing. The computers all have analysis, CAD and desktop publishing capabilities so that students may easily bring their design projects from the idea to implementation stage. Analysis software supported includes Microsoft EXCEL and Lotus 123 spreadsheets, PSpice, MATLAB, MATHCAD, and VisSim. Desktop publishing supported includes Microsoft Word for Windows, Aldus PageMaker, and technical illustration software via AutoCAD and OrCAD. A scanner with image enhancement software and a high-resolution printer are also available in the laboratory.

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

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

There were many projects constructed at NDSU (and probably at many other universities) that proved to be unusable (and sometimes unsafe) for the intended disabled individual, despite the best efforts of the student teams under the supervision of the faculty advisors. These projects are undocumented to protect the innocent and are best forgotten.

Other Engineering Design Experiences

Experiences at other universities participating in this NSF program combine many of the design program elements that are presented for Texas A&M University and North Dakota State University. In addition to the design process elements already described, 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, those projects worthy of a patent application are actually submitted. Thus far, a patent was issued for a "Four-Limb Exercising Attachment for Wheelchairs" and another patent has been allowed for a "Cervical Orthosis."

Each of these university programs are unique and offer their own way of implementing student designed and constructed projects to aid persons with disabilities. Other universities participating in this program have many of the elements of design described in this chapter, brought together in their own unique manner.

The senior design projects constructed by these students have proved beneficial to the student, the disabled individual, the community, and the university. The impact of these grants on the student is felt not only during the time of project construction and afterwards in the project's use by the disabled individual, but also in the involvement of these students into community-minded service.