# Capabilities

Communicating the Science of Prosthetics and Orthotics

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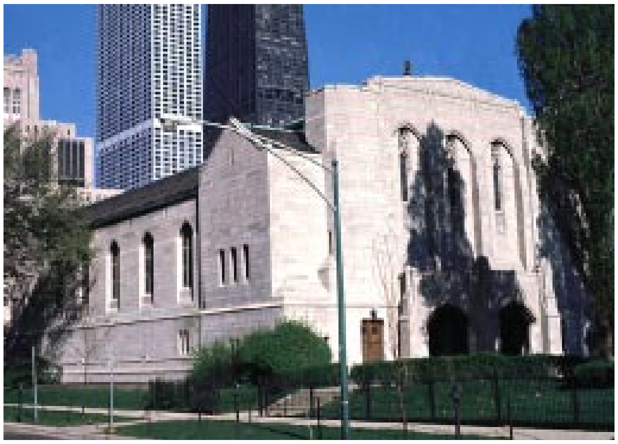

*The nation's research program in prosthetics and orthotics had its beginning 50 years ago in Thorne Hall on the Northwestern University Medical School campus in Chicago. The hall (left) was torn down in the 1980s. The Medical School campus is shown in the left foreground of the photo on the right. When the Thorne Hall meeting was held in 1945, the Palmolive Building was the tallest building in Chicago. Today, it is dwarfed by the towering John Hancock Building, to its immediate left in the photo above on the right.*

## From Craft to Science: 50 Years of Prosthetics/Orthotics Research started with a meeting at Northwestern University

"A three-day conference a half century ago in the charming Thorne Hall of Northwestern University failed to accomplish its primary purpose of advising General Norman Kirk, the Army Surgeon General, by agreeing upon the best artificial limbs available. Paradoxically, it led to a cooperative program of decades which made major improvements in all aspects of prosthetics in public and private practice here and abroad. Some came quickly, but others required decades of effort. Indeed some observers feel that the presently available improvements have barely begun the task of truly replacing human parts and functions and that some of the best early ideas have been partially neglected by later generations."

"These improvements included not only the mechanisms and materials debated so vigorously at the conference, but many other (often more important) areas: fitting and alignment for each individual patient, suspension, attachment with minimal harnessing or none, therapy and prescription and management by organized and well-trained clinic teams."

These observations were made by Eugene F. Murphy, Ph.D., who worked closely with one of the conference attendees, Dr. Henry H. Kessler. Dr. Murphy, a retired engineer, spent the major part of his career in various areas of prosthetic and orthotic research and development. Murphy describes the state of the art in prosthetics and orthotics as World War II was drawing to a close:

"Limb makers (often amputees themselves, or descendents of amputees, had entered the field literally by accident, guided by their own needs) have evolved into professional prosthetists with university level training and certification. Simple experimentation changed to vigorous research, development and evaluation programs not only in the United States, but worldwide. This research has included many topics not clearly recognized at the Thorne Hall Conference, such as biomechanics, energy consumption in gait, dermatology of the stump and techniques of amputation surgery..."

The meeting at Thorne Hall and the events that followed were also summarized in an article by A. Bennett Wilson, Jr. in *Artificial Limbs,* Volume 14, No. 2, Autumn 1970.

"Early in 1945, at the request of the Surgeon General of the Army, the National Research Council spon-

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## 50 Years of Progress (continued from page 1)

sored a conference of surgeons, engineers, physicists and prosthetists to consider the feasibility of effecting improvements in artificial limbs. Conclusions that emerged from the conference were that virtually no organized research of significance had been conducted in the field of limb prosthetics, and that application of technology already in existence should produce improved devices."

"Subsequently, at the request of the Surgeon General, the NRC established the Committee on Prosthetic Devices (later the Committee on Artificial Limbs) to organize a research program. The members of the Committee were: Paul E. Klopsteg, Ph.D., Chairman; Harold R. Conn, M.D.; Roy D. McClure, M.D.; Robert R. McMath, D.Sc.; Mieth Maeser; Paul B. Magnuson, M.D.; Edmond M. Wagner and Philip D. Wilson, M.D. Consultants: Robert S. Allen and Charles F. Kettering. Subcontracts were entered into with sixteen universities, industrial laboratories and foundations." Among the universities were Northwestern University and University of California, Berkeley, San Francisco and Los Angeles.

**Veterans Administration joins the effort**

Wilson's article relates that original funding for the research was provided by the Office of Scientific Research and Development. When that office was dissolved shortly after World War II, the Surgeon General of the Army assumed fiscal responsibility until 1947, when the Army and the Veterans Administration cooperatively funded the program, which was augmented by the establishment of laboratories by the Veterans Administration.

It soon became clear to the Committee that, in addition to development of components and application of new materials, more knowledge of the requirements of the people who used artificial limbs was necessary if significant progress was to be made. Studies of the biomechanics of human extremities were therefore initiated. To provide a basis for rational selection of a series of standard sizes of components, anthropometric data were collected and analyzed.

By the spring of 1947, the Committee felt that it had completed its task of establishing an organized program and recommended that contracts be made directly between the government and the research laboratories. The Committee retained a role as an advisory body, later to be known as the Committee on Prosthetics Research and Development. Although many individuals had experienced amputations as a result of industrial, agricultural and other civilian occupations, the Veterans Administration had assumed the responsibility for the care of service connected amputees, who had been discharged from the armed services. Therefore, the Veterans Administration became the government agency responsible for negotiating contracts with private and public laboratories in which promising developments were being made. Research also continued in the laboratories of the Army, Navy and Veterans Administration.

**Progress Began Immediately**

Developments moved quickly. By 1946, experimental suction-socket above knee prostheses were being fitted and tested. Research was initiated in the areas of socket configuration, fitting and alignment and both the fitting and harnessing of artifical arms were being studied. In 1948, Congress recognized the need for continuity in a program of this kind and passed P.L. 729, authorizing the expenditure of $1 million annually for research in limb prosthetics and sensory aids. The 85th Congress amended this law to remove the $1 million limitation.

Results of the research were that developments in the use of the suction socket provided significant advantages to the users of artificial lower limbs. Feeling that publishing the research findings was not a sufficient means of teaching prosthetists new methods of socket fitting, the National Research Council, in cooperation with the Orthopedic Appliance and Limb Manufacturers Association (now American Orthotic and Prosthetic Association) and a distinguished group of surgeons, organized a series of regional workshops to teach surgeons and prosthetists the proper application of the suction socket.

**The need for education became apparent**

The time required for thorough instruction in fabrication of prostheses made regional teaching sessions im-

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# NUPRL& RERP Staff Presented Research Reports at 8th Annual ISPO World Congress In Melbourne, Australia

Northwestern University Prosthetics Research Laboratory and Rehabilitation Engineering Research Program and the Rehabilitation Institute of Chicago staff shared their research with colleagues from around the world at the 8th World Congress of the International Society of Prosthetics and Orthotics in Melbourne, Australia, April 1-6, 1995. Dudley S. Childress, Ph.D., Director of the Department, Craig W. Heckathorne, Research Engineer and Laura Miller, doctoral student and Whitaker Foundation Fellow scholar, delivered a total of eight presentations. Jack Uellendahl, Director of Prosthetic and Orthotic Clinical Services, RIC, taught an Instructional Course on myoelectric control. Dr. Childress assisted him with the presentation. Dr. Childress also responded to an Expert Viewpoint on upper-limb prostheses.

Abstract of the papers delivered follow:

**The Role of the Non-dominant Hand in Manipulative Tasks (NIDRR)**

Historically, designers of prosthetic prehension devices have used studies of the dominant physiological hand as a basis of rationalizing the choice of prehension patterns to be incorporated in prostheses, in spite of the fact that observation indicates that a person with a unilateral arm amputation preferentially uses the physiological hand while the prostheses is used in a non-dominant assistive capacity. The Northwestern University RERP study focuses on how the non-dominant physiological hand is utilized.

Subjects without upper-limb amputations were videotaped performing a set of activities typically performed bi-manually in common, familiar tasks, such as eating breakfast. Activities studied included handling objects of different sizes and surface features, transfer of objects from place to place and from hand to hand, reaching outward from and inward to the body and repetitive motions utilized in common tasks.

Videotapes revealed that the number of prehension acts performed by the non-dominant hand was 80% of the number performed by the dominant hand. It was also observed that a grasp pattern similar to palmar prehension was used most often for both the non-dominant and dominant hands. Grasp patterns secondary to palmar prehension were observed to be task specific for the non-dominant hand.

Quantitative data stresses the importance of the grasp function in the use of the non-dominant hand. By extension, the results suggest that the grasp function is an important feature of a hand prosthesis in its non-dominant assistive role to an intact physiological hand. The empirically-based emphasis on palmar prehension in the design of hand-like prosthetic prehensors was confirmed. The study encourages incorporation of alternative prehension patterns to better accommodate a variety of common tasks. Research staff: C. W. Heckathorne, P. Toth and D. S.Childress.

**E.P.P. Control of an Electric Hand by Exteriorized Forearm Tendons (DVA RR&D)**

(Conducted in cooperation with the VA Lakeside Medical Center, Chicago and the Rehabilitation Institute of Chicago)

Use and control of a prototype electric-powered hand by a subject with trans-carpal amputation of the right hand has been studied for two years. The hand is controlled by linkage to forearm tendons exteriorized by Dr. Robert W, Beasley, New York University. These are akin to muscle tunnel cineplasties, but do not involve modification of the muscles themselves.

An Otto Bock System Electric Hand has been modified for the fitting to incorporate a cable-actuated electronic e.p.p. (extended physiological proprioception) controller which takes advantage of the inherent sensory apparatus of the tendons and muscles as well as that of the skin lining the tendons. The position and speed of the movement of the tendon (and the muscle) directly control the position and speed of movement of the fingers and thumb of the electric hand. The device has been adjusted to initially operate with 6 mm of tendon excursion and with an actuation force at the tendon of 225 to 500 grams-force.

Among research findings was the fact that the subject was able to develop fair to good control of the hand although he had not utilized the tendons for a number of years. Research staff: C. Heckathorne, D. Childress, E. C. Grahn, J. Strysik, J. Uellendahl.

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**Northwestern Staff at ISPO** (continued from page3)

**Clinical Experiences with the MICA Positive Locking Shoulder Joint (NIDRR)**

(Conducted in cooperation with the Rehabilitation Institute of Chicago)

In 1991, the authors began using the voluntary locking shoulder joint, newly developed by MICA Corporation. This joint differs from the traditional commercially available shoulder joint for shoulder disarticulation prostheses, which are friction based, in that the MICA joint can be free swinging or rigidly locked in flexion/extension (abduction/adduction is friction based). Positioning of the unlocked joint can be accomplished by allowing gravity to position the arm as the trunk is bent or extended. The user can also push or pull the prosthesis against an object. When the desired position is achieved, the user locks the joint with the contralateral hand or, in the case of a user with bilateral amputations, a nudge of the chin. The joint locks at 18$^{o}$ intervals and is limited to approximately 180$^{o}$ of flexion and 36$^{o}$ of extension to allow for cables crossing the joint.

Observations indicate that the ease with which the MICA shoulder joint can be positioned and locked, together with the increased range of positioning of the joint, improves utilization of the total prosthesis. Additionally, the rigidity of the locked shoulder joint allows the person

## In Memorium

*John Strysik shown in his laboratory circa 1990*

# John S. Strysik

For nearly 23 years, the very distinct personality and qualities of John Strysik had a major influence on the activities of the Northwestern University PRL&RERP and on all who knew him. John quietly shared his knowledge with co-workers, stimulating their ideas and adding his own to accomplish research projects that were marked by thoroughness and innovation.

An insatiable reader of publications ranging from the highly technical to the popular, John usually had a solution for that little missing piece needed to move a project forward. He contributed his skills to areas including upper and lower limb prostheses, the human mechanics measurement laboratory and advancement in use of materials and processes for orthoses and prostheses.

But perhaps the most direct impact that John made on the lives of people with disabilities was through his work in making it possible for people with no use of their hands and arms to control and drive power wheelchairs and operate environmental controls, telephones and electronic devices through switches controlled by sipping and puffing on a tube or by minimal movement of the tongue or facial muscles. John and his fellow staff members, encouraged by Dudley Childress, Ph.D., developed the systems that were later copied by dozens of commercial manufacturers. The results were that the question, "will the person with quadriplegia or severe effects of cerebral palsy be able to operate a wheelchair or perform work tasks" is no longer asked. The question is now, "which control and which supplier?".

John's "off-duty" personality contributed equal value to his family and friends. Both of John's children, Kevin and Deborah (Mrs. David Guidos), admired their father's profession to the extent that they both earned degrees in engineering. John's puckish sense of humor frequently led his friends to join in escapades such as riding a bicycle from Chicago to Toronto -- through a couple of torrential rainstorms -- taking over the entire floor of a discotheque or discovering that railroad tracks are not the same width as the wheels on a wheelchair.

John Strysik died on February 23, 1995, leaving family, friends, colleagues and others whose lives he touched with a deep loss. He also left behind a legacy that may never be publicly acclaimed. That legacy is not only the contributions he made in applying technology to assist people with disabilities, but a legacy of the knowledge, ethics and qualities he shared so freely with all who had the priviledge to know him.

to use the prosthesis more effectively as an extension of the body to transmit forces through the structure of the complete prosthesis. Research staff: C. Heckathorne, J. Uellendahl, S. Duff.

**Bilateral Shoulder Disarticulation: Self-care and Use of Complementary Hybrid Prostheses (Partially funded by NIDRR)**

(Produced in cooperation with the Rehabilitation Institute of Chicago )

This video presentation shows the level of independence that can be achieved by a motivated person using a combination of environmental adaptations and high-functioning prostheses. A variety of activities are shown, including bathing, dressing and other activities requiring manipulation with the prostheses including driving a van. Research staff: J. Uellendahl, C. Heckathorne, H. Krick, J. McCauley, J. Meredith and Y. Wu.

**Vertical Compliance in Prosthetic Feet: A Preliminary Investigation**

(Sponsored by the NIDRR and a Whitaker Foundation Graduate Fellowship in Biomedical Engineering)

Biomechanical analysis of prosthetic feet has been extensive since the development of Dynamic Elastic Response (DER) feet. However, vertical compliance feet (e.g. R-Flex VSP™ Foot) have not been studied. In addition to the fiber composite of plastic cantilever spring often associated with a DER foot, the vertical compliance foot has a spring-loaded telescoping pylon. Gait parameters of two trans-tibial amputees, using the DER feet was studied during walking, jogging in place and curb descent. Ground reaction forces, vertical trunk movement, event timing and pylon compression were observed. The pylon compression was immobilized for half the trials to isolate its effect.

Few differences were found in walking between vertical compression and immobilization of vertical compression. Vertical compliance caused the most differences during fast walking and jogging. Increased cadences, higher forces and greater vertical motion of the trunk were observed when jogging. Overall, few significant differences in the measured values were observed; nevertheless, the subjects preferred the feet with the vertical compliance mechanisms. Further studies will seek to determine the effectiveness of added compliance for trans-femoral amputee systems and the optimal values for both trans-femoral and trans-tibial components. Research staff: L. Miller, D. S. Childress.

**Quantitative Assessment of Direct Muscle Attachment as a Control Input for Externally Powered Prostheses (DVA RR&D)**

The objective of this research was to quantitatively compare the control achieved by direct muscle attachment with other prosthesis control methods and with the control of the intact physiological elbow. Direct muscle attachment could be achieved with miniature tunnel cineplasties, or other surgical procedures, such as the tendon exteriorization cineplasty developed by Dr. R. W. Beasley, which externalize the force and excursion of the muscle. The muscle would be connected to the prosthetic component through a controller that embodies Dr. D.C. Simpson's concept of extended physiological proprioception (e.p.p.).

Results show that the dynamic performance of the muscle tunnel is statistically similar to that of the conventional control harness. Tracking performance with the intact contralateral elbow was superior to both the tunnel cineplasty and the conventional harness. Work done at Northwestern University PRL in 1984 by James Doubler showed the superiority of position control over velocity control in pursuit tracking tasks. This indicates control by tunnel cineplasty should be superior to velocity-control techniques. In addition, tunnel cineplasties, in conjunction with e.p.p. controllers, offer a number of advantages over control using conventional harness arrangements. They may: (1) provide both force and excursion amplification while retaining a physiologically-appropriate proprioceptive sense of position, velocity and force; (2) eliminate the need for proximal harnessing; (3) provide an additional control source to supplement existing control sources; (4) make possible the direct control of multiple digits. Research staff: D. S. Childress, R. F.ff. Weir.

**An Investigation of 4-Bar Linkage Knees as an Aid to Floor Clearance During Swing (NIDRR)**

The polycentric nature of 4-bar linkage knees accounts for several potentially useful characteristics of these knees: stance-phase security, stance-phase control and knee-flexion cosmesis. Another characteristic is that the 4-bar linkage knees allow greater foot clearance than single-axis knees for given knee flexion angle. This clearance may allow the amputee to walk with less concern for floor contact during prosthesis swing.

NURERC has developed a computer model of an above knee prosthetic limb that allows evaluation of the

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**50 Years of Progress** (cont'd from page 2)

practical, so a pilot school was conducted in 1952 at UCLA for teams from the Chicago area. The course emphasized a team approach, with prosthetists attending for six weeks. They were joined by occupational and physical therapists for the last two weeks and by physicians and surgeons for the last week. From 1953 to 1955, 12 courses were conducted at UCLA for practitioners representing 30 states and the District of Columbia. The success of these courses proved to be so valuable that the VA sponsored the establishment of a similar education program at New York University in 1956 and, in 1959, the Vocational Rehabilitation Administration funded an additional prosthetics school at Northwestern University.

By 1954, it had become apparent that there was a great need for similar programs which addressed the non-veteran population. In 1953, the Advisory Committee on Artificial Limbs had recognized that child amputees had special problems and had begun to work with the Michigan Crippled Children Commission. A milestone in expanding prosthetic research and development was the enactment of the Vocational Rehabilitation Act by Congress in 1954, which authorized the Office of Vocational Rehabilitation to support research and education in rehabilitation. Today, research in prosthetics and orthotics is supported by a range of government entities including the Department of Veterans Affairs, the National Institute on Disability and Rehabilitation Research housed in the Department of Education, and various institutes in the National Institutes of Health.

Equally as important in successfully delivering advances in prosthetics to the people who would benefit was the involvement of the commercial companies which manufactured and distributed prostheses. By involving the manufacturers in the design and development stage, the pioneers in prosthetics research and development assured that innovations could and would be quickly incorporated in commercially available prostheses. This collaboration has led to competitive development by manufacturers that benefits the user of prostheses not only through more rapid incorporation of new designs, but competitive costs for prostheses.

The progress in design and development of prostheses and orthoses was not confined to the United States. As Dr. Murphy so aptly points out in his writings, attempting to list all the men and women who contributed so significantly to the development of orthotics and prosthetics would be an impossible task as would be an attempt in recording of each milestone. The leaders in the U.S. efforts were also very active in collaboration with scientists in other countries, which resulted in the founding of the International Society of Prosthetics and Orthotics. This organization has resulted in the ability to accelerate research and development by sharing the financial and personnel resources of many nations.

**Bringing the Results to the People**

But perhaps more important than the events and the people who influenced the advancement in design, fabrication and materials used in prostheses is the role the prosthetics and orthotics profession has played in the lives of people who use these devices. Cosmesis — or the attractiveness and appearance matching natural limbs — has been a factor of equal importance to function in the development of new prostheses. Emulation of natural limb function is constantly being improved through intense study of human gait and upper body functions.

**Team efforts bring new attitudes toward amputation**

Prosthetists and orthotists have worked side by side with people who have experienced amputations to help them continue in their preferred style of life. In the past 50 years, the attitude of the public toward people with amputations has gone from one of pity or horror to one of admiration or, better yet, acceptance of the use of prostheses as "no big deal". A *Wall Street Journal* article this spring compared the endorsement of specific prosthetic feet by runners to be akin to National Basketball Association players endorsing athletic shoes. Perhaps the emphasis in the article on product endorsement, rather than disability or bravery -- such as would have been the focus in the past -- is a subtle, but powerful tribute to the progress in prosthetics and orthotics of the last 50 years.

*Our sincere thanks to the support and input to this article from A. Bennett Wilson, Jr., who was involved from 1949 in many capacities with CPRD and served as Executive Director of CPRD, 1961-1975, and Eugene F. Murphy, Ph.D., who, for many years, served the Veterans Administration in prosthetic and orthotic efforts.*

**Readers who wish to know more about the history of research in prosthetics and orthotics may wish to see,**

***Artificial Limbs, Vol. 14, No. 2, pp.1-18 Autumn 1970***
***"The Prosthetics and Orthotics Program"***
***by A. Bennett Wilson, Jr.***

***A copy of Dr. Murphy's paper may be obtained by contacting Northwestern University PRL&RERP***

### Northwestern Staff at ISPO (continued from page 5)

swing phase characteristics of 4-bar linkage knees. Data pertaining to the ability of commercially available 4-bar knees to shorten the leg have been compared to the same capabilities of a single axis knee.

Results show that some 4-bar linkage knees can increase floor clearance by 2-4 cm at a knee flexion angle of $50^o$. Some knees were found to have as much floor clearance at $30^o$ of knee flexion as the single-axis knee has at $50^o$. Knees with 4-bar linkages may be helpful for above-knee and hip-disarticulation amputees who have trouble with floor clearance. Research staff: D. S. Childress, S. Gard, J. Uellendahl.

### Do Shoes Influence the Forefoot Mechanics of Prosthetic Feet? (NIDRR)

New prosthetic feet, labeled “Energy Storing” or “Dynamic Elastic Response (DER) Feet”, which store and release energy, have been designed in the last decade. These feet have generally been well received by lower limb amputees and have significantly different mechanical characteristics from the conventional SACH feet. This study investigated whether the mechanical characteristics of DER feet are modified or affected by shoes worn over them.

Mechanical characterization studies were performed on three prosthetic feet, with and without five different shoe types. These measurements included: force applied to the foot, the center of pressure and the foot deflection and were taken during static and dynamic loading tests using a specially designed foot loading apparatus. Additional data calculated from the tests included stiffness, damping and energy return efficiencies. Results of data analysis appear to suggest that shoes generally make the foot/shoe combination stiffer than the foot alone. Center of pressure vs. force results show that shoes cause a posterior shift in the center or pressure, which research suggests is primarily responsible for the apparent increased stiffness. Dynamic testing indicated that shoes increase damping and increase energy loss.

The general conclusion was that shoes do not seem to change the mechanical characteristics of the foot/shoe combination very much. Alignment alterations caused by shoes can be remedied by foot/shoe realignment. The interpretation of these test results appear somewhat different from the conclusions of van Jaarsveld, et al. (Int. J.P.&O, 1990, 14:117). Differences may be attributable to experimental design. Research staff: D. S. Childress, A. Sandifer, E. Knox.

# *Bits ‘n’ Pieces*

Many interesting things happen at NUPRL&RERP that we’d like to share -- so here’s a column about those things.

WELCOME BACK! **Margaret Pfrommer** is once again back as a research associate and Consumer Advocate at NUPRL&RERP. Margaret was slowed down -- but not stopped -- by an illness in March 1994. Typical of Margaret, she overcame all the obstacles and returned to the labs the first week in April.

It seems that each week, **NARIC** (National Rehabilitation Information Center) adds more references to the **ABLEDATA** selections. In addition to the database with information on more than 20,000 products for people with disabilities, NARIC has REHABDATA, abstracts of disability-related articles from lay and professional publications, the Knowledge Base™ of disability-related services and organizations nationwide, a directory of NIDRR funded research projects and much more. You can tap into NARIC resources by: Calling 1/800/346-2742 (voice/TT) and talking to an information specialist, access the computer bulletin board by calling 301/589-3563 via modem or writing to NARIC, 8455 Colesville Road, Suite 935, Silver Spring, MD 20910-3319. Or -- you can buy a CD for your computer CD ROM or use the Internet to access naric@cap.gwu.edu.

Saturday, May 6, 1995 the **Consumer Advisory Panel** and **Technical Advisory Panel** for the NUPRL&RERP will join us in Chicago to review the projects that are being conducted at Northwestern University. These two panels give the research and administrative staff of the Program invaluable insight into how various research projects apply to the areas each member represents. They also will offer new or slightly changed directions for research projects where applicable.

The theme of this year’s Advisory Panel Meetings is Information: Where is it found? How do we reach the people who need it? Who’s doing research that complements that of the NUPRL&RERP? A full report of the meeting and more information about our panel members will appear in the next issue of *Capabilities.*

***What would you like to see in Capabilities?***

***Send us your ideas and suggestions!***

## NIDRR State Assistive Technology Programs Can Help You Find What You Need

Each of the 50 states and each U.S. protectorate (Guam, for example) now has a program designed to provide technology-related assistance for individuals with disabilities. The Technology Assistance Programs, funded by the National Institute on Disability and Rehabilitation Research (NIDRR), offer varying programs that include locating types of technology appropriate for your needs, helping you evaluate the technology and assisting in finding funding.

To locate the Technology Assistance Program for your state, contact: RESNA Assistance Project, Suite 1540, 1700 N. Moore St., Arlington, VA 22209-1903. 703/524-6686, FAX: 703/524-6630, TTY: 703/524-6639.

### Resource Unit Information Request

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Prosthetics Research Laboratory and Rehabilitation Engineering Research Program
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Chicago, Illinois 60611-4496
Phone Help Line: 312/908-6524
**E-Mail: reiu@nwu.edu**
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