FALL 2008 SPECIAL ISSUE

Assistive Technology

Outcomes and Benefits

A joint publication of the Assistive Technology Industry Association (ATIA) and the Special Education Assistive Technology (SEAT) Center

Delivering on the 'D' in R&D: Recommendations for Increasing Transfer Outcomes from Development Projects

Joseph P. Lane

Special Issue Editor:
Howard P. Parette

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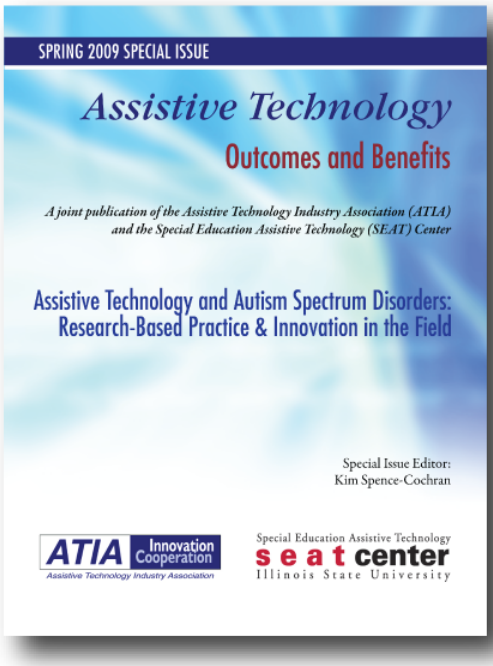

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Fall 2008 Special Issue

Author: Joseph P. Lane
Center for Assistive Technology
University of Buffalo

Special Issue Editor: Howard P. Parette
Special Education Assistive Technology Center
Illinois State University

Production Manager: Brian W. Wojcik

Assistive Technology Outcomes and Benefits (ATOB) is a collaborative peer-reviewed publication of the Assistive Technology Industry Association (ATIA) and the Special Education Assistive Technology (SEAT) Center at Illinois State University. *Delivering on the 'D' in R&D: Recommendations for Increasing Transfer Outcomes from Development Projects* is a special issue publication of ATOB, and is one of a series of topical publications on assistive technology issues.

Editing policies of this special issue are based on the *Publication Manual of the American Psychological Association* (5th ed.). The content presented herein does not reflect the position or policy of ATIA or the SEAT Center and no official endorsement should be inferred.

Assistive Technology Outcomes and Benefits

Editorial Policy

Assistive Technology Outcomes and Benefits is a peer-reviewed, cross-disability, transdisciplinary journal that publishes articles related to the *benefits* and *outcomes* of assistive technology (AT) across the lifespan. The journal's purposes are to (a) foster communication among vendors, AT Specialists, AT Consultants and other professionals that work in the field of AT, family members, and consumers with disabilities; (b) facilitate dialogue regarding effective AT practices; and (c) help practitioners, consumers, and family members advocate for effective AT practices.

Assistive Technology Outcomes and Benefits (ATOB) invites submission of manuscripts adhering to the format of the *Publication Manual of the American Psychological Association* (5th ed.) and which address a broad range of topics related to *outcomes and benefits* of AT devices and services. Manuscripts may include (a) findings of original scientific research, including group studies and single subject designs; (b) marketing research conducted relevant to specific devices having broad interest across disciplines and disabilities; (c) technical notes regarding AT product development findings; (d) qualitative studies, such as focus group and structured interview findings with consumers and their families regarding AT service delivery and associated outcomes and benefits; and (e) project/program descriptions in which AT outcomes and benefits have been documented.

ATOB will include a broad spectrum of papers on topics specifically dealing with AT outcomes and benefits issues, in (but NOT limited to) the following areas:

- Early Childhood and School-Age Populations
- Research and Product Development
- Outcomes Research
- Transitions
- Employment
- Innovative Program Descriptions
- Government Policy

Regardless of primary focus of any submission, primary consideration will be given by the journal to manuscripts presenting quantifiable results.

Types of articles that are appropriate include:

Applied/Clinical Research. This category includes original work presented with careful attention to experimental design, objective data analysis, and reference to the literature.

Case Studies. This category includes studies that involve only one or a few subjects or an informal protocol. Publication is justified if the results are potentially significant and have broad appeal to a cross-disciplinary audience.

Design. This category includes descriptions of conceptual or physical design of new AT models, techniques, or devices.

Marketing Research. This category includes industry-based research related to specific AT devices and/or services.

Project/Program Description. This category includes descriptions of grant projects, private foundation activities, institutes, and centers having specific goals, objectives, and outcomes related to AT outcomes and benefits.

In all categories, authors MUST include a section titled Outcomes and Benefits containing a discussion related to outcomes and benefits of the AT devices/services addressed in the article.

For specific manuscript preparation guidelines, contributors should refer to the Guidelines for Authors at http://atia.org/

Delivering on the 'D' in R&D: Recommendations for Increasing Transfer Outcomes from Development Projects

Joseph P. Lane
Center for Assistive Technology, University at Buffalo

Special Issue Editor: Howard P. Parette

Key Words: Rehabilitation Act of 1973, RERC, Case studies, Development, Transfer, Prototype, Technology, Product, R&D, Output, Outcomes

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Introduction to the Special Issue

Howard P. Parette
Illinois State University

Caroline Van Howe
Assistive Technology Industry Association

Since the 2004 launch of *Assistive Technology Outcomes and Benefits* (ATOB)—a scholarly collaboration between the Assistive Technology Industry Association (ATIA) and Special Education Assistive Technology (SEAT) Center at Illinois State University--the journal has grown in visibility and established itself as a premier multidisciplinary publication. Providing discussions of important assistive technology (AT) research findings and related issues impacting numerous disciplines, we feel strongly that ATOB continues to be a strong voice for both the AT industry and professionals and consumers in the field. To date, this publication has been provided in an on-line format at no cost to readers (see http://atobjournal.org), though hardcopy issues are also available on demand (see http://stores.lulu.com/atob). Evidence of interest in and the perceived value of the journal is reflected in approximately 3,000 downloads monthly from our present Web site.

Accompanying the annual ATOB peer-reviewed publication, we have decided to develop a series of Special Issues focusing on targeted topics having broad appeal. These Special Issues are in direct response to requests from researchers, AT manufacturers and service providers, practitioners, and ATOB readers. One Special Issue currently under development addresses AT and Autism, and is anticipated to be released early in 2009. Another publication under development will present a series of research and development (R&D) case studies.

This monograph, *Delivering on the D in R&D: Recommendations for Increasing Transfer Outcomes from Development Projects*, is the *first* in our Special Issue series. It was prepared by Joseph P. Lane of the Center for Assistive Technology at the University at Buffalo, and presents findings of a retrospective case study of 78 proposed development projects with expressed intent to transfer, as conducted in 11 Rehabilitation Engineering Research Centers (RERCs). Specifically, this report addressed three research questions: (a) Which factors critically facilitate or inhibit the technology transfer process within and across the cases of development and transfer examined? (b) Which facilitating factors appear to be innovative, particularly for addressing the constraints inherent in the AT marketplace? And (c) How can RERCs in particular, and the AT industry in general, adopt these innovative factors to improve the technology transfer process?

Interestingly, Lane found evidence of progress to a transfer outcome in only 19 (25%) of the 78 proposed projects. Two specific characteristics were observed among successful projects that included (a) a *comprehensive plan*, and (b) *planning and coordination*. The report provides a detailed examination of these two characteristics with

supporting examples from specific projects. However, the report also provides a thoughtful discussion of reasons why 59 projects that *did not yield transfer outcomes*. Lane explores in depth each of these core problems that include: (a) project management/staff allocation issues; (b) inability to attract a transfer partner; (c) loss of original transfer partner; and (d) technical issues.

Of particular interest to readers may be the optimism reflected by Lane who notes that these issues are "amenable to the models, methods, and metrics of new product development, which are considered to be standard practice in industry yet not widely applied by people trained as academic researchers." Lane extends recommendations to research and development (R&D) grantees, as well as the National Institute on Disability and Rehabilitation Research (NIDRR) and other funding agencies for R&D projects. Finally, the report culminates in a conservative observation that *greater rigor and relevance* in R&D projects may be required in the future. This is accompanied by a thoughtful analysis of challenges to such changes.

Implications of the recommendations for manufacturers of AT products are numerous. Lane includes an excellent overview of the very different driving forces in the parallel worlds of R&D: the researcher and the developer. He notes that this seeming dichotomy is reflected in the general R&D world–quoting both Alfred E. Mann and Larry Page (Co-Founder of Google)–and is especially highlighted in the current landscape of the AT industry with its provision for government-funded R&D. Lane recommends researchers to adopt standard commercial practices and techniques from the Product Development Management Association (PDMA) and "due diligence" as practiced in corporate mergers and acquisitions. In a similar vein, Lane advises corporate developers to partner with academic researchers to gain the rigor of scientific research techniques.

Lane includes specific references to closer links to AT manufacturers and service providers in his recommendations to NIDRR and other funding agencies. He points out that, "The RERC eligibility criteria have been expanded to include applications from for-profit corporations." (p. 87)

We hope that this Special Issue provides direction to manufacturers and R&D projects, and that it provides a stimulus for discussion leading to improvements in current practices that ultimately impact the lives of persons with disabilities. Comments regarding the content may be directed to Joseph P. Lane at the RERC on Technology Transfer, Center for Assistive Technology, University at Buffalo, 612 Kimball Tower, Buffalo, NY 14214 (email: joelane@buffalo.edu)

Delivering on the D in R&D: Recommendations for Increasing Transfer Outcomes from Development Projects

Joseph P. Lane
Center for Assistive Technology, University at Buffalo

Abstract

The Rehabilitation Engineering Research Center (RERC) Program is charged with generating both research knowledge and development products to improve quality of life for people with disabilities. A retrospective case study of 78 recent development projects from 13 RERCs sought evidence of progress from conception through internal prototype completion and out to uptake and use by an external transfer partner. The results showed evidence of progress to a transfer outcome in 25% of the proposed projects. The lack of progress in the majority of cases is attributed to deficiencies in problem selection and operational issues. These issues appear amenable to the models, methods, and metrics of new product development, which are considered to be standard practice in industry yet not widely applied by people trained as academic researchers. Findings suggest that successful development projects require a level of rigor and relevance in development projects equal to that applied to research projects. That may only be possible if the academic recognition and reward system establishes parity between research and development activities.

The Role of Academic R&D in Development and Transfer of New Products

The Rehabilitation Act of 1973 (as amended in the Rehabilitation Act Amendments of 1998; hereafter referred to as the Rehab Act) was originally established to "to empower individuals with disabilities to maximize employment, economic self-sufficiency, independence, and inclusion and integration into society" (§2(b)(1); U.S. Department of Education [USDE], 2004). The Office of Special Education and Rehabilitative Services (OSERS) in the USDE was charged with accomplishing this unique national mission. The 1978 amendments created what is now known as the National Institute on Disability and Rehabilitation Research (NIDRR).

The Rehab Act mandated scholarly research related to its mission. The generation of new knowledge through scholarly research is the primary domain of higher education. Professionals gain expertise through doctoral programs where they are trained in well-established research methodologies to ensure rigor in the process, and are immersed in the scholarly literature to ensure relevance in the topic areas. Federal agencies expect research funding to generate new knowledge, which is readily captured and disseminated through traditional venues of academic conferences and publishing in professional journals.

The Rehab Act mandated scholarly research related to its mission. The generation of new knowledge through scholarly research is the primary domain of higher education.

What distinguished the Rehab Act from traditional research endeavors was a parallel

mandate to conduct device development and transfer activities that would generate new products. The development and transfer activity was supposed to deliver to the commercial marketplace, new and improved devices and services for people with disabilities. The Rehab Act Research and Training objectives included:

> 3) promote the transfer of rehabilitation technology to individuals with disabilities through research and demonstration projects relating to--
>
> > (A) the procurement process for the purchase of rehabilitation technology;
> >
> > (B) the utilization of rehabilitation technology on a national basis;
> >
> > (C) specific adaptations or customizations of products to enable individuals with disabilities to live more independently; and
> >
> > (D) the development or transfer of assistive technology. [§200(3)(A)-(D)]

Unlike research, new product development is not the primary domain of universities. Instead, it is the primary domain of private sector corporations.

Subsequent amendments designated the NIDRR as the lead entity for sponsoring research and development activities, and defined Rehabilitation Engineering Research Centers (RERCs) as the program vehicle for conducting these activities. Amendments encouraged RERCs to promote the transfer of technology applications generated through their development projects, from the academic laboratory to the commercial marketplace.

NIDRR's Long-Range Plan (National Center for Dissemination of Disability Research, 1996-2008) described the necessary interplay between academic research and development (R&D) and private sector entrepreneurship:

> NIDRR-funded Rehabilitation Engineering Research Centers (RERCs) consider potential industry partners in selecting research projects that will result in marketable products…[NIDRRs] emphasis on applied research challenges researchers to find effective ways of ensuring technology transfer—transfer of ideas, designs, prototypes, or products—from the basic to the applied research environment, to the market, and to other research endeavors.

Unlike research, new product development is not the primary domain of universities. Instead, it is the primary domain of private sector corporations. The ability to progress from idea through prototype to product is a persistent challenge, even for companies. The private sector has its own practices for ensuring rigor and relevance because a company's existence depends on its ability to deliver results that are successful in the marketplace. In view of these public/private distinctions regarding research and development, it is important to study and understand the role and contributions of federal government funding within the product development and transfer process. Thus, three key questions emerge:

1. To what extent can the federal government support product

development and transfer in higher education without compromising the forces of free market enterprise? (Branscomb & Keller, 1998).
2. To what extent do university-based programs apply private-sector models and methods within the context of research and development programs?
3. How can these mandates and resources combine to optimize the outcomes achieved for the benefit of the target populations in this particular field?

…overlaying any transfer project on the generic model helps ground the project within the model's common elements, regardless of the project's source, type, or stage of progress.

Establishing Models Through Observation of Methods in Practice

Technology development and transfer is understood to be a difficult and complex enterprise. Almost a decade ago, the RERC on Technology Transfer (T^2RERC) presented a generic model describing the full technology transfer process from the source of ideas for applying technology to the post-production roll-out into the marketplace (Lane, 1999). This model described the underlying similarities between transfer programs in any field of application, and it penetrated the various jargon and cultures of different stakeholder groups to form a shared understanding of what is involved in the

By applying the Lane (1999) model to internal projects, the T^2RERC found that overlaying any transfer project on the generic model helps ground the project within the model's common elements, regardless of the project's source, type, or stage of progress. Over time, we found that the generic model serves three other unanticipated purposes:

1. As a conceptual model, it helped managers identify and plan the necessary activities within a known process. We applied this model to create and implement successful technology transfer projects, originating with (a) inventions in need of an application (supply push); (b) validated industry needs seeking technology solutions (demand pull); or (c) a partnership between technology sources and industry applications (collaboration).
2. As a practical roadmap, it helped stakeholders locate their contribution at a time and place within a continuum of activity. It showed which activities should have preceded their current focus and which activities were forthcoming. For example, the model enables prototype inventors to view their relative contributions in the context of the overall process – with all of the future work still required of the potential commercial partner. This can help prototype inventors to accept a realistic share of future returns.
3. As a framework for organization, it helps participants to quantify resources expended and to track progress through the process. Project planning and management tools need to be applied within some bounded parameters indicating the start and finish

points. The resulting data on resource allocation and expenditure is important for benchmarking, for identifying barriers to progress, and for relating inputs to expected outputs in terms of critical success factors.

Applying the generic technology transfer model helped the T²RERC develop our own internal expertise in conducting development and transfer projects. We have evaluated hundreds of invention prototypes and collaborated with dozens of companies. Overall, we have brokered or facilitated the transfer of about 50 products to external partners over the past 14 years of operation. Most of these transfers began either as prototypes acquired from external inventors, or as specific technology needs validated by industry. We documented about 10% of those as illustrative cases that demonstrate what happens before and after applying a systematic method to the development and transfer process (Lane, Leahy, & Bauer, 2003).

Since the entire RERC program is expected to develop, transfer, and commercialize, the next step is to study how others conduct technology transfer by tracking activity through the T²RERC generic model's framework.

We studied our approach to the development and transfer process by applying standard program evaluation methods to our RERC's own project activities (Stufflebeam & Shinkfield, 1985). This absolute evaluation process established the technology transfer model's internal validity (i.e., how well it represents our test cases), its effectiveness (i.e., what it accomplishes), and its efficiency (i.e., what it consumes).

Since the entire RERC program is expected to develop, transfer, and commercialize, the next step is to study how others conduct technology transfer by tracking activity through the T²RERC generic model's framework. This will identify innovations in other programs and identify factors that facilitate or inhibit their progress. Some of these factors may be unique to a project while others may be readily applied elsewhere. The results will be used to develop a program-level strategy for facilitating and brokering technology transfers.

This focus on innovative practices responded directly to the NIDRR priority for the RERC on Technology Transfer, which required us to "research and develop innovative ways to facilitate and improve the process…" (National Institute on Disability and Rehabilitation Research Notice of Proposed Priorities, 2003, p. 1447). Here we define innovations as procedures that facilitate successful transfers that may be different from those already identified in the literature, or that may be known procedures applied in novel ways. We look to the other RERCs for examples of innovation, given that we share core objectives, funding levels, and target stakeholders. Demonstrating the value of innovative procedures found in RERCs should encourage their adoption by current and future RERC grantees.

Current Problem in Practice: Undocumented Models and Inconsistent Methods

The 2002 NIDRR Summative Review for nine RERCs included an external observer's recommendation for addressing the challenges of technology transfer:

> Success in technology transfer may be the most appropriate measure of outcome, but the technology transfer area is inconsistent across Centers . . .since there is some indication that extensive 'brokering' may be needed for each product to make it to the marketplace, then a program-level strategy might be warranted if technology transfer is to be realized more consistently. (Stoddard, 2002, p. 9)

One can attempt to accomplish technology transfer in a variety of ways, but succeeding requires the same attention to rigor and relevance as for research projects. Consequently, a valid and systematic model is needed to help all RERCs apply appropriate models, methods, and metrics within their own projects. We expect this approach will increase the number and rate of successful transfers. This will meet NIDRR's goal of developing innovative A/assistive technology (AT) for the benefit of people with disabilities, in fulfillment of the mandates originally established by the Rehab Act.

…a valid and systematic model is needed to help all RERCs apply appropriate models, methods, and metrics within their own projects.

After 30 years, there should be a sufficient record of AT development and transfer activity to propose improving practice by studying the mechanics of actual transfers. By examining other RERCs to explore what works, what doesn't work, and the reasons why, we can increase the quality of technology transfer activities as well as the quantity of successful outcomes. The emerging discipline of technology transfer will also improve when we identify the best practices applied in our target industry because they can be generalized to other R&D programs applied to other industries.

The T²RERC's experience enables us to contribute to a program-level strategy of brokering transfers. Successful brokering must address the needs of all stakeholders in the process given that any stakeholder can influence the transfer's eventual success. For example, a university-based RERC's goal of transferring inventions could conflict with the institution's goal of maximizing the return on licenses if the institution insists on terms that are appropriate for mainstream products but are unacceptable to small-market companies (e.g., those that operate in the field of AT products and services).

All RERCs play a role as brokers to other participants across the entire development and transfer process. A broker should understand and anticipate barriers common to university-based programs and should establish negotiation parameters for RERC inventions before they emerge. Brokers involved in a program-level strategy to facilitate technology transfer should provide proactive consultation at the planning and design stages of technology transfer activity for all stakeholders.

Research Questions and Expected Benefits

Case Study Methodology

Developing a program-level strategy for brokering transfers requires a comprehensive analysis of the state-of-the-practice in all RERC development and transfer projects. The T²RERC proposed that this analysis is best conducted by reviewing case studies of such development and transfer projects

conducted by other RERCs in the recent past. In our grant proposal for the 2003-2008 funding cycle, we proposed conducting a series of retrospective case studies. Those retrospective case studies targeted the 13 RERCs with five-year grant cycles initiated in 1998, 1999 and 2000. (Note: The T2ERC was actually the 14th RERC funded in this study. We excluded ourselves from the analysis to avoid confounding the results and precluding us from comparing our practices to those of other RERCs.)

Developing a program-level strategy for brokering transfers requires a comprehensive analysis of the state-of-the-practice in all RERC development and transfer projects.

We chose to not study RERCs initiated earlier because NIDRR did not specifically require RERCs to develop and implement a plan for technology transfer until the early 1990s. By starting with the 1998 period, long-standing RERCs would have already completed a full five-year cycle of activity in this new area of sponsor emphasis. By gathering information on RERCs initiated in the 1998–2000 timeframe, we had a fairly representative sample of RERC topics and a full cycle to study for about half of the total number of RERCs within the program.

We also chose not to study RERCs with active funding cycles. Although these RERCs may employ innovative transfer programs, it would be illogical for us to draw conclusions during a funding cycle. Nonetheless, we plan to document their progress in a subsequent prospective study.

Research Questions

The retrospective cases studies of development and transfer projects proposed by the 13 RERCs funded between 1998 and 2000 would be analyzed to answer three questions:

1. Which factors critically facilitate or inhibit the technology transfer process within and across the cases of development and transfer examined?
2. Which facilitating factors appear to be innovative, particularly for addressing the constraints inherent in the AT marketplace?
3. How can RERCs in particular, and the AT industry in general, adopt these innovative factors to improve the technology transfer process?

Expected Results

Short term. The approach would result in completion of each case to include Results Mapping (documentation of key variables); Benchmarking Process (efficiency); Listing Outcomes (effectiveness); and Identifying Critical Factors Influencing Transfer Outcomes (barriers & carriers).

Intermediate term. The retrospective case analyses would result in dissemination of results to other RERCs and to the AT community through publications and presentations in order to positively impact the technology transfer practices of RERCs by 2008.

Long term. The RERC system would be changed to ensure that we are meeting the mission of the Rehab Act to improve the quality of life for people with disabilities by introducing new or improved A/T products.

Method

The overall approach in this case-based analysis included a five-step process. First, all RERC development projects with intent to transfer were identified by reviewing the funded proposals and classifying them by anticipated product category. Second, evidence of progress in development and transfer activities for each project was identified through secondary sources of information. Third, a preliminary summary of each project's progress was prepared in a structured format and submitted to the principal investigators for review, revision, and elaboration. Fourth, the final cases for evidence of innovation were examined, thus providing an overall assessment of progress for each RERC and for the RERC program as a whole. Fifth, recommendations were made for improving the development and transfer process to the RERCs and NIDRR, based on standard practices as well as demonstrably effective innovations.

Rationale for Retrospective Case Study Design

Case studies may encompass newly initiated projects, projects in process, or completed projects. We chose to focus on a set of retrospective studies of completed projects conducted during the same timeframe. This approach and sample enabled us to (a) document the entire process from conception through completion, and quantify the time and resources expended in the process, and (b) provide a context for determining what does and doesn't work based on completed work.

Retrospective case studies permitted us to explore the various approaches to technology transfer implemented at different RERCs. Because we previously documented and disseminated our internal methods for accomplishing technology transfer, using retrospective case studies allowed us to compare these internal methods to approaches used by others. We wanted to ensure our methods are comprehensive and that we are aware of any alternative methods used by others.

We expected the case studies to expand our understanding of the development and transfer process and better prepare us to provide technical assistance to current and future RERC grantees. By reconstructing the methods applied by others, we expected to offer benchmarks regarding the threshold of personnel and resource commitments required to attain success and provide general expectations for the length of time from idea conception to transfer completion.

Retrospective case studies permitted us to explore the various approaches to technology transfer implemented at different RERCs.

RERC Case Study Sample: Identifying Development Projects with Intent to Transfer

We read each of the project narratives and identified only those in which the investigators expressed both intent to develop some tangible product and an expectation that the product would be transferred for use outside of the RERC. Once we identified development projects with an expressed intent to achieve a transfer, we could trace progress forward to the present, identifying the critical factors that influenced the eventual outcomes of every proposed project. RERCs whose development projects did not express intent to transfer were excluded from the study.

We identified all RERC development and transfer projects by examining the original proposal narratives that were submitted for review and approved for funding by the NIDRR/USDE between 1998 and 2000. Given the difficulties in reconstructing past events, and the potential for revisions based on actual outcomes, we designated project narratives as starting points for every project submitted under headings of either development or technology transfer.

Product development projects are concerned with creating a tangible artifact for internal or external use. Not all development projects intend to achieve transfer outcomes. A RERC may develop a standard or an instrument for internal use only. Development projects that do not expect to result in a transfer have the same internal focus and autonomy as research projects. By comparison, development projects that are planned to result in transfer require a higher level of involvement and commitment because the results will affect another group of stakeholders.

Development projects with transfer outcomes often run indefinitely. The internal work must be planned and completed. Then the procedural and legal aspects of the transfer process must proceed. We were mindful to not examine the results of transfer projects prematurely; by studying the progress of projects initiated between only between 1998 and 2000, we could account for activity from each project's full five-year grant cycle and up to one or two additional years of elapsed time. Even if we found that a final transfer outcome had not yet been achieved, we could still expect the elapsed years to yield substantial evidence of progress toward the intended outcome. Conversely, we were aware that any development project may result in an unintended transfer outcome. We planned to identify and study any such serendipitous event as an additional successful transfer for the RERC.

Development projects with transfer outcomes often run indefinitely. The internal work must be planned and completed. Then the procedural and legal aspects of the transfer process must proceed.

Data Collection and Organization

In the spring of 2004, we obtained copies of all 13 proposals submitted by successful RERCs funded from 1998 through 2000. The copies were obtained directly from NIDRR/USDE as program sponsor through a Freedom of Information Act (FoIA) request. This ensured that the copies represented the projects precisely as they were initially proposed. (Note: A 14th RERC–the RERC on Technology Transfer–was excluded from the analysis because it has a unique mission to study and conduct technology transfer. Its external focus on identifying advanced technologies and commercializing prototypes developed by others makes it unrepresentative of RERCs in general.)

While waiting for delivery of the proposals, we developed a standard, 10-question form titled, *History of Development and Transfer Project (HD&TP)*. The form was designed to identify each step in the development, transfer, and commercialization process, and to organize the information in a uniform manner regardless of the RERC or specific project studied. The form sought to reveal (a) the source of the idea; (b) whether the project was implemented as proposed; (c) the resources allocated to the project; and (d) the progress from concept through prototype development and testing, to negotiation with outside entities.

…we reviewed each RERC's proposal sections on Development Projects, Dissemination Plans, and Technology Transfer to identify proposed projects where the authors explicitly expressed intent to achieve a transfer outcome from a development project.

In the Summer and Fall of 2004, we reviewed each RERC's proposal sections on Development Projects, Dissemination Plans, and Technology Transfer to identify proposed projects where the authors explicitly expressed intent to achieve a transfer outcome from a development project.

For all RERCs funded in 1998- 2000, we created a separate HD&TP form for each development project identified. Each form contained the project title, parent RERC name, year the grant cycle was initiated, and a description of the project excerpted verbatim from the original proposal. The resulting summaries were grouped under the appropriate RERC.

Two RERCs proposed zero development projects with intent to transfer a tangible prototypes. A follow-up phone call to the former directors verified that transfers were neither intended, nor occurred unexpectedly. We excluded these two RERCs from further analysis, leaving a total of eleven RERCs for the case study process. The distribution of Development/Transfer projects proposed by each RERC is shown in .Table 1.

For each development project that intended an external transfer outcome, we independently sought evidence of progress as measured by the criteria listed in the HD&TP form. We relied on secondary sources of information in the public domain. These sources included RERC status reports, web postings, conference presentations, journal articles, prototypes or instructions for construction, technologies available or licensed through the technology transfer office, and announcements from standards groups or corporations on products related to the work of the RERC. When evidence of progress referenced prior work or other sources, we also reviewed those prior materials. Collectively, these documented materials formed the progress reports for each case. Information available on each project ranged from nothing beyond the initial proposal narrative, to announcements that products were in use or were available for purchase through commercial sources.

For each development project that intended an external transfer outcome, we independently sought evidence of progress

Operational Definitions: Four Categories of Technology Transfer Outcomes

After reviewing all 78 projects, we identified four categories of transfer outcomes proposed by RERCs, which are defined in this section.

Our mission statement for the RERC on Technology Transfer is: "Moving new or improved products to market, which improve the quality of life for persons with disabilities." Thus, we focus on the transfer of commercially viable products to the competitive marketplace. The output of a prototype from internal or external sources must be transformed into an outcome by acceptance for implementation by an external

entity. This is the 'transfer' in technology transfer (i.e., transfer of ownership and responsibility to another party for its purposes).

More broadly defined, a transfer involves the internal development of a draft, proof, or prototype that will eventually be acquired and used by external parties. We identified four types of transfer:

1. *Category 1*: Standard/Protocol. This included a written standard or documented protocol. It is transferred at no cost through review and acceptance by the external partner, possibly subject to peer review and consensus approval, a process similar to that undergone by academic journal articles. The target transfer partners are research, clinical, or industry associations whose constituents will use it.
2. *Category 2*: Freeware. This included a hardware device or software application with a utility that hadn't previously been available to users. The transfer takes place when end-users download or order the new device or application. The distribution is free or it may contain a fee that is designed to recoup the cost of distribution by the creator.
3. *Category 3*: Instrument/Tool. This included a non-commercial instrument for data capture or

Table 1
Distribution of Proposed Development/Transfer Projects Per RERC

Project	*N* of Proposed Development Projects with Expressed Intent to Transfer
Trace –Telecomm Access	12
Trace - Information Tech Access	8
Lexington/Gallaudet – Hearing	4
Duke – AAC	6
PALM – Land Mines	4
Pittsburgh – Wheeled Mobility	9
Rancho Los Amigos – Children	6
Northwestern – P&O	7
Buffalo - Universal Design	9
National Rehab Hospital – Tele-Rehabilitation	3
Smith-Kettlewell – Vision	10
Michigan – Workplace	0
N. C. State – Universal Design	0

measurement, or a tool for design or fabrication. The instrument itself, or plans for its construction, are distributed at no cost by the creator. The intended transfer recipients are researchers in laboratories or practicing clinicians.

4. *Category 4:* Commercial Product. This included a new or improved software or hardware product, intended for commercial distribution and sale in the competitive marketplace. The transfer may involve an upfront or royalty-based charge with ownership and rights determined by conditions of sale or license. The intended transfer partners are companies with manufacturing, distribution, and support capabilities. These capabilities ensure availability of the product to end users for a price that may include cost recapture and profit margin.

> …a transfer involves the internal development of a draft, proof, or prototype that will eventually be acquired and used by external parties.

Note that each of the four transfer outcome definitions includes two elements. First, the RERC must generate something tangible to accomplish an 'output.' Second, the output must transfer out for use by external stakeholders to achieve an 'outcome.' Both are necessary to represent a transferred project. The output embodies the RERC's internal intentions but lacks external validation of the output's value to others. The transfer outcome indicates that external stakeholders perceive sufficient value to invest themselves in applying the output in practice. Significant distance remains between the transfer outcome–adoption, use, or acquisition (i.e., license or purchase)–and the presence of an actual product in the marketplace.

> The transfer outcome indicates that external stakeholders perceive sufficient value to invest themselves in applying the output in practice.

The commercialization outcome is the final result of a Category 4 project, and may take additional time to accomplish. However, the introduction of such products into the marketplace, and its value to the end users actually represent the end-state impacts originally intended by the Rehab Act. Assessing the full future impact of past projects is beyond the scope of this analysis, given the documentation of the quantity, quality, and duration of use it would require.

Even though we are unable to trace the results of products in use, the relative attributes of these four categories of transfer outcomes need to be examined, as each has different implications for the stakeholders involved. All four categories require an investment of personnel and materials by the RERC team to result in a tangible output. Further, each success category requires an increasing amount of investment by the RERC. For example, a validated prototype of a new commercial product requires more total input and process than does the replication of a laboratory instrument.

The increasing level of investment is more apparent from the perspective of the external partner who is the recipient of the initial transfer. For Category 1 (standard/prototype) transfers, a professional association may have to review and adopt a new standard through its membership. Category 2 (freeware) transfers require an external actor to download the software or order and build the hardware device. In either case, their investment is an initial trial to determine whether the freeware is useful. For Category 3 (instrument/tool), an instrument user may have to buy or build the instrument, receive training on its use, and then rely on the instrument for data critical to research or practice. Category 4 (commercial product) transfers involve a company negotiating terms for a license, investing in the production design and materials, committing resources to mass production and then supporting distribution sales, marketing, and customer service.

It is important to stress that we begin with the RERC's intended outcome.

It is important to stress that we begin with the RERC's *intended outcome*. The RERC proposal must explicitly state that it will implement a development project intended to accomplish one of these four types of transfers. Once that intention is clear, we can assess their progress through the interim milestones appropriate for each type of project, determine the extent to which they succeeded, and then consider the causal factors underlying the results.

Request for Information and Elaboration from Principal Investigators

In the end we received input from three RERCs, for a response rate of 27% (3 out of 11).

Once that intention is clear, we can assess their progress through the interim milestones appropriate for each type of project, determine the extent to which they succeeded, and then consider the causal factors underlying the results.

We anticipated that the collection of information from secondary sources would only yield some of the facts about the planned and actual result for each project. We expected that the Principal Investigators (PIs) would supply the rest of the facts as well as the post-hoc analysis about why those plans and results were obtained. We assumed we could obtain PI input through the 'technical assistance' mandate by which we have previously granted RERC requests for information and assistance.

In the Fall of 2004, we electronically forwarded a complete set of HD&TP (proposed by the RERC) to the PI of record for each of the 11 RERCs under study. Each PI was asked to review the material, respond to as many questions as possible, and then participate in a teleconference regarding the case studies. Where other investigators were named for individual projects, we asked the PI to forward the material for his or her review and input.

Meanwhile, we continued to search secondary sources for information about progress on any of the 78 projects proposals. Mindful that some RERCs under study were only concluding the final years of their budget cycles at that time, we continually monitored

RERC websites and progress reports, conference proceedings and journal articles, and the websites of companies named as actual or potential partners for transfer.

…we discovered additional evidence of progress through secondary sources

When we discovered additional evidence of progress through secondary sources, we added it to our internal copy of that project's HD&TP form, under the appropriate question. We excerpted the evidence verbatim from the source and we cited it appropriately. This search also identified evidence of possible prior or parallel efforts at development or transfer, whether by the same RERC in a prior cycle, by other research centers or by private sector companies. This material was included along with notations to ask the appropriate PI for clarification of prior or parallel efforts.

By the Spring of 2005, most of the internal HD&TP forms included some additional material regarding evidence of progress or non-progress, as well as material that required clarification by the PI. Having received no PI replies to this point, the updated forms were grouped by RERC again and forwarded electronically to the PI of record for comment and clarification. The PIs were again asked to review the material, provide additional evidence of progress, or reference the location of additional relevant material or sources. They also received a second request to schedule a teleconference.

Hard copy versions of our internal HD&TP forms were taken to the RESNA 2005 conference. Each PI or Co-PI present was contacted personally by the author, handed a set of his or her project forms and again asked to review the materials and schedule a teleconference. The project team spent the remainder of 2005 exploring additional secondary sources, and transforming the HD&TP materials into case narratives for each proposed project. These case narratives were classified and assigned numeric values, resulting in scores for both proposed and actual deliverables as described in the next section.

We excerpted the evidence verbatim from the source and we cited it appropriately.

The case narratives and summary scores were then sent to the PI of record for that RERC in Spring, 2006. This was the final chance for the PI to revise the content of each case narrative, provide additional documentation on progress we were unable to identify, or to direct us to other sources for additional explanation or clarification. We informed the PIs that no response from the PI would be considered as verification that the case studies were accurate and complete.

Content Review of Proposal Narrative

In the absence of substantive input from the majority of RERC directors, we decided to internally conduct a secondary review of the proposal narratives themselves. Characterizing and quantifying the planned and actual transfer achievements of the RERCs was only the first step in understanding which practices were and were not working. We expected that understanding the reasons underlying the results would be the crux for improving technology transfer as practiced within the RERC program.

…the overall intent of the PDMA guidelines is highly relevant–to ensure value for the commercial vendor and to ensure utility for the target consumers. This intent matches that of the Rehab Act.

We returned to projects that we'd identified in our initial review as having intent to transfer. In our secondary review, we identified the extent to which the authors approached these intended transfer projects using standard practices recommended by experts in product development. We turned to the Product Development Management Association (PDMA) as the source of expertise on technology transfer and new product development (Rosenau, Griffin, Castellion, & Anschuetz, 1996). The PDMA offers industry-based guidelines on all aspects of new product development, analogous to the standard reference manual for research methodologies (Shadish, Cook, & Campbell, 2001). Although some aspects of the PDMA guidelines designed for commercial products are not fully applicable to some categories of transfers that are not commercial products (e.g., protocols, freeware, and instrumentation), the overall intent of the PDMA guidelines is highly relevant–to ensure value for the commercial vendor and to ensure utility for the target consumers. This intent matches that of the Rehab Act.

The PDMA publishes a reference book on new product development. The book includes a simple set of guidelines addressing the content review of the proposal narratives. The guidelines are referred to as the seven forms of essential preliminary analysis. Performing these analyses is considered essential prior to initiating a development project and include (a) *initial screening for need* (i.e., screen to objectively substantiate the presence of need); (b) *technical assessment* (i.e., determine that it is feasible to provide the desired features or functions); (c) *customer interest build/buy* (i.e., ensure that the proposed end product will actually be perceived as useful and relevant); (d) *collaborations* (i.e., identify the necessary partners for supply and distribution); (e) *assessment of uniqueness* (i.e., determine that there is an absence of alternative equal or better solutions); (f) *implementation plan* (i.e., determine how to move efficiently and effectively from the concept to the market); and (g) *allocation of resources* (i.e., determine which resources for the prototype are necessary, and ensure sufficient, timely access to them).

Scoring System for Proposal Content Review

T^{2}RERC members reviewed each project's narrative in order to determine the extent to which each of the seven forms of preliminary analysis were mentioned or described, using a four-point scale ranging from no mention at all (0) to comprehensive treatment (4) (see Figure 1). (Each proposal narrative was reviewed by members of the T^{2}RERC project team who had not previously been involved in

Score = 0 Absolutely no mention of the factor in the project narrative.
Score = 1 Simple declarative statements present but without any substantiation.
Score = 2 Statement supported by a partial justification or some evidence of analysis.
Score = 3 Factor addressed in comprehensive manner instilling confidence in reader.

Figure 1. Ordinal scale ratings used to evaluate preliminary analyses.

constructing the original case studies.) A content review of each project narrative provides a baseline indication of the extent to which the proposal authors conducted any or all of the seven forms of preliminary analysis deemed essential by a leading authority on best practices. Their presence or absence helps shed light on the reasons for the various levels of success achieved by each project, as compared to the intended results. This helps identify areas which current RERC practices should be emulated or modified.

A content review of each project narrative provides a baseline indication of the extent to which the proposal authors conducted any or all of the seven forms of preliminary analysis deemed essential by a leading authority on best practices.

The content review was completed in the summer of 2006. A summary of the case study materials and the preliminary findings was reviewed with both the NIDRR's current RERC Program Manager, as well as the former Program Manager who served during the 1998-2003 study period. These reviews revealed no significant oversights, and the Program Managers reported that the results matched general expectations for RERC development and transfer productivity. This method of content review of the 11 proposals completed the case study project's information and data collection phase.

Data Analysis

Assigning Point Values to Product Categories

Each project proposal was classified into one of the four product categories described previously (i.e., Category 1: Standard/Protocol; Category 2: Freeware; Category 3: Instrument/Tool; Category 4: Commercial Product). Each product category was assigned a specific point value. The scoring system used whole numbers in a simple ordinal scale to create weighted sums and compute proportions.

It is important to note that these values were assigned without regard to the potential or actual social impact of any particular transfer. RERCs conduct a wide range of activities, whose endeavors might be modest or grand in scope, involving outputs ranging from simple and low tech to complex and high tech. An actual transfer might eventually have a limited impact on a niche market, or it may profoundly impact a mass market. We assumed that every project approved by the peer review process was meritorious.

Our purpose was to compare intended results and actual results, and not to judge the absolute merit of any or all projects. We aimed to differentiate between transfer categories to the extent that each requires different types and amounts of internal input from the RERC, as well as different types and amounts of external investment by the target audience. In recognition of the difference between achieving internally driven outputs (e.g., draft/prototype), versus the external outcomes resulting from adoption and use by others (e.g., industry standards, commercial products), we assigned a specific point value for the completion of the output, and another specific point value for the completion of the outcome.

We aimed to differentiate between transfer categories to the extent that each requires different types and amounts of internal input from the RERC, as well as different types and amounts of external investment by the target audience.

The approach for assigning points for each category is described below.

1. *Category 1: Standard/Protocol* – The level of internal effort and external scrutiny exceeds that of a peer-reviewed publication, although this development result follows models and methods similar to those found in academic research. More important for transfer purposes is the decision by an external entity to internalize the work by integrating the standard/protocol into practice. Given the similarity of this output to research outputs (e.g., monograph or article), generating the output has a value of one point. Evidence of transfer (acceptance, adoption, refinement, and use) has a value of '2' points. Therefore, a Standard/Protocol transfer has a total point value of '2' points (1 output + 2 outcome = 3 transfer).
2. Category 2: Freeware – The *freeware output itself* is a fully functioning and reproducible software application or hardware device. The effort involved in accomplishing the output falls further outside the traditional realm of academic output. It is also assumed to be more intensive and prolonged than the internal work involved in drafting a new or modified standard. Conversely, the decision to access and use freeware is made by individuals or small groups, rather than associations. Thus, accessing freeware is presumed to be less involved than transferring a standard. Generating a freeware output has a value of '2' and evidence of use by others has an outcome value of '1.' Therefore, a freeware transfer also has a total point value of '3' (2 output + 1 outcome = 3 transfer).
3. *Category 3: Instrument/Tool* – An instrument/tool is by definition a fully functional and reproducible software application or hardware device. In addition, an instrument infers a level of precision not necessarily required of freeware. It also requires external adopters to rely upon the instrument/tool to add value to their own professional work. Like freeware, the additional work involved in calibrating and validating the output falls outside traditional academic activity, so generating the output also has a point value of '2.' Evidence of external use by researchers or clinicians has a point value of '3.' Therefore, an instrument/tool transfer has a total point value of '5' (2 output + 3 outcome = 5 transfer).
4. *Category 4: Commercial Product* – A commercial product transfer is furthest removed from traditional academic research, and requires the highest level of management commitment and resource investment by external partners. The completion of the internal

work necessary to generate a prototype worthy of consideration by a company requires the (a) technical work involved in creating freeware, (b) needs analysis that goes into determining a standard, and (c) consideration of end-user requirements requisite in the creation of an instrument. The decision to acquire the intellectual property for use in a commercial product by an external partner assumes an intensive and protracted investment of resources. The creation of the output has a point value of '3,' and evidence of external commercialization adds a point value of '4.' Therefore a commercial product transfer has a total point value of '7' (3 output + 4 outcome = 7 transfer).

The different values indicate the distance between the project category outcome and the anticipated impact on the intended target audience of people with disabilities. Category 1 (standard/protocol) outcomes require adoption by an oversight board or governing body, then application by members who adhere to the standards of that board or body into the product design and development process. Category 2 outcomes (freeware) might be more readily applied by end users, but only by those in a position to learn the Category 2 outcome exists. Dissemination of information about the availability of freeware may extend the timeframe for impact. Category 3 (instrument/tool) outcomes require application by an interim recipient such as a laboratory researcher or a clinician. The knowledge generated by research projects using new instruments must be diffused, just as clinical tools must demonstrate efficacy before widespread application and subsequent benefit to target populations. Commercial products (Category 4) are the most readily distributed through vendors or directly to the end users. Category 4 is most closely aligned with the goal of Rehab Act for putting new and improved products in the marketplace.

The different values indicate the distance between the project category outcome and the anticipated impact on the intended target audience of people with disabilities

Our scoring system also differentiates product categories using the ratio of external to internal effort necessary to transform outputs into outcomes. Category 1 and Category 2 successes are generally considered relatively equal in the combined level of internal and external investment necessary to achieve success. Category 3 requires more exact calibration and function, while Category 4 successes require the most investment by internal and external participants.

While these generalizations don't fully apply in cases such as major industry guidelines versus orphan commercial products, they suffice for our purposes of gathering evidence of success in the four transfer categories.

The distribution of proposed projects by RERC and across the four product categories are noted in Table 2.

Each proposed transfer project was classified under one of the four categories. The classification was based solely on the intended transfer type described in the original RERC grant proposals. The content of each proposed project was carefully reviewed to identify the intended outcome. If the stated intent was to generate a Standard/Guideline (Category 1) outcome, it received a potential

score of '3.' If the intended outcome was a Commercial Product (Category 4), it received a potential score of '7.' The score for each proposed project reflected its potential transfer value, or how likely the project was to result in transfer. Thus, the *Potential Transfer Value per Project* (PTVP) was calculated using the following formula: PTVP = intended output value for the product category + intended outcome value for the product category. Summing PTVP for all projects proposed by a specific RERC yielded the total Potential Transfer Value per RERC (PTVR), which was calculated using the formula:

Table 2
Distribution of Proposed Projects by Product Category for RERCs

	N Category 1	*N* Category 2	*N* Category 3	*N* Category 4	*Total N*
Trace, Wisconsin –Telecommunications Access	8	0	1	3	12
Trace, Wisconsin - Information Technology Access	1	1	1	5	8
Lexington/Gallaudet – Hearing Enhancement	0	0	3	1	4
Duke University – AAC	0	0	3	3	6
PALM – P&O for Land Mines	1	2	1	0	4
Pittsburgh – Wheeled Mobility	0	0	3	6	9
Rancho Los Amigos – Children with Orthopedic Impairments	0	0	1	5	6
Northwestern University – Prosthetics & Orthotics	0	2	1	4	7
Buffalo - Universal Design	0	0	1	8	9
National Rehab Hospital – Tele-Rehabilitation	0	1	0	2	3
Smith-Kettlewell – Vision Enhancement	1	1	1	7	10

Note: In the interest of full disclosure, for the 1998–2003 grant cycle, the RERC on Technology Transfer proposed no projects under Categories 1, 2 and 3, but proposed 30 projects under Category 4.

PTVR = $PTVP_1 + PTVP_2 + PTVP_x$.

The PTVR score for a RERC represents the 'maximum total value' should all proposed projects accomplish their intended transfer outcomes. Every RERC received a score for each proposed project and a sum total for all proposed projects.

Each proposed transfer project was classified under one of the four categories based solely on the intended transfer type described in the original RERC grant proposals.

Results: Scoring Actual Transfer Values

We scored the case narratives in a similar fashion. We reviewed content for evidence both of an output generated by the RERC and an outcome generated by an external entity. Thus, an *Actual Transfer Value per Project* (ATVP) was computed using the following formula:

ATVP = actual output value + actual outcome value. Summing the ATVP for all projects originally proposed by a specific RERC yielded the total Actual Transfer Value per RERC (ATVR), which was computed in the following manner: ATVR = $ATVP_1 + ATVP_2 + ATVP_x$.

The ATVR score for a RERC represents the total value of all its transfer accomplishments. To ensure each RERC obtained full credit for its transfer achievements, the scoring process included all outputs and outcomes even if they differed from those originally intended in the proposal. For example, a project intending to transfer an instrument might instead have transferred a new standard, or a project intending to transfer a commercial product might instead have transferred an instrument. In all cases, RERCs received points for their accomplishments.

Transfer Achievement Index: Converting Two Scores into a Single Transfer Value

To convert scores into a single transfer value, we created a *Transfer Achievement Index* (TAI). This index represents each RERC's success at accomplishing what it originally proposed.

The transfer value is a percentage value that we determined by dividing the Actual Transfer Value per RERC by the Potential Transfer Value per RERC yields a percentage value. This percentage is the proportion of intended transfer that was actually achieved or the degree of success in obtaining transfer. Thus, we call this number the TAI, represented by the formula TAI = *ATVR* / *PTVR*.

We computed the TAI for each project, across all projects within a RERC, as well as for projects in each of the four categories of transfer among the RERCs we studied. The same calculation is completed across all RERCs. The TAI results permit comparisons between RERCs and among the four categories of transfers. The TAI results also provide useful benchmarks such as average results across all RERCs and average results across the four categories of transfers.

The rate of success indicates a RERC's ability to generate an output with sufficient relevance to a transfer partner and an intended target audience.

The TAI does not assess the specific value of any one product's outputs or outcomes, nor does it compare the value of any one output/outcome to another. The TAI simply reports the level of success in achieving the intended deliverables, as presented in the original proposals. The rate of success indicates a RERC's ability to generate an output with sufficient relevance to a transfer partner and an intended target audience. Secondarily, the rate of success indicates the NIDRR's ability to address the goals of the Rehabilitation Act, through its sponsored RERC program.

Results

Validity of the Methodology and Results Obtained

We expected to identify evidence of outputs (internal development to the prototype stage), and then to identify evidence of outcome (transfers to external entities for their own adoption, application, or use). The evidence of internal activity was not always articulated in easily accessible formats, nor did we necessarily accept statements of progress as evidence. The completion of tasks and activities associated with progressive stages of development provided the most objective evidence. Much of this material was gleaned from conference presentations by project participants, or Web site postings by the RERC or by the technology transfer administrators.

Evidence of external activity is actually more difficult to detect because it is more diffuse. Specific questions raised include (a) How does one know when external parties have accessed, downloaded, and used freeware? And (b) Where does one locate people who have applied an instrument or tool in their own settings? We had to rely on material disseminated by the RERC or on external reports of product use.

Of course, even this evidence only demonstrates interim progress toward meeting the goals of the Rehab Act. The goals are geared toward improving access and use of new or improved products by the target end users. Evidence of transfer across the four product categories only establishes the interest of external entities in pursuing adoption and application. There are additional steps required for each category of transfer to eventually impact the intended beneficiaries. *Standards and Protocols* in Category 1 must be followed by manufacturers in the design, production, distribution, and support of future products, or by clinicians in the design, application, and evaluation of services. *Freeware* in Category 2 must be downloaded, ordered or constructed, then applied by the target audience. *Instruments/tools* in Category 3 must be constructed, calibrated, and used within laboratory or clinical settings. *Commercial products* in Category 4 must be designed for production, manufactured, distributed, and supported.

Our search would have missed evidence of progress on internal work or even external transfers if the RERC involved hadn't yet disclosed this activity in any public forum or in on-line project updates, and had not divulged work in process in response to our queries. This can happen when transfer activity is in any early stage, when it remained proprietary at the time of this analysis. Given the number of cases studied and the availability of evidence demonstrating progress, we believe any instances of on-going proprietary work will be few and will not appreciably change the results or conclusions about the RERC program as a whole.

We are confident that we've identified virtually all of the transfers from the 11 RERCs initiated between 1998 and 2000 and that we've also identified the vast majority of progress along internal project milestones. We were able to trace the majority of the 78

proposed projects to their absolute end points. If other outputs or outcomes are identified, we would welcome information about them, but they wouldn't appreciably change the overall results or the analysis of those results.

> The RERCs' intentions spanned all four categories of transfer products with the majority of projects focused on Category 4, commercial product outcomes.

Our interviews and case reviews with two RERC principal investigators indicate that many details regarding roles and event cannot be known from secondary sources. Obtaining these details for the other nine RERCs would enrich our understanding of the specific projects. However, this detail would change neither our ability to verify the actual outputs and outcomes, nor or our ability to identify innovations. Thus, the absence of these details does not greatly hinder the present analysis.

Retrospective Case Studies: Evidence of RERC Activity in Development and Transfer

Table 3 shows the total number of development projects with an expressed intent to transfer the internal work for use by external partners, for all 11 RERCs included in this analysis. The RERCs' intentions spanned all four categories of transfer products with the majority of projects focused on Category 4, commercial product outcomes.

Creation of a tangible outcome involves a great variety of activities by multiple actors, but the evidence of progress can be easily observed at two critical points: the (a) internal completion of the prototype (document, tool, code or device); and (b) external access and use as a product (standard, instrument, freeware, commercial). Prototype completion is chiefly under the control of the RERC while the external use is not. One measure of relative progress across categories is to compare progress between prototype and product.

Table 4 shows the total number of projects showing evidence of attaining either prototype output or transfer outcome, across all eleven RERC's. About one-half of the 78 projects proposed achieved a prototype output (N = 40), while about one-fourth yielded a transfer outcome (N = 21). The highest rates of success fall under Category 1 (Standards/Guidelines). The success rate might be attributable to the specific skills of one RERC team given that 3/4 (9 of 12) of Category 1 transfers proposed came from two RERCs lead by the same PI. This PI places a high priority on development projects and has invested several decades building close working relationships with the companies in his focus industry. Or, this high level of

Table 3
Total *N* of Development Projects with Expressed Intent to Transfer

	N Intended CAT 1 Transfer	*N* Intended CAT 2 Transfer	*N* Intended CAT 3 Transfer	*N* Intended CAT 4 Transfer	Total *N* Projects Intending Transfers
Total projects proposed by all 11 RERCs	11	7	16	44	78

Table 4
Project Completion of Internal Prototype and External Transfer by Product Category

	Categories			
	1	2	3	4
N Projects Proposed by All 11 RERCs	11	8	15	44
Total *N* (%) Showing Evidence of Completing Internal Prototype Stage	12 (100+)	2 (33)	7 (44)	19 (43)
Total *N* (%) Showing Evidence of Transfer for Use by External Partners	11 (100)	2 (29)	2 (13)	6 (14)

success in Category 1 might be because drafting standards/guidelines is the transfer activity most closely resembling the authoring/publishing skills common to academically trained professionals. In either case, the cases showed that RERCs succeeded in accomplishing even more Category 1 internal draft documents and more successful transfers than they initially proposed. According to our metrics, this translates into a total score greater than 100% success in achieving the acceptance and use of the standard/guideline by the external target audience.

The highest rates of success fall under Category 1 (Standards/Guidelines).

The success rate of Category 2, 3 and 4 transfers were all similar, regardless of the differential weights assigned to these three categories of transfers. All three were also relatively low compared to the success rate for Category 1 transfers. Less than half of all the projects proposed across Categories 2-4 demonstrated evidence of successfully completing an internal prototype. Success rates drop even more dramatically from the prototype output to the transfer outcome, dropping to slightly more than 10%. The reasons underlying these levels of success are explored later. At this point it is sufficient to say that one can readily determine the success rates of development projects with an expressed intent to transfer, and can further discriminate between success over internally controlled activity and success with external target audiences.

By using the weighted score systems devised for each transfer category to compare the proposed and actual results, one can readily determine which RERCs work within a realistic performance envelope, and which may be promising more than they can deliver during the very competitive proposal review process. Of course, RERCs with lower success rates may be pursuing a more aggressive portfolio of high-risk projects–pushing the performance envelope–and experiencing a higher failure rate in the process. This explanation is explored later in the monograph.

RERCs with lower success rates may be pursuing a more aggressive portfolio of high-risk projects–pushing the performance envelope–and experiencing a higher failure rate in the process.

Table 5 shows the scores for each RERC on Potential Transfer Value (PTV), Actual Transfer Value (ATV), and Transfer Achievement Index (TAI). Table 5 reveals distinctive breaks in the Transfer Achievement Index (TAI) scores across the 11 RERCs. The two RERCs managed by the Trace Center at the University of Wisconsin-Madison are clearly operating at a level of success unmatched by the other nine RERC's. Both of these RERCs record nearly 100% congruence between the planned and actual results of development and transfer projects. Two RERCs fall around 50% (plus or minus five percent) in their congruence between planned and actual results. Three RERCs achieved around one-third of the transfer potential they proposed. The remaining four RERCs accomplished between 10% and 25% of what they planned to develop and transfer.

Demonstrating Evidence of Successful Transfers

The following section presents a description of successful projects across Categories 1-4.

Category 1: Standards & Protocols (N=10 Successful Transfers)

The RERC on Hearing Enhancement proposed a Category 4 project to commercialize an Electromagnetic Interference Analyzer (EIA). The EIA had been developed as a laboratory instrument (Category 3) in a prior cycle. The project failed to attract a corporate partner. While the industry was already using an instrument that was less technically sophisticated and less able to duplicate conditions of actual use, the instrument better served industry's own agenda regarding EMG testing. The project's laboratory testing for technical validation generated new data on EMG interference that was eventually used to modify an existing industry standard. Even though the result was unplanned, the RERC ensured that the data was properly used in practice and that its value was recognized.

The RERC on P&O for Land Mine Survivors proposed a Simplified Alignment Procedure that was developed as a protocol and disseminated to other nations. There is evidence it was used by a clinic in Thailand. Tracking the amount of use there and in other clinics would help build evidence of eventual impact in developing nations.

The RERC on Wheeled Mobility proposed a Standardized Postural Measurement Tool (Category 3) that resulted in a clinically validated prototype. Although the project did not result in a functional and reproducible tool, the project influenced the content of a new ISO standard for the measurement of seating posture – a Category 1 transfer.

The RERC on Telecommunications Access proposed eight different projects intended to influence various aspects of telecommunications protocols or standards. The RERC successfully added new language to three standards and influenced the Federal Communications Commission (FCC) to include relevant language in three of their own regulatory standards. Two of the planned changes were obviated by advances in telecommunications products, but those were offset by successful interventions in two areas not initially anticipated, as noted in the following paragraph.

The RERC on Telecommunications Access proposed developing a prototypical cell phone with alternative access features to work as a model for obtaining consumer input and as a template for future industry designs. This project preceded 2003 amendments to the Hearing Aid Compatibility Act of 1988 by the FCC. In addition, subsequent RERC conference presentations referenced new products conforming to FCC regulations. While it is not always possible to document

specific RERC contributions, the interplay of the Trace RERC industry and federal regulators lends sufficient weight to consider this a successful transfer. The RERC proposed another project to develop and transfer a 'Multi-purpose Phone and Messaging Device.' Although the phrase *personal digital assistant* (PDA) was not widely used when the proposal was written a decade ago, the Trace Center correctly anticipated potential access and use issues surrounding such a product. Given their early and constant advocacy, and its ability to accurately model and disseminate accessibility features, it is

Table 5
Results for 11 RERCs as of Winter 2006

RERC	*M* Projects Proposed	Potential Transfer Value (PTV)	Actual Transfer Value (ATV)	Transfer Achievement Index (ATV/PTV)
Trace –Telecomm Access	12	50	48	96%
Trace – Information Tech Access	8	46	44	96%
Lexington/Gallaudet – Hearing	4	22	12	55%
Duke – AAC	6	36	17	47%
PALM – Land Mines	4	14	6	43%
Smith-Kettlewell – Vision	10	57	23	40%
Pittsburgh – Wheeled Mobility	9	37	13	35%
Rancho Los Amigos – Children	6	40	12	30%
Northwestern – P&O	7	38	9	24%
Buffalo – Universal Design	9	52	11	21%
National Rehab Hospital – Tele-Rehabilitation	3	17	3	18%
M All 11 RERCs	7	37	18	46%
Range All 11 RERCs	(3–12)	(14–57)	(3–48)	(18%-96%)

Note: In the interest of full disclosure, the RERC on Technology Transfer accomplished the full number of 30 transfers originally proposed for an EBR rating of 100%.

likely that its protocols influenced the features and functions of commercial PDAs.

> Many successful transfers are facilitated by established personal relationships that overcome reservations about intent, value, and interests.

The RERC on Information Technology Access proposed 'Alternatives to All Verbal Interfaces' as guidelines to influence a new Microsoft® product called the Auto PC. The product's voice-only interface would overly restrict access and use. Although Microsoft® did not proceed with the product, its future design guidelines called for multiple interfaces on new products. Several of the RERCs' co-investigators were directly involved in integrating the same multi-interface requirement into the design guidelines for the American National Standards Institute (ANSI) International Committee for Information Technology Standards (INCITS).

The 12 Category 1 transfers were dominated by new or improved federal regulations and industry standards. These transfers were successful because project investigators had previously invested significant time and effort becoming widely known and highly credible as experts in their field. They had also worked to ensure their expertise was valued across academic, business, and government sectors, since they had contributed significantly to each sector. Similarly the protocol for the Simplified Alignment Procedure was disseminated through investigators and clinicians who were known to, and respected by, practitioners in the field.

This example shows why practitioners humorously refer to technology transfer activity as a 'contact sport.' Many successful transfers are facilitated by established personal relationships that overcome reservations about intent, value, and interests. People are more willing to listen to guidance from others they know and respect, and such people enjoy the benefit of any doubt that may linger over unknowns associated with unfamiliar practices or guidelines.

Category 2: Freeware (N=1 Successful Transfer)

The RERC on P&O for Landmine Survivors developed a novel casting system for socket fabrication, using low-tech technologies appropriate to many nations addressing the need of land mine survivors. The RERC wisely patented the system. It is a defensive patent that prevents others from claiming ownership and freely disseminating the tool and its methodology. The RERC has disseminated information about the system to nations in Africa and Southeast Asia. An external group conducted a clinical trial on the sand casting technique with subjects in Southeast Asia (Steen, Jensen, Poetsma, & Thanh, 2005). While the group has not specifically posted evidence of use by people in these nations, web-postings suggest that participants in the RERC-sponsored workshops at least 'occasionally' apply the tool in practice (Stanton & Reisinger, 2006). The intended target users are unlikely to post their experience on the Internet, so it is incumbent upon the RERC to provide evidence of use in remote locations. A lack of effort to document transfer and use was common among these non-commercial transfer projects.

Several other RERC projects intended to develop freeware. The majority of projects never even reached the prototype stage, suggesting that the project was either a low priority from the beginning or lost prominence as the demands of other RERC work–or extraneous professional demands–

increased over time. In a few cases they completed the internal work on the hardware or software, and had even posted it in a web form for dissemination or download access. For freeware items where there is no formal adoption and use, nor legal and monetary trails, it is important for the RERC to establish a method for documenting access and use by external parties. Such documentation helps the funded program and the sponsoring agency demonstrate the results achieved, particularly in terms of demonstrating benefit to the target audience.

For freeware items where there is no formal adoption and use, nor legal and monetary trails, it is important for the RERC to establish a method for documenting access and use by external parties.

Category 3: Instruments & Tools (N=2 Successful Transfers)

Several RERCs demonstrated successful progress through development when the entire process was under internal control and no external partner was needed for transfer and application. The RERC on Prosthetics and Orthotics created several instruments deemed absent but necessary for completion of laboratory research studies. The instruments were built and used internally as expected, resulting in new knowledge important to prosthetics design and which actually changed the fundamental understanding of gait biomechanics in textbooks.

Few Category 3 projects revealed evidence of external use to satisfy the requirements for transfer, although there were two noteworthy exceptions. The RERC on Telecommunications Access developed an instrument used to evaluate the accessibility of telecommunications devices for use by persons with various types, degrees, and combinations of functional limitations. The instrument–Product Design Idea Browser– is available to professionals and consumers on-line (Trace Center, 2004). The RERC on AAC developed a standardized instrument called AAC Literacy Software in partnership with Don Johnston, Inc., which licensed it for their corporate use. We were not able to obtain details of how the project progressed through prototype completion, when the corporate partner joined the process, or how the intellectual property was treated.

An internal development project designed to support research objectives, with no intent to transfer the results externally, is a legitimate endeavor.

The other 12 Category 3 projects that did not reach fruition fell into two forms of non-delivery. One RERC generated four prototype devices that were used internally to support research project objectives, including a test-bed for devices and a laboratory tool for measuring clinical performance. An internal development project designed to support research objectives, with no intent to transfer the results externally, is a legitimate endeavor. Statements about intent to transfer externally may be secondary to the internal need, or may be made as an afterthought in response to the review criteria. The narrative could instead explain why the instrument or tool was important for internal RERC use, and why there was little or no likelihood of transfer. Then the public expectations would be

aligned with the actual internal intent of the proposed project.

The second form of non-delivery included nine projects that were simply not completed in the RERC's five-year timeframe or in subsequent years. The majority of projects showed no evidence of achieving the prototype stage, and most projects did not even report initiating the project at any point in the grant cycle. The remaining projects were last reported to be involved in on-going laboratory testing, which may have ended at the completion of the grant funding cycle. Regardless of their levels of progress, a project that falls short of transfer fails to achieve results of use to the target audience, the project sponsor, or even other development projects with similar intent.

The Category 3 projects lack the Category 4 requirement for commercial market value, nor do they even require the Category 1 adoption and use by formal entities. They are most like Category 2 projects, where there is neither predetermined target audience nor does any audience have any expectations regarding results from those projects.

Category 4: Commercial Products (N=7 Successful Transfers)

More than half of the 78 development projects (*N*=44) described in the competitive proposals expected to achieve Category 4 transfers, i.e., to result in a new or improved commercial product. Of these proposed projects, seven projects yielded transfers to nine different industry or government entities. All Category 4 transfers came from three of the funded RERCs.

The RERC on Information Technology Access accomplished four of the seven Category 4 transfers. The RERC on Information Technology Access was one of the original RERCs funded by NIDRR. This RERC spent the past 25 years conducting pioneering research on accessibility issues, while maintaining an equally rigorous development program in partnership with innovative corporations in the emerging information technology field.

During the 1998-2003 cycle, the RERC converged a variety of development projects under the unifying concept of EZ Access™. These projects addressed audio/video/tactile screens, visual/acoustic redundancies, accessibility features for public fare machines, voting tablets, and ATM terminals. As part of this process, the RERC formed a partnership with Storm Interface (formerly Keymat Technology, Ltd.) to create a set of EZ Access keypads that could be purchased by companies implementing kiosks and other public information systems. Two keypad models (5-button and 8-button) were developed and are now offered by Storm via various electronic catalogs or direct sales (NewarkInOne, 2007). This joint development might be considered as yet another distinct transfer because the keypads are incorporated into the other transfers from this RERC. For the purpose of this case study, scoring this transfer was considered superfluous since the RERC has already accrued all of the points possible. For this same reason, the case studies did not attempt to quantify the RERCs continuing contributions to other electronic systems such as voting machines and automatic teller machines.

A company called isSound (formerly Productivity Works) integrated these EZ Access™ features into a product called pwKiosk™. IsSound donated the pwKiosk™ software (for use in accessible prototype kiosks designed by the National Cash Register Corporation) to the Smithsonian Institution in Washington, D.C. to commemorate the July 2000 commemoration of the Americans with Disabilities Act of 1990. Although isSound

vacated the accessibility industry and eventually went out of business, its investment and promotion of the pwKiosk™ raised awareness of the value of these access features and functions.

Examples of innovations resulting in more than one transfer success. The Touchscreen Web Kiosk was licensed to Eagle Collaborative Computing Services (ECCS, 2007). ECCS developed a set of accessible information kiosks for use in the National World War II Memorial in Washington, D.C. The accessibility features include the Trace Center's Touchscreen system integrated with its EZ Access™ techniques, which offer interface enhancements to make electronic systems accessible to people with a wide variety of impairments. ECCS had previously participated in a RERC-sponsored workshop for industry on access issues, so their awareness was heightened prior to this specific business opportunity.

The EZ Access™ was licensed to U.S. Postal Service for Automated Postal Centers (IBM, 2006). The U.S. Postal Service had contacted the RERC in early 2001, after the initial deployment and pilot testing of an earlier-model Automated Postal Center (APC). The Postal Service wanted to add accessibility into the APC before deploying it on a larger scale, so it circulated a bid to prime contractors, requiring implementation of EZ Access™ techniques. The RERC eventually provided technical assistance to the IBM Corporation on design, and to U.S. Postal Service project managers prior to completion of the final design. By 2004 more than 2,000 APCs were distributed in U.S. post offices, with thousands more forthcoming. It was certainly a highly visible transfer, and one of national significance. In the current case study, it counts as one transfer and earns the maximum of '7' points ('3' points for the prototype and '4' points for the transfer).

The EZ Access™ was licensed to ARINC Incorporated for Airport Paging System (CNET Networks, 2005). The Phoenix Sky Harbor International Airport requested bids to design and deliver a cross-disability accessible paging and information system. ARINC Incorporated, which specializes in transportation communications and systems engineering, contacted the RERC for technical assistance. After attending the RERC's five-day industry training course, i.e., Designing for Usability, Flexibility & Accessibility, in 2003, ARINC Incorporated continued to consult with the RERC. In 2004, it completed a certification process that was added to the EZ Access™ licensing contract. The fully functional system was unveiled in March, 2005, and is likely to be a model system for other airports nationwide.

The 'ShowSounds' feature was licensed to Microsoft® Corporation for use in all Operating Systems (Microsoft® Corporation, 2007). The RERC originally planned to improve the accessibility of both IBM's JavaOS and Microsoft®'s Windows 95/98 operating systems for users with hearing impairments – or anyone working in high ambient noise environments. The 'ShowSounds' feature permits any program to display a visual caption for any speech or sounds generated. Although IBM discontinued Java OS for Business in 1999, Microsoft® adopted 'Showsounds' as a standard feature in all subsequent operating systems released during this funding cycle: Windows 98, Windows 2000, Windows ME, and Windows XP. Microsoft® then added 'SoundSentry,' which displays a visual alert when the system generates any sound. Given that these features are standard in every Microsoft® operating system, this particular feature to enhance accessibility and usability

may be the most widely diffused transfer ever accomplished in the field of AT.

The RERC on Universal Design completed two Category 4 transfers with assistance from the RERC on Technology Transfer. In the first transfer, features of the RERC's prototype 'universal bathroom suite' were eventually integrated into the 'Freedom Line' of new bathroom products introduced by Lasco Bathware (Lasco Bathware, 2006). During the 1993-1998 cycle, the RERC on Universal Design developed components and a non-working model of a universal bathroom suite. The primary features were the ability to move the fixtures vertically and horizontally to accommodate users of various sizes, to adjust the shape and location of support systems, and to configure the shower space to accommodate a person, a bath chair, or a wheelchair. After proper disclosure, the University at Buffalo filed for provisional patent protection and attempted to market the invention to bath fixture manufacturers. After an unsuccessful period, the RERC on Technology Transfer was asked to lead the transfer effort. Our discussions with manufacturers revealed that no one would commit to such a broad redesign of multiple products without a commitment from a major customer. We identified several major potential customers in the hospitality and long-term care industries, and succeeded in engaging them in discussions with Lasco Bathware. They took an option to license the invention while they explored the potential relationships with these major industry customers.

Rather than licensing rights to the prototype invention from the University at Buffalo, Lasco Bathware opted to engage the Principal Investigators in a consulting contract to improve the features and functions of their new 'Freedom Line' of assisted care and barrier-free products. Engaging the PIs through a consulting contract enabled Lasco Bathware to access the expertise they developed through the federal funding to the RERC, without (a) having to pay any licensing fees to the university, or (b) the need to link their new product designs to the chain of innovation developed through federal funding. The faculty did disclose its invention and the university protected it in compliance with the requirements of the Bayh-Dole Act of 1992. Although neither the university nor the NIDRR as the federal sponsor could claim ownership of these new products, their availability in the marketplace satisfies the mission of the Rehab Act.

The RERC on Universal Design also licensed the 'Family Toilet Seat' to Maddak, Inc. (ABLEDATA, 2006). During its 1993-1998 cycle, the RERC on Universal Design developed a prototype of a universal toilet seat consisting of a series of toilet seats stacked one atop another. The RERC's 1998-2003 proposal included a plan to transfer this invention to the marketplace. The RERC disclosed the invention to the University at Buffalo, which filed for provisional patent protection. In theory, any user could select the appropriate seat height by lifting the excess seats out of the way. In practice, manipulating the excess seats raised issues of hygiene and securement. Institutional attempts to find a licensing partner were unsuccessful, so the RERC on Technology Transfer was eventually approached to review the device. Our review identified design options to accommodate multiple toilet seat users with fewer seats, and we had a relationship with Maddak, Inc., that possessed the compatible manufacturing capabilities and product lines. Maddak, Inc. liked the product enough to perform its own 'due diligence' and found an existing patent for a multi-seat system called the 'Family Toilet Seat.' Maddak, Inc. elected to license rights to manufacture the 'Family Toilet Seat' from the patent holder. We count this as a transfer because there is evidence that the work of the two RERCs clarified

market need and business need for Maddak, Inc., which led to the company's decision to introduce the product.

The RERC on Wheeled Mobility had a Category 4 transfer that involved licensing the Wheelchair Docking System to the Kinedyne Corporation. The development of a docking system superior to traditional strap-based solutions began with the work during the RERC on Wheeled Mobility's 1993-1998 cycle. The RERC aimed to define the parameters of an improved solution and to create new industry standards. The next generation Wheelchair Docking System was proposed in the RERC on Wheeled Mobility's 1998-2003 funding cycle, but the entire project was eventually transferred to the RERC on Wheeled Transportation Safety, when it was funded from 2001-2006. This second RERC was not studied because its inception date of 2001 fell outside the timeframe for inclusion. Both of these RERCs were operated by the University of Pittsburgh.

The three RERCs involved in all seven Category 4 transfers during the study period shared four procedural characteristics

All the while NIDRR was funding this work, the University at Pittsburgh had secured parallel funding through the National Institutes of Health Small Business Technology Transfer Research (STTR) program with Phase 1 funding in 1997-1999, and Phase II funding from 2001-2005. The work was conducted through a collaboration involving the University of Pittsburgh, the University of Michigan, and the Kinedyne Corporation (University of Pittsburgh and Kinedyne Corporation, 2005). Through this combination of funding, the RERC team was able to complete the broad scope of work related to the standards, the prototype, and the related testing under various expected gravitational force loads, and in a variety of transportation systems.

Although considered a successful transfer, because Kinedyne elected to file a provisional patent in 2004 based on the collaborative work, in the summer of 2005 the company declined to file for a full patent or to pursue commercialization. As of this writing, the University of Pittsburgh's Office of Technology Management had filed provisional patents for the inventions claimed by the university's team members, and both versions of the prototype Docking System–MK-III and PV-1–are available for license and commercialization.

The total amount of federal financial and personnel resources invested in the Wheelchair Docking System over the past decade is unknown. Nor is it known to what extent the contributions and claims of the various sponsors (i.e., U.S. Department of Education, National Institutes of Health), and multiple investigators from each of the three collaborating entities (i.e., University of Pittsburgh, University of Michigan, Kinedyne Corporation), might complicate any offer of licensing rights to a future potential manufacturing partner.

The three RERCs involved in all seven Category 4 transfers during the study period shared four procedural characteristics:

1. All projects targeted specific industries and worked diligently to learn their needs and incentives. They treated the manufacturers in those industries as primary customers for the internal prototype, and presented the intended end user beneficiaries as their customers.

2. All project managers established and cultivated close working relationships with multiple decision-makers within target corporations, and calibrated emerging prototype features and functions to reflect the dynamic nature of specific market opportunities.
3. All transfers accomplished in this funding cycle resulted from prototypes developed in prior cycles. This suggests that the time from full internal development to transfer may be longer than expected by external observers.
4. All projects constructed prototypes to address broad issues of access and use, rather than address niche markets or make minor modifications to existing products. This approach created business opportunities with high market relevance.

Achieving both high internal process rigor and high external market relevance seems to be the critical standard for accomplishing the very difficult result of transfer for commercial use.

Attributes of RERCs That Drive Success

Two attributes that are characteristic of successful projects include (a) *a comprehensive plan,* and (b) *planning and coordination*. Each of these attributes are discussed in more detail in the following section.

A comprehensive plan for all development and transfer projects. The Trace Center, at the University of Wisconsin, Madison had two RERC proposals that are distinctive from the other nine in that they describe a thorough plan for accomplishing the transfer outcome for development project outputs. Like the RERC on Technology Transfer, the Trace Center's two proposals describe the development and transfer process as one that is entirely different than the process used for conducting research projects. The narrative sets realistic goals, acknowledges limitations and describes the RERCs' roles in an ambiguous and constantly changing application environment.

Two attributes that are characteristic of successful projects include (a) a comprehensive plan, and (b) planning and coordination.

The narrative presents a seven-stage model for advancing development projects from concept to product (see Figure 2). It is applied to all projects listed under the development section. The model is the most detailed of the 11 RERC proposals studied, showing the highest awareness of the complex process involved.

The Trace Center notes that stages after laboratory simulation (Stage 3) should be conducted by a company or in partnership with a company. This ensures that the product is poised to fill to a corporate need, and that the product's features and functions are tailored to that company's specific interests and capabilities. The Trace Center has sufficient expertise in its industry and its products to proceed with the first three stages independently. Parties with less expertise risk making an irrelevant product if they complete even the first three stages independent of a corporate partner. If the initial effort is based on an internal champion's assumption, then the temptation is to continue investing resources so long as that prior ego-investment remains untested.

Adding the technology transfer officer to the site visit would put the host institution on notice that grant funding is intended to result in transfers, and that the institution should work diligently to accomplish transfers…

Even with the Trace Center's expertise, its model requires a stage-gate approach. It seeks industry input before investing more time and resources. The RERC states a willingness to hand off the project to appropriate industry partners at the earliest opportunity, but it commits to implementing the full seven-stage model as necessary. This is evidence of a business approach to transfer rather than an academic approach to development; the project deliverables are the focus of the effort, and the organization commits those resources necessary to achieve the result, rather than permit other factors to change or terminate the project.

Planning and coordination with institutional administration. Another important hallmark of the Trace approach is its awareness of its role in a larger technology transfer process, specifically its planning and coordination responsibilities with the University of Wisconsin- Madison.

All RERCs are sponsored programs managed by a Principal Investigator, but the federal funding is actually granted to the host institution. The regulatory and fiduciary responsibility rests with the institution's administration, and this responsibility includes appropriate handling of intellectual property. Since the Bayh-Dole Act of 1980, research universities have established offices for technology transfer. Therefore, RERCs should work closely with their own office of technology transfer when their proposals intend to generate intellectual property and result in transferable materials. The Trace Center acknowledges that the University of

Stage 1 – Collecting ideas and identifying an opportunity to apply an internally developed discovery to an external need in the market (supply push), or identifying an opportunity to develop a solution in response to a problem of the external marketplace (demand pull).

Stage 2 – Designing a paper that involves RERC and external consultants to articulate the problem and solution at a conceptual level.

Stage 3 – Demonstrating that what is described in the paper design is feasible in tangible form.

Stage 4 – Constructing a full prototype to test both the product's compatibility in the target system, and the utility of new function to intended end-users.

Stage 5 – Reducing costs for design, fabrication and materials at an estimated scale of production to permit a computation of required investment and future returns.

Stage 6 – Commercialization planning to anticipate all the downstream activities involved in production, distribution, sales and marketing, support and product line integration.

Stage 7 – Disability group sign-on – validation by target users or representatives of the final product, although this final review does not substitute for the essential consumer input at prior stages of conceptualization and development.

Figure 2. **Trace Center 7-stage model stage model for advancing development projects from concept to product.**

Wisconsin-Madison's Wisconsin Alumni Research Foundation (WARF) is responsible for intellectual property protection and licensing for its two RERCs. In the cases studied here, WARF cooperated with the RERC to ensure it could attract a partner for the RERC's accessibility inventions. In some cases WARF tailored its standard licensing practices facilitate the licensing agreement. In recognition of the U.S. Postal Service's (USPS) quasi-government role, and its support in prior RERC cycles for related accessibility studies, its license royalty was actually waived for the APC application.

Such collaboration with institutional authorities is particularly critical for small market innovations, yet it is rarely seen in practice. One way to increase university support for the transfer of project outputs would be to require the university's technology transfer officer to participate in the sponsor's site visit. The sponsor typically conducts a site visit to the grantee prior to issuing the grant award, to confirm the grantee's capabilities and resources, and to confirm university management's commitment to the grant team. The site visit usually includes meetings with the (a) PI and colleagues, (b) Dean of the School where the program is housed to confirm infrastructure, and (c) Vice President of Research to confirm accounting and audit systems. Adding the technology transfer officer to the site visit would put the host institution on notice that grant funding is intended to result in transfers, and that the institution should work diligently to accomplish transfers even if the markets are small and the royalty revenues are correspondingly low.

Involving multiple investigators or multiple agencies in a single project may complicate the identification and protection of intellectual property, but these circumstances do not preclude doing so. The RERC on Land Mines was operated by a not-for-profit entity called Physicians Against Land Mines (PALM), which changed its name in 1999 to the Center for International Rehabilitation (CIR). The PALM/CIR collaborates with the Rehabilitation Institute of Chicago and Northwestern University. The nexus of this collaboration is Northwestern's Feinberg School of Medicine located within the RIC. The institute and the university jointly support the Northwestern Prosthetics-Orthotics Program (NUPOC), the long-time home of the RERC on Prosthetics and Orthotics.

> The regulatory and fiduciary responsibility rests with the institution's administration, and this responsibility includes appropriate handling of intellectual property.

This case involved the development and transfer of a novel sand-casting system for trans-tibial sockets, intended for use in nations where high-tech systems are impractical. The project team was lead by Dr. Yeonchi Wu, a PALM staff member, who was supported by (a) Mr. Jack Uellendahl, the RIC's clinical director of prosthetics services; and (b) Dr. Dudley Childress, the lead rehabilitation engineering professor from the Northwestern University-based RERC on Prosthetics and Orthotics.

In this case, the resulting invention was solely claimed by Dr. Wu so the patent was solely assigned to PALM/CIR (i.e., the prosthetic system was issued U.S. Patent #6,709,617 on March 3, 2004). Because Dr. Wu was solely funded for this work by one federal agency, the project participants from other entities did not claim ownership, and there were no inter-agency conflicts over ownership. As noted previously, this was filed as a defensive patent,

to preclude others in the U.S. from claiming the invention and thereby preventing PALM/RIC from freely distributing the invention worldwide. Given the intended target nations, one would expect this defensive strategy to also include the filing of international patents, but no information is available on such actions. The RERC's PI had previously noted that the patent application through PALM was relatively fast and uncomplicated. His experience with a patent claim on a different project and through one of the other participating entities was comparatively slow and complex.

Another PALM project incorporated ongoing research and development at the Northwestern RERC on Prosthetic and Orthotics for a low-cost prosthetic foot design for use in low-income countries. Like the sand cast system, the 'shape foot' (later called the 'shape-and-roll foot') was designed to be transferred through a no-cost distribution system (Category 2). The product was developed and tested and a provisional patent was granted to a team of inventors associated with Northwestern University in 2002. Because a provisional patent gives the inventor a year of protection in which to file a full patent application, the full application was submitted in 2003. The application was amended in 2004, rejected for unspecified grounds in 2005, and the application was listed as 'abandoned for failure to respond to office action' in 2006. Without further explanation from either of the collaborating RERCs, this analysis gives no basis for assessing Northwestern University's decision to abandon the patent application, nor PALM/CIR's decision not to pursue assignment of rights over the invention. Nor are there grounds for determining the defensive value of a patent for this freeware invention.

In the context of the RERC program, the University of Pittsburgh exemplifies the complexities inherent when operating multiple collaborative ventures within the same area of application. The RERC on Wheeled Mobility, having operated for several funding cycles, subsequently added the RERC on Wheelchair Transportation Safety. Both RERCs share space, personnel, and resources with many other sponsored research and development projects funded by various sponsors and which operate at multiple university, medical center, and community-based locations.

Tracking and assigning ownership of intellectual property is easiest when the claim is submitted by one investigator, or an internal team of collaborators, based on work funded by one sponsor. The issue of co-invention gets complicated when the claim includes people outside the institution, particularly when claimants include people from different sectors (e.g., academic, industry, and/or government). The University at Pittsburgh's two RERCs operate within the most challenging intellectual property circumstances identified in the case studies. These RERCs involve a complex mix of organizations, investigators, extramural sponsors, and overlapping project activities. Any one specific project may span multiple RERC funding cycles, and in some cases also spans both RERCs. These projects involve multiple investigators with combinations of appointments at the host institution, joint appointees at other institutions including medical centers or research universities, and even positions in collaborating corporations.

Any potential transfer partner will expect a clear intellectual property history, while uncertainties or complexities will discourage involvement.

To further complicate matters, different elements of the same project may have also received prior or subsequent funding from other sources such as the National Institutes of Health, the Department of Veteran's Affairs, and most recently, the National Science Foundation. For University at Pittsburgh projects with supplemental funding from Small Business Innovation Research (SBIR) or Small Business Technology Transfer (STTR) programs, the partner company may be a company in the AT or mainstream marketplace (e.g., Kinedyne), or may be a small business enterprise established in cooperation with RERC investigators (e.g., Three Rivers Holding LLC). Those able to explain the management of intellectual property in such a complex mix of sponsors, participants, and projects is were not accessible to the study. However, this example reinforces the need to track invention creation and properly disclose them through the appropriate channels. Any potential transfer partner will expect a clear intellectual property history, while uncertainties or complexities will discourage involvement.

Reasons Underlying the Low Level of Success Achieved

Seventy-five percent (*N*=59) of the 78 proposed projects did not result in any type of transfer. The information compiled through the case studies provides some reasons underlying this low success rate and their relative impact. Insufficient funding as a common explanation for project failure is not appropriate here as the RERCs received the full funding they budgeted for each project within their overall grant proposals. By knowing in advance that the requested level of funding was provided, we can better assess the contributions of non-monetary factors, even if those factors included the allocation and disbursement of the funds supplied by the sponsor.

At the center of the various factors are the people responsible for conducting the proposed work. Planning, implementing, and coordinating multiple complex projects requires a set of skills typically acquired over years of project work at successively higher levels of supervision and responsibility. People with a record of successful individual scholarship and the ability to write a persuasive proposal, are assumed to have those skills when they are appointed as a PI for an RERC award. Regardless of their prior experience, all at once they receive full funding for staff and materials to initiate the entire scope of work, and the five year timeframe begins.

Nearly half of the total number of unsuccessful projects appeared to experience problems at the most elemental level of project management and personnel resource allocations.

We found that the 59 projects that did not yield transfer outcomes clustered into four groups representing different core problems: (a) *Project Management/Staff Allocation* accounted for 43% of the total; (b) *Inability to Attract a Transfer Partner* accounted for 37% of the total; (c) *Loss of Original Transfer Partner* accounted for 14% of the total; and (d) *Technical Issues* accounted for 6% of total. Each of these and related issues are described in more detail in the following sections.

Project Management and/or Staff Allocations

Nearly half of the total number of unsuccessful projects appeared to experience problems at the most elemental level of

project management and personnel resource allocations. No matter how great a project's potential value, it cannot be realized if fundamental practices are not followed. Three problems at this fundamental level are described below.

Failure to launch the project. Twelve of the projects (21%) showed no evidence of ever being initiated. They were proposed as important, received sponsor support, yet apparently were never launched. The lack of information on specific personnel and actions leaves us unable to provide any credible explanation.

The RERC may have proposed too many projects, judged these development projects less important over time, or may have had more compelling incentives competing for its time and effort. One such incentive is the ongoing research program within every RERC. The majority of PIs are academic faculty, and their reward systems center on research publications, along with the other institutional demands of teaching, mentoring, and governance. These demands can easily make development projects a lower priority.

RERC allocation of staff time should be appropriate for the tasks ahead. The general practice reported in the project proposals was to allocate some percentage of the PI's time equivalent to less than half-time and in some cases less than one day per week to the RERC *as a whole*. Then, the PI's time was further divided into even smaller percentages of time devoted to each individual project. As a result, the PI might on paper be spending as few as several hours per week on average on a given project. One may fairly ask how such a low level of effort might be expected to contribute something of value to a product or an industry.

Even within a specific RERC, personnel time is allocated across research, development, dissemination,and training projects. The relatively low priority of development projects is suggested by the time allocations for the assigned personnel. Full Time Equivalent (FTE) allocations of anywhere from one day per week (20% FTE) down to two hours per week (5% FTE) for the Project Director, compare unfavorably to industry-based projects where managers and staff may devote their full-time, and where projects may involve entire teams of full-time professionals. The PIs supplement their own time with time allocations from support staff–also typically a part-time percentage of support.

One method for distinguishing development projects from research projects is to develop criteria related to progress according to generally accepted milestones that successively lead to increasingly visible and tangible results.

Given the research and education mission of university faculty and even of the RERC programs, specific grant projects may also allocation time from Graduate Research Assistants (GRAs). By campus regulations, GRAs cannot work more than half-time, so any allocation of GRA time is already taken from people who are devoting at least half of their time to their highest priorities of classes and coursework. The potential contribution from GRAs is further diminished in projects spanning multiple years because the projects will likely extend beyond the each particular GRA's window of participation. It is fair to question the productivity one might expect

from an assemblage of part-time people with periodic substitutions.

If one compares the RERC approach to project staffing to standard business practice, it seems to fall short of corporate expectations where teams of professionals focus their full time and attention–and overtime at crucial periods of transition–on the specific project at hand. Major projects typically require the undivided attention of key personnel, particularly the managers responsible for accomplishing the deliverables.

One method for distinguishing development projects from research projects is to develop criteria related to progress according to generally accepted milestones that successively lead to increasingly visible and tangible results. By comparing the time allocated to activities associated with milestones that are plotted along a project timeline, one could better assess whether the management team has accurately assessed the full weight of all projects in the RERC, and whether the personnel assigned to each project and activity are sufficient to deliver the expected results in the anticipated timeframe. Periodical monitoring of progress according to these tangible deliverables would readily determine whether progress warrants continued funding.

Loss of internal champion. Eight of the proposed projects (14%) were terminated because the Project Director left the RERC. This explanation offers a contrast between the academic and business models relevant to development projects that intend to generate products to improve the quality of life for people with disabilities.

In the business model, when a key manager departs a project, the company replaces the project manager. In the academic model, project managers typically invest neither their own nor their institution's funds, but instead rely on resources obtained through a third party. Although the proposal may reflect a perceived need, the project's chief motivation may be the intellectual curiosity of its manager. For example, when this manager abandons the project or departs, the original motivation is gone. The business model, on the other hand, includes a plan of succession for the project director, as well as cross-project coordination among managers to ensure continuity during periods of disruption.

In the academic model, faculty members generate new knowledge through objective and publicly disclosed research methods. Their expertise is transferable from one academic setting to another. They may cease working on a hypothesis in one location and then resume the work in another location, without a great deal of concern over proprietary issues. The transfer and commercialization activity of the business model is less mobile and more proprietary. The departure of a team leader may terminate the effort, the host institution may not be willing to share ownership or control over intellectual property generated through discovery, and other stakeholders involved may not be positioned to work with a relocated PI.

Given that development projects differ from research projects, there is no reason not to include succession plans in the proposal, along with an explanation of how the various projects will continue under a variety of changes in constraints and opportunities.

Given that development projects differ from research projects, there is no reason not to include succession plans in the proposal, along with an explanation of how the various projects will continue under a variety of changes in constraints and opportunities.

Project period expired prior to completion of testing/trials. Another five projects (8%) did not reach the transfer change because the project funding and time schedule expired before bench testing or customer trials were completed. These projects experienced some combination of delayed start, slow progress, or stops and re-starts due to personnel changes or problems during the testing/trial protocols. One might assume that projects planned for a five-year window of activity are likely to experience delays or problems, but the proposals gave no indication that such issues were addressed by incorporating slack time into the project timeline. Moreover, there was no mention in any project of using project-planning tools to help avoid fatal delays and complete projects within the allocated time and budget.

In some cases, it is difficult to determine the actual scope of the project and the level of resources required for completion. The RERC on Vision Enhancement had several development projects supported with funding across multiple RERC funding cycles or from related Field Initiated Programs. In some instances these projects also involved subcontracts from companies with SBIR funding. To the extent these projects demonstrated evidence of progress to prototype outputs or transfer outcomes, it is difficult to assign credit to participants or ownership to Federal funding sources.

Inability to Find a Transfer Partner

Twenty-two projects–more than one-third of the total number funded–failed to generate sufficient external interest to demonstrate evidence of transfer and use outside the RERC. Even when RERCs follow sound protocols and generate a viable prototype, their devices may not be attractive to commercial partners. For example, the RERC device may compete with products in proprietary development by the company, or the device may fall outside the company's current or planned product mix, which also requires a close working relationship to deliver a prototype that matches a constantly moving target. In some cases, the device may offer capabilities that run contrary to the company or industry position.

Avoiding a premature end to a project requires front-end validation of a legitimate and unmet need among the end users and within the market mechanisms that serve them.

The only way to avoid this conflict is to work closely with the intended transfer partner. Even if the intended transfer partner does not divulge its internal work, it may be willing to steer the RERC's effort to an area where external innovation is welcome.

Avoiding a premature end to a project requires front-end validation of a legitimate and unmet need among the end users and within the market mechanisms that serve them. As noted in prior publications, a *supply-push* project is where the champion assumes the need, generates a solution, and then searches for the target users who may not even exist (Leahy, 2003). Conversely, *demand-pull* projects begin with a validated need in the target audience, with interest in addressing that need expressed by a viable transfer

partner (Bauer, 2003). The evidence is typically obvious in a proposal meeting the demand-pull criteria, whereas a supply-push proposal is rife with assumptions.

In some cases, proposal narrative statements regarding an intent to transfer may be there as an obligatory component to meet the requirements of the review criteria, rather than as an earnest commitment to accomplish the results. This seems to be the case for some of these projects where there is no evidence of efforts to either protect the intellectual property that results from the funded activity–although this is a requirement under the Bayh-Dole Act of 1980. Nor is there evidence of attempts to offer the prototype product to either potential commercialization partners or members of the target audience.

Loss of External Partner

At the proposal stage, eight projects had identified a candidate partner for transfer, some of which committed to collaborative activity during the project cycle. However, during the five-year timeframe, the projects lost their partners and were either unwilling or unable to find another partner and realize the transfer goal. Several partner companies simply went out of business during the project life cycle. The RERC on Tele-Rehabilitation linked its transfer plans for multiple projects to a single company. This small business (Guynes Designs), which manufactured a completely unrelated product line, went out of business during the RERC's funding cycle.

The lesson for academics in this is that it's important to assess whether the partner company is healthy enough to stay in existence. Unlike universities and academic departments, companies can go out of business at almost any time, and for any number of reasons. While there is no guarantee of stability–no 'tenure' for companies–one can perform an operational and financial analysis of the company to determine its state of health. In the private sector such a review is called 'due diligence.' Failing to perform due diligence is as erroneous as a university's failure to control variables in a research projects.

Occasionally, a potential transfer partner's robust health may be a downfall, though. In some cases, RERCs lost healthy companies due to mergers or acquisitions involving other companies, or changes in executive-level management. Since the RERC projects were not core activities of the initial partner companies, the changes prompted new executives to re-assess the project's relevance to their internal goals. In one case, a corporate merger terminated the RERC collaboration, but it did not prevent the company from independently introducing a product with features and functions reflecting the intent of the original RERC projects. Should a RERC pursue intellectual property claims on behalf of its institution and the sponsor? Or are there benefits to simply promoting the new product's existence to maintain goodwill with the private sector? These questions merit further consideration in the future.

An important distinction between academic and corporate culture is the presence of a 'chain of command.' Companies have hierarchical decision-making structures where thee transfer process involves a successive series of activity stages and decision gates. Each activity stage culminates in a decision to proceed or stop. The decision to proceed is bounded by the next phase of activity, which will be followed by yet another decision gate. A decision to proceed at any one gate, only leads to the next gate. A decision to stop at any one gate ends the project. The inability of any party to deliver the information or resources necessary to complete the current phase of activity, typically defaults to a negative decision gate. The decision to stop or

proceed is influenced by business, management, and even competing personalities within the transfer partner, with each decision to proceed representing an additional level of internal investment. The stakes rise with each stage which itself makes progress more difficult for corporate decision-makers who are inherently risk averse. The academic culture lacks such hierarchies, so a development project with potential transfer value may be perpetuated by a group or successive series of groups of faculty and students who are involved in the process of analysis and discovery. It may not even occur to anyone involved to impose a stage/gate decision framework on the activity, so long as it serves an intellectual purpose.

Another gap between academic and corporate cultures is the ability to control variables.

Another gap between academic and corporate cultures is the ability to control variables. Academic research adheres to rigorous methods and it proceeds deliberately from one stage to the next; alternatively, corporate culture may present temporal opportunities spontaneously and unpredictably. Meshing these cultures is a challenge inherent in the relationship between academia and corporate culture. Researchers apply appropriate methods to their studies, so they can control variables and thereby have confidence that the results are due to the experimental effect. This is important for RERCs where project timelines extend over a period of five years. In this example a research project may be proposed in 1998. Regardless of whether the study involves bench testing or human factors, the investigator will assemble the components, control and manipulate the relevant variables, and thereby generate the results. The actual study may occur in Year 1 or even Year 5 and the availability of resources, the opportunity to interact with the variables, and the results themselves will vary little. The empirical study is deliberately constructed with high rigor in the methods to ensure the results are objective and replicable.

Unlike research projects, the timing is absolutely critical for a development project involving external partners and responding to an immediate market opportunity. The dynamics that made the partners and opportunities present in 1998 may change unpredictably over time. If the project is initiated immediately while the opportunity is still somewhat close to the proposed description, there is a greater chance of accomplishing something close to the original plan. If the project starting point is delayed, the circumstances may change enough to make the opportunity unrecognizable. In the latter case, the external partners will move on to other opportunities by choice or by necessity. The relevant variables in the external world are in flux and uncontrollable, which means that the emphasis on rigor is in the results rather than in the methods. One can hit the target in any number ways without penalty, as there are no cultural incentives to be objective or to accommodate independent replication.

Overall, commercial development projects are more time and context sensitive than laboratory research projects. Ironically for RERCs, the research projects are likely to garner more immediate attention because they are more closely tied to the incentives and rewards for the faculty involved in the work. These incentives and rewards are themselves closely tied to timeframes in two ways. First, faculty typically have a fixed time period of five to seven years to demonstrate productivity and receive permanent employment (i.e., tenure). Second, tenure decisions are primarily based on the person's record of publication, and there is a time lag

of from one to several years between obtaining results from a research project and having those results published in a peer-reviewed journal. Faculty have every reason to emphasize the completion and publication of their research activity, and none to emphasize development.

Technical Issues

Professionals in any sector understand the risk/return ratio, where the riskier ventures have a lower probability of success and therefore demand a higher rate of return. Venture capitalists underwrite the high costs of multiple opportunities with potential for high returns, as one success can repay the investment in a dozen failures while still yielding a substantial profit.

> …commercial development projects are more time and context sensitive than laboratory research projects.

R&D projects experimenting at the boundaries of technical feasibility expect high failure rates, but only when the failures are related to technical issues. In the RERC cases, only 6% of the projects that failed to achieve a transfer exhibited evidence of technical barriers. Two of the four projects had their technology platforms rendered obsolete by laboratory advances made elsewhere. In the two other projects, technology-based products developed elsewhere in parallel beat the RERC projects to the marketplace.

In one case, exploratory work on a tinnitus analyzer was initiated in the RERC on Hearing Enhancement. A very similar development project was initiated the following year in a newly established Veteran's Administration (VA) R&D center. Although the VA work started later, it was progressed faster and the resulting tool was transferred to the internal market of VA vendors and customers. While the RERC's project resulted in a laboratory instrument still in use by its corporate partner (Mimosa Acoustics), the presence of the VA's instrument eliminated a transfer opportunity from the RERC to the VA. One might question whether the same or similar work should be funded by two different agencies at the same time? Is there competition for funding between federal programs, and to what extent does such competition invite or preclude collaboration?

> …it is incumbent on the RERC investigators to remain aware of the current state of the practice and evolving state of the art, in technologies used as platforms for delivering new product innovations.

Regardless of the particulars, it is incumbent on the RERC investigators to remain aware of the current state of the practice and evolving state of the art, in technologies used as platforms for delivering new product innovations. Changes in technologies and new product introductions both require a reassessment of the value of continuing projects initiated prior to those events.

Content Review Using PDMA Best Practice Guidelines

The retrospective case studies documented the progress of each of the 78 projects on achieving their intended development and transfer goals. Every project has unique attributes that can confound attempts to

generalize or make summary conclusions. The absence of input from the majority of RERC principal investigators necessitated our use of additional secondary analysis. We turned to a content review of the proposal narratives to determine the extent to which they demonstrated attention to the factors considered critical to new product development.

The content review looked for evidence in the narrative of the PDMA's Seven Forms of Essential Preliminary Analysis, based on the following three assumptions: (a) by definition, preliminary analyses are performed prior to deciding to initiate a development project; (b) favorable results from these preliminary analyses add credibility to the proposal project for both the sponsor and transfer partners; and (c) proposal authors have no reason to exclude a description of such preliminary analysis if they were indeed completed.

> Every project has unique attributes that can confound attempts to generalize or make summary conclusions.

Therefore, any narrative description related to these seven forms of preliminary analysis is treated as evidence that they were performed while their absence indicates they were not. To the extent these preliminary analyses were addressed, we can be confident that the approaches taken were valid and appropriate. To the extent these analyses were not addressed, we identified a gap between investigators' stated intentions and their use of standard practices. Such gaps represent an opportunity to increase RERC awareness of accepted practices for development projects, analogous to those applied to research projects. Their presence or absence in the narrative was rated on a four-point scale, with a score of '3' meaning that the analysis was fully described in the proposal.

Presented in Table 6 are the summary scores across all projects and all RERCs for each of the seven forms of critical preliminary analysis. The numbers represent the average score for all seventy-eight development projects.

Content Review Summary

Overall, the RERC project narratives contained simple declarative statements without substantiation to the extent the seven forms of analysis were even considered. The two forms of analysis with the lowest scores were *Allocation of Resources* (0.24) and *Initial Screening for Need and Demand* (0.75). These first and last in the list of seven may be equally and

Table 6
Evidence of Seven Critical Forms of Preliminary Analysis in RERC Proposals

Critical Form of Preliminary Analysis	Score Range 0–3
Initial Screening for need and demand	0.75
Technical Assessment	1.60
Customer Interest in Build/Buy	1.00
Confirm Key Collaborations	1.43
Assessment of Uniqueness	1.06
Project Implementation Plan	1.53
Allocation of Resources	0.24
Average for all 78 projects	1.09

crucially important to eventual transfer success. Without a valid need and demand, there is no legitimate justification for initiating a project. And without the appropriate allocation of resources to ensure timely completion of the other critical tasks, the entire project may fall short of the intended goal.

Without a valid need and demand, there is no legitimate justification for initiating a project.

An alternative explanation for the lowest score in the *Allocation of Resources* category is that RERC grant proposals contain budget summaries *and* personnel loading charts in sections of the document not reviewed in this study. However, that explanation only accounts for summary information possibly residing elsewhere. It is still reasonable for any project plan to describe how the budgeted resources will be used. There should be a detailed work plan for the overall project as well as precise descriptions for the first 12 to 24 months of activity.

Slightly more attention was paid to issues related to *Customer Interest in Build/Buy* (1.00), and *Assessment of Uniqueness* (1.06). Even then the scores only reflected the presence of simple declarative statements without substantiation. It should not be surprising that all four of these issues relate directly to the two factors accounting for 84% of failures to achieve transfers in the prior results sections for *Project Management/Staff Allocation* and *Inability to Attract a Transfer Partner*.

The two highest scores--*Technical Assessment and Project Implementation*--were closely linked within the narrative. Wherever we found narrative content addressing these forms of preliminary analysis, it was in the context of the technical aspects of prototype construction and performance, and the related implementation tasks dealing with the technical aspects of the prototype. The narrative substantiated the project team's approach to engineering, reflecting their confidence in their technical expertise. It is evident that in the aspects of the development project where the project team has in-depth knowledge, it demonstrates that knowledge in a manner intended to persuade the reviewers of their ability. One is left to infer why the same level of detail is not present for the other factors, which are deemed equally critical by practitioners in the field.

The content review shows that factors considered critical to commercial success do not commonly appear in RERC development project narratives. This indicates a critical gap between the models and methods used by academic researchers to implement their stated intentions, and industry's standard practices for achieving product development outcomes.

No RERC scores showed sufficient and consistent uni-directional variance from these summary scores to merit specific discussion. The variability in content review scores within and between RERCs seems reasonable, given that the evidence sought in the narrative is based on criteria that are not part of the original proposal criteria. That is the precise point of this particular content review exercise, i.e., the sponsor criteria used to present and review plans for development projects do not specifically address the seven preliminary analysis considered essential to standard product development practice, nor do they address the four factors considered critical to commercial success.

Combined Results from Transfer Achievement Index and Content Review

Presented in Table 7 are the average scores across the 11 RERCs studied. RERCs accomplish less than 50% of what they intend to with about 90% of those accomplishments terminating at the output stage. When viewed in light of the stated goals of the Rehab Act, RERCs accomplish less than 10% of the outcomes that result in new or improved products reaching the targeted end users.

The PDMA factors relating to successful outcomes are shown to be under-represented in the proposal narratives with little information to suggest use of the seven forms of preliminary analyses. There was no clear or predictive relationship between mention of PDMA criteria in the narrative and RERC project success. This may be because the level of detail provided did not reach a threshold critical to representing the difference between success or failure. Most of the content relating to the PDMA factors concerned the achievement of the technical goals related to prototype (output) performance, and not to the successful transfer (outcome) to an external partner. This internal focus is appropriate for research projects generating knowledge, but not for development projects requiring external investment.

In the absence of generally accepted methodologies, development projects are vulnerable to a wide range of barriers to progress, including invalid problem definitions, ineffective planning and implementation, disruptions from intervening external variables, and sub-optimal allocation and expenditure of project resources. All of these are explored in greater detail in the following section.

In the absence of generally accepted methodologies, development projects are vulnerable to a wide range of barriers to progress,

Discussion

Barriers and Limitations of the Study

Low PI response rate. We expected the initial independent review of secondary sources to provide basic evidence of what happened in each project. We then expected that input from PIs would fill in gaps about what happened, while also providing more essential information on why projects did or did not accomplish their objectives. Unfortunately, the first year's call for input resulted in no responses from the 11 RERCs under study, but one response from a 12th to confirm it had no transfers planned or accomplished. A series of follow-up requests in the second year resulted in a telephone interview with one RERC PI. This was followed by a more exhaustive search of secondary sources for evidence of progress in

Table 7
Evidence-Based Values for RERC Development Projects with Transfer Intent

	N Projects Proposed	Potential Transfer Value (PTV)	Actual Transfer Value (ATV)	Transfer Achievement Index (TAI)	PDMA Preliminary Assessment (0.0 – 3.0)
Average for 11 RERC's	7	37	18	46%	1.09

the study's third year.

Distributing semi-final case narratives to all PIs drew responses from the PI of two RERCs in which the RERC PI and team members actually reviewed and revised the case narratives. Their input clarified several project cases where the roles and responsibilities were ambiguous in the secondary source materials. It is important to note that the RERCs that eventually consented to interviews did not appreciably change their individual project scores, nor did they affect their overall standing among the 11 RERCs. After this study's results were presented to NIDRR and all RERCs in 2007, one additional RERC submitted additional documentation of external use, which did change their score and their overall standing.

This one example of how intensive collaboration on the case studies demonstrated that we could not presume too much regarding the details of the cases for the other nine RERCs. The final RERC response rate of 27% (3 out of 11) forced us to focus on the objective evidence of progress and to limit speculation on why these results were or were not achieved.

Absence of project management tools. In the process of benchmarking project progress from initial idea through transfer and use by external parties, we expected to collect data on the resources consumed in each stage of activity. By knowing what percentages of personnel were allocated and during what timeframes, we hoped to identify thresholds for these resources. For example, if all successful transfers involved a project director committed at two days per week (.40 FTE), we could suggest that as the minimum commitment level. Similarly, if all successful transfers within any product category required a minimum period of elapsed time, or if none transferred after a maximum period of elapsed time, we could set some thresholds for internal planning and external review purposes.

However, we were not able to extract such specifics regarding personnel, financial, or time allocations from secondary sources. Follow-up queries to RERC PIs suggest that none of the RERCs applied project management tools; or, if such tools were used, no RERC maintained a record of resource investment by project and over time. Without such tracking, the project was unable to perform any quantitative analysis on resources expended, or establish thresholds for consideration by any of the stakeholders in the process.

The retrospective case studies identified multiple critical factors that exert their influence early in the development and transfer process.

Answering the Study's Three Research Questions

Question 1: Which factors critically facilitate or inhibit the technology transfer process within and across the cases examined? The retrospective case studies identified multiple critical factors that exert their influence early in the development and transfer process. These factors involve valid problem definition, accurate resource planning, and careful management of project implementation. Errors in these early stages of development activity generally preclude success at the later transfer phase.

Factors thought to facilitate the transfer process were not frequently evident in the analysis of the proposal narratives or subsequent documents, although they are well documented in industry manuals such as the *PDMA Handbook of New Product Development*

(Kahn, 2004). To the extent these factors were addressed in the pre-transfer activity, their value was evident in the eventual progress to prototype and transfer achieved.

Overall, the factors that facilitate or inhibit successful transfer are well documented in product development literature and are routinely addressed by private sector companies. The scant evidence in the case studies suggests a lack of familiarity with business practices by people with expertise in research practices. This suggests that the phrase 'research and development' may connote an assumed synergy not substantiated by the available evidence.

Question 2: Which facilitating factors appear to be innovative, particularly for addressing the constraints inherent in the AT marketplace? Although the facilitating factors might appear novel to those trained in the academic research model, they are considered standard practices to those trained in the business model. The business model already distinguishes products for the mainstream market from those for niche markets, so the constraints of the AT marketplace are analogous to those in other industries.

Of the RERCs studied, the two operated by the Trace Center demonstrated the most innovative approach to applying the standard methodologies of new product development and transfer. The Trace Center's seven-stage model (see Figure 2) is embedded in the singular goal of accomplishing the transfer of the internal innovation through an external partner, and then out to the target audience. Its ability to begin with the end in mind goes beyond even the business model's definition of transfer to the external partner, and instead sees them as a necessary intermediary to impact the lives of people with disabilities.

The two RERC proposal narratives authored by the Trace Center characterized its approach to external partners not as marketing but as 'evangelizing.' This terminology seems appropriate for its perceived and assumed role as advocate for the target audience. The Trace Center process identifies and validates opportunities to increase the accessibility or usability of a target product, and then applies a successively intensive level of persuasion to achieve transfer and market delivery. By keeping this end in site, the Trace Center is able to enlist others as external champions to not only transfer the invention, but to benefit the end users. This goal can be a powerful inducement in efforts to enlist people, organizations, and entire industries.

Applying standard practices instills a greater appreciation among investigators for the timeframes and resource investments necessary to move from an initial idea for a development project, all the way through prototype to external transfer.

Question 3: How could RERCs in particular, and the AT industry in general, adopt these innovative factors to improve the technology transfer process? The widespread adoption of these standard industry practices by the RERCs might be considered an innovation. There certainly appears to be tremendous room to improve the quality and quantity of outputs and outcomes accomplished through development and transfer projects. To the extent these practices are novel for small businesses in the AT industry, they could

benefit equally from their adoption and application.

Applying standard practices instills a greater appreciation among investigators for the timeframes and resource investments necessary to move from an initial idea for a development project, all the way through prototype to external transfer. With that in mind, a RERC might redirect its time and resources to increasing the accessibility and usability of products already in development by private-sector companies. By partnering with companies at the product design stage, RERCs would dramatically reduce the timeframes, target products that a company has already committed to commercializing, and increase the number of development outcomes the RERC could influence. This approach runs counter to the 'supply push' orientation of research activity, i.e., independent creation and ownership, and instead applies the 'demand pull' strategy of identifying your customer's needs and then filling them with one's expertise.

In addition, RERCs could commit to achieving the eventual impact on the target audience in a manner similar to the Trace Center's. A focus on the eventual benefit keeps the activity directed toward outputs and outcomes in line and on time. A focus on shorter term goals makes them the likely end point and collapses the broader perspective needed to attain long-term goals.

All of the above described strategies can help achieve the long-standing mission of the Rehab Act.

The Study's Conceptual and Procedural Contributions

The Retrospective Case Study project involved an ambitious scope of work made more challenging by RERC directors who provided less cooperation than expected. Nonetheless, the study process yielded several original conceptual and procedural contributions that may prove useful to the field. These are presented in the following section.

Articulating goals of the Rehab Act in the context of RERC activity. If RERC activities are supposed to result in improved quality of life for people with disabilities, what lines of causation can we draw between the funded activities of those programs and the needs and demands of the intended beneficiaries? This study distinguished development projects from research projects to avoid the intractable and ill-defined catch phrase 'research and development' and the equally vacuous acronym 'R&D.' Research generates knowledge while development generates products. Both may be necessary to improve the quality of life for people with disabilities, but they are not synonymous in model, method, or metric.

Another study will have to link research knowledge to audience benefit. This study focused on the tangible prototype outputs created through development activity, and requiring transfer to others as an evidence or measure of outcomes. Even though we admit that the transfer from internal to external use does not itself constitute a benefit to the target audience, we at least provide a milestone by which we can judge progress toward the intended goal.

Creating an instrument to track progress through the development process. One cannot measure what one cannot observe. Presented in Appendix A is an instrument that provides an outline for observing progress from idea conception through market release. The questions were phrased without reference to the merit of any individual project, but only in the context of determining how the proposed activity progressed through a series of stages. The instrument asks for time elapsed and resources consumed since project

implementation; any particular project has a finite quantity of each independent of our expectations. The final question asks for the project leader's opinion about the single factor most critical to the actual results– independent of whether those results were positive or negative. This answer is key to understanding what works and what doesn't work.

> Even though we admit that the transfer from internal to external use does not itself constitute a benefit to the target audience, we at least provide a milestone by which we can judge progress toward the intended goal.

Defining four product categories and delineating their outputs and outcomes. NIDRR's own program evaluation process recently added an Annual Portfolio Assessment Expert Review (APAER; New Editions Consulting, Inc., 2006). The pilot study for creating the APAER process took place in 2005. The pilot involved a review of the outputs and outcomes for the agency's portfolio of technology-based sponsored programs, including a subset of the RERCs (New Editions Consulting, Inc.). Our review of the Panel Summary Report showed that the classification system for 'accomplishments' did not distinguish research from development and did not delineate various forms of outputs and outcomes. The Panel Summary Report further stated, "There was limited information in many individual grant reports, the terminology used in the performance measures was complicated, and scoring process was interpreted differently in different clusters, and some information was provided too late or was inaccessible" (Editions Consulting, Inc., p. 5).

The APAER tracking in the technology portfolio could be simplified and clarified by differentiating research and development accomplishments, and then applying the four Product Categories defined in this paper, along with the related definitions for development project outputs and outcomes. The same structure can then be used to track progress from the point of project implementation. The weighting system for the four categories could be eliminated or expanded, depending on how the program expects to value different forms of accomplishments.

Identifying PDMA criteria for content review. The seven forms of essential preliminary analysis are well established and broadly practiced in industry. Once known, they can be applied readily by sponsor and grantees alike. In fact, they would well serve anyone who is involved in invention or innovation and who means to avoid replicating existing products or addressing problems. Stephen Covey's second habit of highly effective people is to, "Begin with the end in mind" (Covey, 1989, p. 95). This habit is grounded in the principle that all things are created twice: first, mentally, and second, physically. He asserts that most projects that fail do so mentally. These PDMA guidelines help avoid errors at the mental or idea stage of creation.

> The call to increase rigor and relevance is not isolated to the field of rehabilitation engineering or the AT industry.

Calling for rigor and relevance in development projects. NIDDR has labored to ensure its

grantees demonstrate adequate rigor and relevance in their research projects. Parity in rigor and relevance for development projects is justified on the same grounds of improving the quality and quantity of deliverables. In this context, increased rigor means a more efficient process, and relevance means more effective results. They combine to validate the utility of the intended and then actual results to external customers expected to receive the transfer, and in turn to their target beneficiaries.

The call to increase rigor and relevance is not isolated to the field of rehabilitation engineering or the AT industry. Alfred E. Mann has generated controversy in the academic world by challenging the ability of universities to capitalize on their research knowledge through technology transfer. Mann (2006) asserts: "The current approach to technology transfer at universities just does not work effectively." Even more recently, Larry Page (2007), co-founder of Google™, urged members of the American Academy for the Advancement of Science to be more entrepreneurial and engage in the solution of the significant problems facing humanity. His focus on the business model of relevant outcomes was evident in the comment: "There are lots of people who specialize in marketing, but as far as I can tell, none of them work for you" (Page).

The Rehab Act legacy involves NIDRR as a visionary and proactive agency focused on addressing the needs of people with disabilities. This legacy has resulted in pioneering program themes and equally innovative advances by a notable few. A worthy contribution to academia in general is to demonstrate how best to optimize rigor and relevance in development projects.

The results drawn from this Retrospective Case Study illustrate many lessons worth considering in the context of matching intentions to results. The results shed light on the actual accomplishments being achieved by the RERCs, with the funding granted in expectation of generating new and improved products in the marketplace.

Recommendations to R&D Grantees

Four primary recommendations are presented for consideration by R&D grantees. These are discussed in the following section.

It is critical to avoid biases that generate erroneous ideas for development through standard models, structured methods, and objective metrics.

Recommendation 1: Avoid Biases

It is critical to avoid biases that generate erroneous ideas for development through standard models, structured methods, and objective metrics. Conceptual development and decision-making are susceptible to perceptual, contextual influences (i.e., cognitive biases; Gilovich, Griffin, & Kahneman, 2002). There are dozens of specific cognitive biases that can only be avoided with adequate rigor and relevance. Standard empirical research methods are designed to eliminate bias by rigorously controlling and isolating the experimental conditions. Most RERC PIs hold doctoral degrees, signifying a high degree of training in research methods. Although we did not study the RERC research projects, our experience suggests that RERC work meets the academic standards for publication and peer acceptance. The apparent absence of an equivalent level of rigor in development and transfer projects suggests that participants do not safeguard themselves against cognitive biases.

The following cognitive biases were all related to the recurring operational problems evident in the RERC case studies:

1. *Bias blind spot*. This refers to the tendency to fail to compensate for one's own cognitive biases. It can be difficult for staff or students to contradict the position of a professor in the PI role.
2. *Confirmation bias*. This is the tendency to search for or interpret information in a way that confirms one's preconceptions. A thorough analysis according to PDMA criteria can dispel this.
3. *Deformation professionelle*. This is the tendency to look at things according to the conventions of one's own profession, forgetting any broader point of view. An applied field like rehabilitation science may value an intervention differently than will generalists in charge of decision making in companies.
4. *Endowment effect*. This is a tendency for people to value something more as soon as they own it. This is commonly seen in inventors' infatuation with their own creations.
5. *Illusion of control*. This is the tendency for people to believe they can control or at least influence outcomes that they cannot. PIs have substantial power and control over their immediate resources and may be highly influential thought leaders within their scholarly arena. However, localized prestige does not necessarily translate into an ability to persuade an independent company to adopt an internal invention.
6. *Optimism bias*. This is the systematic tendency to be too optimistic about the outcome of planned actions. The project narratives we studied are suffused with this optimism, sometimes in place of objective data.
7. *Planning fallacy*. This is the tendency to underestimate task-completion times. A serious problem considering the time and resource deadlines of grant funding, and evidenced by the number of grant cycles terminated prior to project completion.
8. *Selective perception*. This is the tendency for expectations to affect perception. Hence the headstrong pursuit of development goals–particularly at the prototype and transfer stages–in the face of objective perceptions to the contrary.

Recommendation 2: Overcoming Operational Barriers

The data show that only 20% of projects initiated by the RERCs failed due to technological barriers (6%), or barriers generated by the external partner (14%). In this analysis, four out of five failures–80% of the total–were attributed to operational issues. The four major threats to success are: (a) no validation of need, (b) improper planning and allocation of resources, (c) insufficient screening of transfer partners, and (d) inadequate project monitoring and management.

No transfer will happen unless the external partner perceives the need and values the solution.

No validation of need. No transfer will happen unless the external partner perceives the need and values the solution. In this study, 37% of the development projects accomplished the objective of creating a prototype yet failed to attract an external transfer partner. This illustrates the need to apply a structured and objective process for selecting development projects, while avoiding cognitive biases. The PDMA guidelines for preliminary analysis and critical success factors focus on this point.

Improper planning and allocation of resources. RERCs should conduct their own internal assessments of personnel and resource allocations to development projects. They can retrospectively study the results achieved by the resources applied and, perhaps, independently establish the thresholds of investment that our case studies were unable to quantify across the RERC program. Being unable to compile the data needed to perform this analysis is good justification for acquiring and implementing project management and monitoring tools, such as those used in industry and described in PDMA literature. Collecting this data will improve project performance and enhance our ability to provide the sponsor with information important for program improvement.

The window of opportunity to transfer prototypes may be time or resource dependent so keeping to a schedule is imperative.

Insufficient screening of transfer partners. For projects with intent to transfer between agencies, it is critical to ensure that the transfer partner is organizationally stable and financially sound. These considerations may seem foreign to federal agency staff and academic faculty who all function within stable and sound institutions. However, transfer partner entities are likely to be smaller corporations given the size of markets in the overall AT industry. In light of the dynamic environment of the private sector, and the very real possibility that a company could cease to exist anytime, a RERC must conduct an analysis of the transfer partner's managerial and fiscal health. In the private sector, this analysis is called due diligence and is commonly practiced prior to mergers or acquisitions. In the case studies, eight projects failed to achieve a transfer because the private sector transfer partner ceased to exist during the five year funding cycle. In some cases the partner merged with another company and the newly constituted management team declined to pursue the collaboration. In other cases, the company simply became insolvent or was liquidated by the owners. Merely having a partner company express an interest in the transfer is an insufficient basis for pursuing a development project. Experienced participants realize they must determine if the corporate partner will be viable in the near term. Even then, a RERC should develop contingency plans for the transfer phase in the event a partner changes its commitment to the joint project. If the project team's objective is delivery of a final product to a target audience, they will plan accordingly.

Inadequate project monitoring and management. Research projects are conducted under the control and discretion of the investigator, while development with intent to transfer must consider the future control and discretion of external partners. The window of opportunity to transfer prototypes may be time or resource dependent so keeping to a schedule is imperative. Researchers are accustomed to turning responsibility for projects over to junior staff or to graduate students, but their time allocations may be insufficient to keep the project moving. To the extent the project lacked a highly detailed

implementation plan at the front end, the ability to monitor and manage the project downstream is further compromised.

Correcting these four operational problems would dramatically increase results from development projects. It might be anticipated that up to a fourfold increase in successful outputs and outcomes would potentially be demonstrated, and perhaps even would have led to improvements in the other 20% of failures.

> "Are all partners who are necessary to ensuring a path from laboratory to market identified?"

Recommendation 3: Apply the Standard Practices of Industry within a Business Model

There are seven forms of Preliminary Analysis that increase the likelihood that a project is worth undertaking, will be done well, and will achieve the intended results. Each of these is described below.

1. *Evidence of initial screening.* This refers to prior work conducted by the PI or others to ensure that the basic idea is sound and timely. The question to be asked is, "Who said the idea was good?"
2. *Evidence of technical assessment.* This refers to the feasibility of a working prototype, and the prototypes ability to function as envisioned. The question to be asked is, "How do we know it will work?"
3. *Evidence of customer analysis.* This refers to the analysis of customer (manufacturer) and end user (consumer) needs and wants. The question to be asked is, "Who said they would manufacturer the output and who said they would buy/use it?"
4. *Evidence of key collaborators.* This refers to whether the project can attract essential partners based on a sound plan and shared expectations for success. The question to be asked is, "Are all partners who are necessary to ensuring a path from laboratory to market identified?"
5. *Evidence of preliminary market assessment.* This refers to research about existing products in the marketplace, or competing options for performing the same task. The question to be asked is, "What is the level of confidence that nothing similar exists in the market, that nothing similar has been rendered obsolete, and that nothing similar is in development elsewhere?"
6. *Evidence of an implementation plan.* Evidence of an implementation plan. This refers to something like a "business plan" which lays out the objectives, timeframes and resources at a level of detail sufficient for an external reviewer (e.g., investor, manager) to have confidence in the plan's success. The question to be asked is, "Is there enough detail regarding what will happen, in what order, and within what timeframes.
7. *Evidence of allocation of adequate resources.* This refers to the amount of personnel effort, elapsed time, and financial resources allocated. The question to be asked is, "Are the budgeted amounts sufficient to accomplish all anticipated deliverables with sufficient reserves to compensate for unanticipated variables due to

circumstances outside our control?"

Recommendation 4: Incorporate Learned Lessons into the Development and Transfer Process

The following strategies are recommended to more effectively support the development and transfer process. First, efforts should be made to validate the need for the project's deliverables before and after initiation. Second, contingencies should be specified during the project planning stage to limit the impact of unanticipated barriers during implementation. Third, standard methods and metrics should be applied in development projects that are comparable to research methodologies, such as those available through the PDMA. Fourth, all projects should be required to undergo thorough preliminary technical, market, and customer analyses, no matter how good they sound to the project's champion. Fifth, efforts should be made to ensure that the internal team resources and commitment are comparable to that expected from the external transfer partner. Sixth, contingency plans should be made to account for changes in corporate transfer partners over a project cycle. Seventh, project management tools should be used to help track resource allocation for completing the tasks, benchmarking the efforts, and for planning future projects. Eighth, incentives should be identified for development and transfer achievements comparable to career incentives for research publications. Ninth, consideration should be given to how to perpetuate a project commitment beyond specific investigators or established budget cycles. Finally, regular and sustained effort is required of projects to maintain a stable path of progress in a dynamic context over an extended time.

Recommendations to NIDRR or Other Federal Sponsors of R&D Programs

Three specific recommendations are provided to assist federal agencies who provide funding for R&D programs. Each of these is described below.

Recommendation 1: Empower Applicants to Allocate Resources Between R&D Programs

Differences between research projects and development projects have important implications for the design of grant proposals. Various RERC topics lend themselves to specific forms of activities, and various applicants are more predisposed to conduct one form of activity than the other. Mission-oriented federal sponsors of programs that involve both research and development should be mindful of the applicant's orientation toward one or the other, and provide guidance based on the desired outcomes. One way to do this is to change the structure of the proposal rating system.

RERCs provide a clear example. At present, the RERC proposal structure allocates '50' of '100' available points to research and development, with '25' points allocated to each. In response, RERCs typically structure their proposals–particularly given the page limits so that research and development sections each consume about the same number of pages, and each propose about the same number of projects. To obtain the full '25' points of each section, applicants are almost forced to divide their proposals in this manner.

One option would be to devote the full '50' points to the general category of research and development but permit the application to allocate the points between the two as they deem appropriate. Given the state of knowledge and relevance of products to a topic area, a RERC might devote most or all

of the points to either research or development. That would allow the applicant to focus on their capabilities, while still permitting the review panel to assess the relative merits of each proposed approach. The RERC eligibility criteria have been expanded to include applications from for-profit corporations. By permitting universities to propose strong research proposals, and companies to propose strong development proposals, the sponsor could choose the approach most relevant to the perceived national need.

Three specific recommendations are provided to assist federal agencies who provide funding for R&D programs.

A second option is to fund research projects and development projects separately. The NIDDR already distinguishes between research and development projects under the 'Field Initiated Program' where the applicant identifies the project as one type or the other, and the review involves different criteria and different reviewers.

The agency also funds development projects applying business models and criteria, under the 'SBIR' program. This program involves three phases with sponsor funding for Phase I proof-of-concept demonstration, and for Phase II prototype completion. Phase III funding is left to the grantee and/or their previously identified external corporate partner. RERC program reviews might focus on their research programs. To the extent that any RERCs wish to propose development projects either at the outset or after conducting some amount of research, those proposals could be reviewed and monitored separately using some hybrid of the existing criteria from the Field Initiated Program and SBIR program, supplemented by criteria and tools borrowed from established programs like the Product Development Managers Association.

Regardless of the approach, the overall process should change from *grant-based to contract-based,* or at least *collaborative-agreement-based*. This would ensure the program sponsor can maintain adequate oversight and intervene when the circumstances dictate. The overall goal would be to generate outputs and outcomes that translate into impacts for the target population, and which would bolster the federal sponsor's ability to demonstrate achievement on government performance measures. Increased sponsor input or oversight would most likely require the hiring of additional staff to perform this role for the agency.

Recommendnation 2: Set a High Standard for Development Activity in Selection Criteria and Reviewer Qualifications

Federal sponsors should ensure that their selection criteria and their reviewer qualifications match the intended deliverables. Mission-oriented R&D programs, such as those sponsored by the U.S. Department of Defense, should focus on their mission of supporting the 'war fighter.' Similarly, NIDRR can best focus R&D on supporting people living with disabilities.

Federal sponsors should ensure that their selection criteria and their reviewer qualifications match the intended deliverables.

The criteria used in the RERC program to judge the merit and worth of development projects with intent to transfer, and applied by the members of the review committees, do

not appear to adequately address the generally accepted criteria for judging new product development proposals.

The RERC program's review criteria, proposal narratives, and annual performance monitoring, should be revised to clearly address the operational issues involved in development projects. Our content review shows that grants were recommended for funding *despite the absence of narrative content considered critical* by experts in product development managers. Articulating these critical factors in the selection criteria would serve as a guide to grantees and reviewers alike to ensure those analyses were performed and described.

People trained in research methods need to understand why that training does not fully translate into development terms. They also need to embrace additional training and to employ the requisite tools for appropriate identification, planning, implementation, and management of development projects. Then they can make informed decisions about whether the development projects are worth doing. This decision would then be judged by reviewers trained in the business model of new product development, and the resulting project management data would be fed directly to agency program managers in standard summary reports.

It is also noteworthy that RERC proposals' budget information is attached to the front of the proposal document. At the same time, the individual project plans are under the section headings of 'Research' or 'Development,' and the personnel loading charts, project timelines and budget justifications are scattered throughout. One might improve project management, along with sponsors' and reviewers' abilities for assessing the management plan, by re-organizing the criteria to ensure appropriate planning tools are introduced and applied.

Grant and site reviewers should be made mindful of the need to scrutinize needs statements. The proposal review criteria for RERCs do not clearly require a validation of need among the target audience, nor do they require an expression of interest from transfer partners. Perhaps if RERC criteria for development projects were altered to reflect the transfer and commercialization requirements of the SBIR, the applicants and their reviewers would have to comply with a higher standard of evidence.

Sponsors get what they ask for at the proposal stage, and the grantees deliver what best suits their prevailing incentives at the implementation stage.

The departure of key personnel should be sufficient justification for a project review to include a revised project narrative explaining what will or will not continue, what will be lost if the project is terminated, and how the reallocation of those resources will benefit the original target audience. Such plans were not expressed in these project proposals, nor do the sponsors or reviewers require them.

Recommendation 3: Establish Expectations Congruent with the Agency's Mission

Sponsors get what they ask for at the proposal stage, and the grantees deliver what best suits their prevailing incentives at the implementation stage. The U.S. Department of Education has its own mission, and NIDRR's mission is clearly defined in the Rehab Act.

However, at present the language of the RERC program describes the funded RERCs and their individual projects in the language of

research activity, not in the language of development activity. To the extent development is mentioned, it is typically in the phrase 'research and development' or the acronym 'R&D' but not described in operational terms. Even the language of the priorities and the criteria used to score proposal submissions are oriented toward research models, methods, and metrics. Even the title, 'rehabilitation engineering center,' has no (a) 'D' for development, (b) 'T' for transfer, and (c) 'C' for commercialization. Instead there is only an 'R' for research.

Development, transfer, and commercialization offer unique challenges and require specialized expertise. Even when these expectations are specifically articulated in Federal programs, such as in Field Initiated Development or SBIR, grantees are challenged to deliver the intended results. By not holding development and transfer activity to the same standard as that established for research activity, grantees face an even greater and largely unanticipated set of challenges to delivering intended outcomes.

Establishing congruence between the ends and means leads directly to issues of national policy. To what extent are people trained and acculturated in the academic model appropriate candidates for leading development projects intended to benefit external target audiences? This question is the crux of points made by people like Alfred Mann and Larry Page regarding the results and benefits expected to result from government sponsorship of research and/or development projects. The Rehab Act set clear expectations that programs intended to benefit people with disabilities must deliver both knowledge and products.

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Appendix A

HISTORY OF DEVELOPMENT AND TRANSFER PROJECT -- 10 QUESTIONS

Case Study Project - RERC on Technology Transfer

Development Project: _____.
RERC: _____. Year Grant Cycle Initiated: _____.

1.(a) Where did Project's enabling technology (materials, techniques, knowledge) originate? (Check one)
___ (i) Internal to the field of A/T or ___(ii) External to the field of A/T.
(b) Describe technology involved (e.g., hardware devices, software tools, instruments, standards, processes)
_____.

2. Where did the specific idea for this Development Project originate? (Fill in blanks for option a or b).
(a) With a need/opportunity perceived by an individual actor (e.g., PI or inventor)
Title: _____. Brief Justification:
_____
(b) With an articulated and validated need from a stakeholder group (e.g. clinicians or industry)
Group: _____. Brief justification:
_____

3. Was the project implemented as described in grant once RERC funding was received?
___Yes. Describe the resources allocated:
_____.
___No. Explain difference in the way implemented
_____.

4.(a) Did the project idea continue through to the creation of a proof-of concept prototype?
___Yes; the prototype was built in-house, by others, collaboratively (circle one)
___No; Why not? (Check best reason.)
___Inability to overcome technical barriers inherent in problem;
___Time /money budget exhausted or reallocated to other opportunities;
___Inability to prove market need or overcome regulatory barriers;
___Insufficient expertise to master design or deliver functional capabilities;
___Inability to find/transfer enabling expertise or technology from outside sources;
___Other _____
(b) Please estimate the total expended on project to this point in (i) elapsed time _____; (ii) total personnel hours _____; and (iii) in total funds _____.

5(a). Did the proof-of-concept prototype pass or fail ensuing testing? (Check the appropriate blanks)
___ Pass. If so, were Intellectual Property issues addressed? __ (i) YES or ___(ii)NO.
___ Fail. The primary cause was bench testing, standards, interface issues, or clinical trials. (circle one).

(b) At this point, estimate the total expended to this point since prototype was initially developed (i) in elapsed time _____; (ii) total personnel hours _____;and (iii) in total funds_____.

6. For Passing Proof-of-Concept Prototypes, how did product design occur? (Check the appropriate blanks)
___ Internal to the RERC;
___External to the RERC through (circle one) a sub-contract, R&D agreement, license or sale.

7 (a). Did this design/development work result in a pre-production prototype of a product?
___ Yes. If so, was the pre-production design approved for commercial production? Yes or No.
___ No. If not, why was the product manufacturing effort terminated? (check one)
___ User acceptance, market analysis or technical performance barriers;
___ Management decision to reallocate resources or exhausted time/money budgets;
___ Lack of corporate interest or regulatory barriers;
___ Manufacturing design, production, cost barriers;
___ Other: _____.
(b) Please estimate the total expended to this point in (i) elapsed time _____; (ii) total personnel hours _____, and (iii) in total funds _____.

8. For Products in commercial marketplace, what was the date of market introduction? _____, and total elapsed time from project initiation to market introduction? _____.

9. For each Product Market Introduction, what is the current status of the Device/Service?
____ Terminated – product not competitive due to (circle one) price point, distribution, support or competition;
____ Active – product available or integrated into other devices/services. Contact information for manufacturer:

10. In retrospect, what was the single dominant factor that determined the project's outcome and why?