

# Technology Transfer and Technology Transfer Intermediaries

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## **Abstract**

A standard and comprehensive model is needed to evaluate and compare technology transfer systems and the stakeholders within these systems. The principle systems considered include federal laboratories, U.S. universities, the rehabilitation engineering research centers (RERCs), and large small business innovation research programs. An earlier model accounts for technology transfer activities, events, stakeholders, and resource providers (Lane, 1999). This model is augmented to account for dynamic aspects of technology transfer (transfer efficiency, transfer latency) and scale (micro-, macro-). The critical role of technology transfer intermediaries is emphasized. Examples pertaining to the assistive technology industry are used to illustrate important concepts and issues. The technology transfer model with extensions is applied to the four technology transfer systems. Major studies pertaining to the technology transfer performance of: large small business innovation research programs, the federal laboratory system, the U.S. Department of Education RERCs, and U.S. universities are reviewed. Study outcomes are examined in terms of a uniform and comprehensive technology transfer model. Conclusions are drawn regarding the evaluation of program performance. The need for a uniform and comprehensive technology transfer model is demonstrated by showing inconsistencies within and between research study outcomes for major technology transfer systems. Barriers that prevent the full and optimal use of these programs by the assistive technology industry are discussed. The

authors conclude that technology transfer from the public to private sector is a major and critical economic driver. Large federal programs, which are generally established through legislation, facilitate and structure the technology transfer efforts of federally funded entities. Effective program oversight and good public policy requires systematic program evaluation in reference to a standard and complete technology transfer model. Identifying and promoting best practices for technology transfer intermediaries requires that the technology transfer model encompass both the macro (systems) and micro (stakeholders within systems) scale.

**Key words:** Technology Transfer, Demand Pull, Supply Push, Assistive Technology Devices, Transfer Latency, Transfer Efficiency

## **Technology Transfer and Technology Transfer Intermediaries**

The Rehabilitation Engineering Research Center on Technology Transfer (T<sup>2</sup>RERC) funded by the U.S. Department of Education, National Institute on Disability and Rehabilitation Research (NIDRR) completed its third five-year funding cycle in September 2008. The T<sup>2</sup>RERC conducted research to advance the state-of-the-art for technology transfer while also practicing technology transfer to facilitate technology development, transfer, and product commercialization benefitting elders and people with disabilities.

Technology transfer (TT) is an emerging field. As such, in both research and practice, ad hoc

and borrowed terminology is employed for TT activities, stakeholders, and events. In 1999, a detailed TT model was published that addressed many of these shortcomings (Lane, 1999). In this paper we suggest how that model might be extended, and we provide a rationale for doing so. We propose terminology and concepts for *transfer efficiency*, *transfer latency*, *transfer context*, *push* and *pull* transfer strategies, and *transfer scale*. To illustrate terminology and concepts, examples are presented with reference to familiar TT programs and activities. These examples illustrate the somewhat disjointed manner in which TT programs are currently evaluated.

Readers who will benefit from this paper include TT intermediaries and resource providers, managers and evaluators of TT

## Events, Activities, and Stakeholders: Definitions and Examples

### *Events and Activities*

A comprehensive and extensible model and language is required in order to discuss TT clearly and accurately. The model and language should also provide a framework for evaluation and research. Lane's 1999 paper provided an excellent model and vocabulary upon which this paper will expand. Figure 1 captures many of the key elements of this model. For example, within the figure, bounded areas represent *activities*, which include Technology Applications, Technology Research and Development (R&D), Product R&D, and Product Commercialization. These activities are carried out by various *stakeholders*,

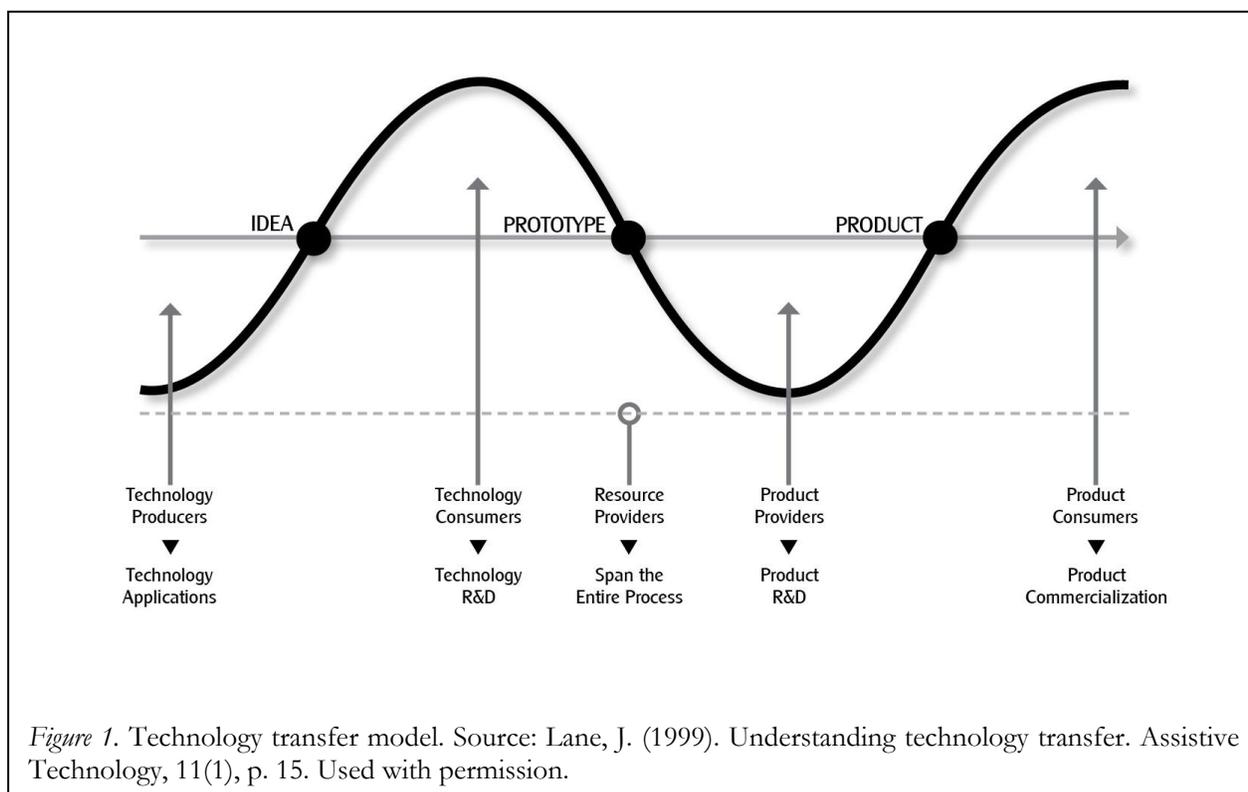


Figure 1. Technology transfer model. Source: Lane, J. (1999). Understanding technology transfer. *Assistive Technology*, 11(1), p. 15. Used with permission.

programs, members of the TT research community, and other stakeholders who participate in TT activities.

who include Technology Producers (TP), Technology Consumers (TC), Product Producers (PP), and Product Consumers (PC). Resource Providers facilitate TT activities in various ways throughout the entire TT process. Activity outputs are called

*critical events*, which include idea, proof of concept prototype, and product. These outputs serve as inputs to subsequent activities. Activities above the horizontal midline are generally visible, or public, while activities below the midline are generally hidden, or confidential and proprietary.

The reader can understand 'TT' conceptually by 'walking along' the midline of Figure 1 from left to right. Technology-related activity is on left side of the model, and product-related activity is on the right side of the model. The technology-to-product transition occurs around the midpoint (prototype event). Table 1 presents the activities and critical

**Table 1**  
**Technology Transfer Model: Critical Events and Activities**

<b>Event/Activity Name</b>	<b>Event/Activity Description</b>	<b>Event/Activity Exemplar</b>
<b><i>Technology Applications</i></b>	Theoretical and basic research activities leading up to conceptualized idea.	Eye gaze technology was explored by the U.S. Air Force as a way to enable Vietnam fighter pilots to track, point, and shoot at a target without using their hands.
<b><i>Idea Event</i></b>	Point in time when a new or novel application is recognized for a new or novel technology.	LC Technologies founders formed the company to develop a commercial eye gaze product. At the time they saw value in using the product for people with disabilities, but they had no viable prototype.
<b><i>Technology Research</i></b>	Applied research activities leading up to proven concept prototype.	All image processing and pattern recognition code was rewritten to enable the system to recognize eye features. When completed, the unit was two to three times more accurate and precise than before.
<b><i>Prototype Event</i></b>	Point in time when a new or novel application is embodied as a working prototype that demonstrates the proof of concept.	The first unit ran on a 286 computer and sold for almost \$50,000. The unit was functional, but the price was far too high for commercial success.
<b><i>Product Development</i></b>	Market research, design, and development activities leading up to 'production-ready' product that also includes other features and functions wanted by customers.	Further refinement of the system focused on improved pointing accuracy and increasing tolerance to: ambient infrared light, inter-user differences, and head motion.
<b><i>Product Event</i></b>	Point when a working prototype is refined; includes other necessary features and functions and is ready for manufacture, distribution, and sale.	Solving many previously encountered technical problems lowered the price sufficiently to enter the marketplace. Current units sell for \$7,250 to \$10,500.
<b><i>Product Commercialization</i></b>	Production, distribution, marketing, and sales of the product to customers.	The Eye Gaze Edge Communication System is available through LC Technologies, Inc and a network of dealers. Refinements to the system are ongoing.

Source: D. Cleveland (personal communication, October 31, 2008)

events of the TT process as experienced by one company, LC Technologies, Inc. in the development and commercialization of their eye gaze mouse emulator.

*Stakeholders*

Typical TT stakeholders are listed in Table 2. Citing examples of TPs and PPs and PCs is relatively straightforward. However *Resource Providers* encompass a wide range of actors whose resources may be leveraged throughout the entire TT process. Examples of Resource Providers include: (a) government and private entities that fund research, development, production, marketing and distribution activities; (b) government and private third-party payers that fund product purchases and create market demand; (c) TT intermediaries that facilitate a range of activities including market research, grant development, brokering, and technical support; and (d) government entities that shape and implement

of overgeneralization, the following examples suggest the continuum of roles played by Resource Providers.

1. Federal agencies provide extramural grants to university faculty to conduct basic research. Basic research usually takes place under *Technology Applications* prior to the Idea event and before market demand and business opportunities are readily apparent.
2. Large federal agencies provide Small Business Innovation Research (SBIR) grants to small U.S. businesses and in 2005 these grants totaled more than \$1.85 billion (Wessner, 2008). Across agencies, multi-phase SBIR grants vary greatly in size. However, the combined Phase I and Phase II grants frequently exceed \$1 million. Phase I grants typically fund *Technology Research* leading up to the Proof-of-Concept Prototype Event, while Phase II grants typically fund *Product*

**Table 2**  
**TT Model: Stakeholders**

Stakeholder Group Name	Members of Stakeholder Group
Technology producers	Universities and federal laboratories (public sector), corporate laboratories, and independent inventors (private sector)
Technology consumers	Manufacturers (private sector) and government agencies (public sector)
Product producers	Manufacturers (private sector)
Product consumers	Primary (end-users) and secondary consumers (individuals who buy and recommend or service providers)
Resource providers	Government agencies (grants, contracts, public insurance), private insurance companies (reimbursement), TT intermediaries (brokers), venture capitalists and angel investors (private investment)

TT policy.

There are many examples of resource providers with greater or lesser relevance to the four TT activities. Setting aside the risks

*Development* activities after the Proof-of-Concept Prototype event and leading up to the Proof-of-Product Event.

3. Angel investors (AIs) pool resources from one to a few affluent individuals to offer second-round funding to (typically) high-growth start-up companies. Company owners generally wish to maintain their controlling equity positions but turn to AIs when they have exhausted, or do not wish to further pursue funding from friends or family. Additionally, other mechanisms such as SBIR grants are not always suitable because of timing, risk, or funding level issues. AIs tend to be risk-tolerant, and may fund late stage *Technology Research* and early *Product Development* activities. Typical AI funding ranges from \$250,000 to \$1 million. Return on a successful investment ranges from 10 times to 30 times the original AI investment over a five- to seven-year period (Wiltbank & Boeker, 2007). AIs recoup their investments through exit strategies such as initial public offerings (IPO) and business acquisitions.
4. Venture capitalists (VCs) pool resources from private investors, investment banks, and institutional investors; they typically make investments of \$1 million to \$2 million. VCs are often less risk-tolerant than angel investors, and they generally fund 'later stage' *Product Development* activities up to the Proof-of-Product event. VCs often prefer to invest in established companies entering a phase of rapid growth. However, VC funding is also sought by high-risk, high-reward tech companies that do not qualify for standard bank loans. In return for taking on high-risk, VCs may ask to

own controlling equity positions in these companies, guide business plan development, or to have input on decisions regarding management practices, staffing, development, and production. VCs typically employ a '2 and 20 formula' whereby the VC receives 2% of the committed capital plus 20% (or more) of the company's net profits on an annual basis. By employing this (or similar formulas), VCs typically recover their initial investment over three to seven years. VCs then generate profits through exit strategies that include IPO and business acquisition.

5. TT intermediaries (TTIs) are the most diverse group of Resource Providers. They offer various assistances to the stakeholders associated with *Technology Research*, *Product Development* and *Product Commercialization* activities. Examples of TTIs include university TTOs, federal laboratory ORTAs, and other federally funded brokers such as the T<sup>2</sup>RERC. It is common for TTI to draw upon the capabilities of other resource providers. For example, a university TTO might help a university researcher to obtain SBIR funding to support further research and development.

Figure 2 maps Resource Providers against their likely involvement within the TT model. Although Resource Providers are typically involved during portions of the process indicated by the horizontal dotted lines, there will occasionally be instances that fall outside of the norm.

### Extending the TT Model

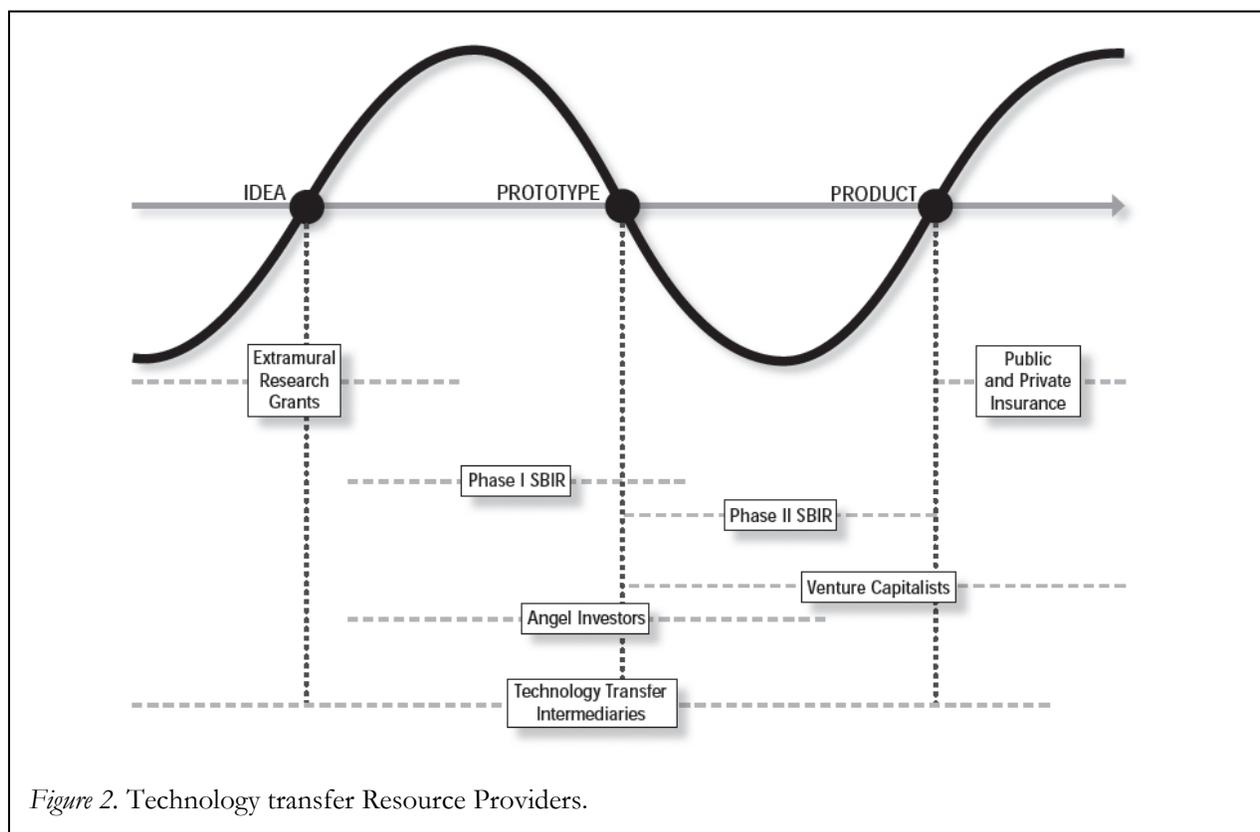


Figure 2. Technology transfer Resource Providers.

Lane’s model, while excellent, has focused delivering information on static TT concepts, including: (a) what happens within an activity; who participates in an activity; (b) which Resource Providers support the activity; (c) what event terminates an activity; and (d) what forces might initiate TT. Equally important, however, are concepts and language to describe the dynamic processes of TT and the facilitating roles of TT intermediaries. It is also important to examine TT activities at different scales, recognizing that normative outcomes determined from aggregate measures are likely to obscure both the successful and the unsuccessful practices of individual TT intermediaries. We begin our extension of the model with terminology and examples of new concepts.

### Concepts and Terminology

1. *Innovation*--In TT, an idea is transformed from proof-of-concept prototype, to proof-of-product and

finally to a commercial product. According to the Merriam-Webster Online Dictionary (2008), an innovation is “2: a new idea, method or device.” Throughout the remainder of this article, *innovation* will be used to represent ideas through their subsequent transformations to become commercial products.

2. *Context*--This refers to the various environments in which TT occurs. *Technology Applications*, *Technology Research*, and *Product Research* activities that transform innovations take place in different contexts, including public sector labs and universities, private sector companies, and in the domains of independent inventors. For example, an idea might result from research conducted at a university (context) to be published in a technical journal (purpose). A proof-of-concept prototype might result from research conducted in a federal

laboratory (context) and be patented to facilitate future licensing opportunities (purpose). A proof-of-product might result from production research carried out by a manufacturer (context) as a precursor to introducing a commercial product (purpose).

3. *Transfer Mechanism*--This mediates the movement of an innovation from a source context to a destination context. For example, a journal paper could mediate the movement of an innovation from a university to a manufacturer. A license agreement could mediate the movement of an innovation from a federal lab or university to a manufacturer.
4. *Technology Transfer*--This is the movement (via a TT mechanism) of an innovation (idea, method or device) from a source (original context and purpose) to a destination (new context and purpose). For example, prototype software developed by university researchers (context) for user-friendly creation of keystroke macros is patented and licensed (movement or transfer mechanism) to a private sector manufacturer (new context) for use in a software product that allows blind individuals to independently create screen reader macros (new purpose). A federal lab (context) develops technical expertise and capacity in the area of nanotechnology fabrication (purpose); a cooperative research and development agreement (movement or transfer mechanism) is entered into with a private sector manufacturer (new context), to collaboratively develop a novel refreshable Braille cell (new purpose).

Throughout the remainder of this article, we'll often employ these terms to discuss the dynamic aspects of TT. In the following section the critical role of TT intermediaries is

discussed. TT intermediaries employ some combination of push transfer strategies and pull transfer strategies. These strategies facilitate progress and transformation of an innovation from idea to commercial product.

#### *Push Transfer Strategies*

Push transfer strategies start by identifying one or more innovations (initiator) from an independent inventor, university, federal lab, company outside of core industry, etc. Then a manufacturer or federal agency (destination) is made aware of the innovation, associated market need, and business opportunity, and the innovation is transferred (via some transfer mechanism) from source to destination.

For example, the T<sup>2</sup>RERC Case study project (T<sup>2</sup>RERC, n.d.b) examined 78 development projects being conducted by 11 RERCs previously funded by NIDRR. RERCs must transfer their research knowledge to the private sector to facilitate the development of new products benefitting people with disabilities. RERCs have historically used push transfer protocols, which is to say that basic research precedes market research, product development, and product commercialization. Each RERC proposed a certain number of development projects, which in principle should result in prototypes. RERCs are usually university-based and TT offices (TTOs) serve as their TT intermediaries. In principle, TTOs help to license RERC-based patents (sometimes embodied as prototypes) to manufacturers who subsequently develop new or improved products based on these prototypes. The Transfer Achievement Index (TAI) of RERCs that began five-year funding cycles in 1998, 1999, or 2000 was defined as the number of actual transfers divided by the number of proposed transfers for any given RERC. For the 11 RERCs that qualified for the study, the average TAI was 25%. TAI

scores for individual RERCs ranged from 10% to 100% (Lane, 2007).

Although the average of the 11 RERCs showed fairly low TT efficiency, two RERCs had TAI scores of 100%. These exceptional performances suggest that most of the RERCs studied were employing sub-optimal push transfer strategies, which could be improved to achieve a higher TAI, as demonstrated by the top performers.

This study is especially significant to AT manufacturers, given that the RERC system is the premier federally funded research program pertaining to disability and AT. A low transfer efficiency implies that the RERC system may not provide full and optimal benefits to the AT manufacturers or the disability markets that they serve. (However, a more recent and complete study is needed.)

#### *Pull Transfer Strategies*

In contrast, pull transfer strategies start by identifying one or more market needs (initiator). Then a manufacturer or federal agency (destination) is made aware of the market need and wants to fill this need; an innovation that addresses this need is sought and identified (source); and the innovation is transferred (via some transfer mechanism) from source to destination.

For example, the SBIR program was established under the Small Business Innovation Development Act of 1982 (SBIR Act; P.L. 97-219) and most recently reauthorized in September 30, 2008, as the Small Business Reauthorization Act of 2000 (P.L. 106-554). The SBIR Act requires that large federal agencies with extramural research budgets of at least \$100 million designate 2.5% of these funds for grants to small U.S. businesses. Basic requirements to participate in an SBIR program stipulate the business must be U.S.-based, U.S.-owned (at least

51%), and U.S.-operated. Also, the principle investigator must be employed by the business; the business must have fewer than 500 employees; and the business must be a 'for profit' entity. For practical purposes, SBIR grants allow small businesses to pursue high-risk, (often) small-market product development.

SBIR programs have two funded phases. SBIR Phase I completion typically results in a proof-of-concept prototype. SBIR Phase II completion typically results in substantial progress towards a proof-of-product plus establishment of commercial viability. In this way, SBIR granting agencies are resource providers who target funding to small businesses for high-risk technology research activities (Phase I awards) and product research activities (Phase II awards).

SBIR programs are all *demand pull* strategies of two sorts; non-acquisition-based (e.g., U.S. Department of Education [USDE], National Institutes of Health [NIH], National Science Foundation [NSF]) or acquisition-based (e.g., Department of Defense [DOD], National Aeronautics and Space Administration [NASA]) programs. In *non-acquisition-based programs*, manufacturers identify a market need and business opportunity and compete for SBIR grants to support the development of technology solutions. In *acquisition-based* SBIR programs, the federal agency has a specific technology need and typically serves as the primary market for the technology solution. In this case, the federal agency is often the primary 'market' and knows its technological need prior to solicitation of proposals from manufacturers to develop technology solutions.

The Department of Commerce (DOC; 2003) published a study (the 'DOC study') of 359 responding AT manufacturers, 98% (349 businesses) of which were businesses eligible to apply for SBIR awards. Of those

businesses, only 52 companies (15%) applied for SBIR funding. A T<sup>2</sup>RERC study evaluated five acquisition-based SBIR programs (NIH, NSF, USDE, Department of Transportation [DOT], U.S. Department of Agriculture [USDA]) for the period 1996 through 2005. Another study conducted at the T<sup>2</sup>RERC found for the period 1996 through 2005 that AT companies received 663 Phase I awards totaling \$67 million and 328 Phase II awards totaling \$201 million (Bauer & Arthanat, n.d.).

Another study shows that firms obtaining Phase II SBIR awards are very likely to obtain follow-on funding (e.g., angel investors, venture capitalists, and additional SBIR awards) (Wessner, 2008). If these results generalize to AT manufacturers, it is likely that AT firms that regularly utilize SBIR program resources gain a significant advantage over their competitors.

### Transfer Efficiency and Transfer Latency

Up until this point, we have discussed the TT model, defined related terms and provided examples of various TT strategies. *Transfer efficiency* and *transfer latency* are useful concepts with which to consider TT outcomes. In particular, the effective intervention by TT intermediaries should increase transfer efficiency and or decrease transfer latency.

#### *Transfer Efficiency*

*Transfer efficiency* can readily be tied to critical events such as the likelihood that an idea will result in a commercial product, or the likelihood that a proof-of-concept prototype will result in a commercial product. Examples of transfer efficiency include the ratio of commercial products (or technology licenses) to patents as a measure of transfer efficiency for a university TTO, or federal lab Offices of Research and Technology Applications (ORTA). Transfer efficiency provides a useful

basis for comparison between two or more TTI or between TT systems.

For example, a study published by the National Research Council (NRC; Wessner, 2008) evaluated the five largest SBIR programs; they are administrated by DOD, NIH, Department of Energy (DOE), NASA, and the NSF. The NRC study employed stratified random sampling that included 20% of Phase II recipients from each agency. Data is reported for various timeframes between the years 1983 and 2005. The typical culmination of a Phase I award is a proof-of-concept prototype. Phase II awards typically culminate in substantial progress toward proof-of-product and the establishment of commercial viability.

For study respondents receiving Phase II awards, 47% led to marketed products, 19% were expected to produce marketed products, while 5% of projects were still in development. The remaining 29% failed to reach the market. In addition, 43% of Phase II awardees received additional non-SBIR investment averaging about \$1.54 million; 54% received one or more related Phase I SBIR awards; and 40% received one or more related Phase II awards (Wessner, 2008).

High transfer efficiencies and follow-on funding opportunities should make SBIR grants extremely attractive to AT manufacturers. For these five SBIR programs, the NRC study suggests a transfer efficiency of at least 49% and at most 71% when the small business has won both a Phase I award (for proof-of-concept prototype development) and Phase II award (for proof-of-product development and establishing commercial potential). Leveraging initial Phase I and Phase II awards to obtain follow-on funding is undoubtedly critical to successful product development and commercialization.

Two considerations temper the NRC study results. Survey methodology removed award recipients (and their awards) if: they were out of business ( $n=25$ ), lacked an email address ( $n=893$ ), or had defunct email addresses ( $n=500$ ). From the 6,408 firms in the sample, 4,523 firms (71%) had working email addresses, and 1,916 (42%) of the firms responded. It is a reasonable conjecture that firms without working email addresses (which may even signify that the company is no longer in business) did not introduce commercial products consequent to receiving Phase II SBIR awards. It is also reasonable to conjecture that firms that *did* respond to the survey were more likely to have introduced a commercial product than contacted firms who *did not* respond. If either or both of these conjectures were supported, then the excellent transfer efficiencies (49% minimum to 71% maximum) obtained for the five SBIR programs would be upwardly biased.

It should also be determined whether AT manufacturers pursue SBIR grants from acquisition-based SBIR programs (such as DOD, NASA, and portions of the DOE) or non-acquisition-based SBIR programs (such as NIH, NSF, and portions of the DOE). Agencies with acquisition-based SBIR programs often serve as the primary market for commercial products consequent to their SBIR Phase II grants. As a consequence, it is reasonable to conjecture that transfer efficiency for acquisition-based SBIR programs will be higher than the transfer efficiency of non-acquisition-based SBIR programs.

#### *Transfer Latency*

Transfer latency can also be tied to critical events such as (a) the time required for an idea to result in a commercial product, or (b) the time required for a proof-of-concept prototype to result in a commercial product. An example of transfer latency is the average

time between the issuance of a university patents (proof-of-product event) and the resulting commercial product. Transfer latency also provides a useful basis for comparison between two or more TTIs or between TT systems.

For example, in 2006, patent applications were filed for more than 60% of university invention disclosures (Association of University Technology Managers, 2007). There are significant latencies from invention disclosure to patent application, from patent application to patent issuance, and from patent issuance to license. In fact, most patented technologies are never licensed (Government Accounting Office, 1998).

An old study estimated the latency from technology license to the introduction of a commercial product (when successful) to be eight years (Ditzel, 1991). Survey results of university TTO and industry technology licensees found that licensed technologies require further development (asserted by 88% of TTO respondents and 84% of industry respondents) and that licensed technologies are no more than proof-of-concept (asserted by 45% of TTO respondents and 44% of industry respondents). Industry respondents to the survey indicated that for 40% of technology licenses university inventors assisted further development (Thursby & Thursby, 2002). A large portion of university technologies are licensed through exclusive and non-exclusive agreements to start-up companies (16.7%) or existing small companies (50.7%). These results should encourage AT manufacturers who are predominantly small businesses (Association of University Technology Managers, 2007).

Transfer latency for university technologies has two logical phases. The first phase comprises roughly the period from technology disclosure through technology licensing. University TTO activities can

greatly shorten or lengthen this first latency through services to faculty and potential licensees. The second phase comprises roughly the period from technology licensing to product commercialization. A university TTO can support a manufacturer's product development through faculty consulting, contracted research and development, industry and university consortia, etc. University TTOs that effectively support product development will increase the rate of product commercialization and shorten the second latency.

### Macro and Micro Perspectives on TT

Thus far we have described the dynamic aspects of TT, push and pull transfer strategies, and their impact on TT efficiency and latency. TT can and should also be viewed at large (macro) and small (micro) scales. A large-scale view pertains to the activities and performance for entire systems or large portions thereof. A small-scale view takes into account the activities and performance of individual actors within these systems. For example, a federal laboratory system might comprise all Department of Energy labs and its associated offices of research and technology applications (ORTA), Federal Laboratory Consortium (FLC) for TT contractors, and manufacturing partners. System actors include individual labs, ORTA, FLC contractors, and manufacturers.

#### *Macro Scale*

In analogy to macroeconomics, TT, at a macro-scale examines aggregate activities that are common to large TT systems. Aggregate data is used to construct system-level models, to identify trends, and to make forecasts. In terms of the TT model, aggregate activities can often be associated with critical events (idea, proof-of-concept prototypes, proof-of-product, commercial products).

For example, many public and private entities collect and analyze macro-level data pertaining to universities, federal laboratories, and SBIR programs. These entities include the U.S. Congress' General Accountability Office, the DOC, SBIR, the NRC, and professional organizations such as the Association of University Technology Managers (AUTM).

AUTM annually surveys its membership, which includes TT offices of U.S. research universities, hospitals, and institutes. From each TT office AUTM collects information regarding the amount of funding revenues, type of funding revenues (public or private). It also gathers data on the number of disclosures, patent applications filed, patents granted, intellectual properties licensed, equity positions taken, and revenues generated. Survey data provides a basis for macro evaluation of relative and aggregate transfer efficiencies and transfer latencies for U.S. universities.

The 2006 AUTM Survey found that TTOs at research universities comprised 85% ( $n=161$  of 190) of survey respondents. Some universities had two or more TT offices (e.g., at medical centers). As a consequence, the 161 TTOs are part of 116 U.S. universities, and these 116 universities comprise 84% of U.S. universities receiving \$20 million or more in research funding (Lombardi, Capaldi, & Abbey, 2007). In 2006, AUTM reported that 161 university TTOs executed 4,192 licenses or options ( $n=1,622$  exclusive;  $n=2,570$  non-exclusive) with startups ( $n=698$ ), small companies ( $n=2,127$ ), and large companies ( $n=1,327$ ). To refill the technology licensing pipeline, TTOs reviewed 18,874 technology disclosures, prepared and filed 11,622 patent applications, and were awarded 3,255 new patents. Total revenue for research was \$45.4 billion in 2006. From 1997 to 2006 industry grants and contracts accounted for 8% of all university research revenue, peaking at 10% in 1999 and tapering off to 7% for 2003 through

2006. Federal, state, and other sources account for the bulk of research revenue, with federal grants averaging about 65% of the total for the period 1997 through 2006. For the fiscal year 2005-2006, university licensing accounted for \$1.3 billion in revenue generation for the universities themselves (AUTM, 2007).

Firms licensing university technologies often invest substantially in infrastructure and staffing in order to carry out development activities. Induced investment is especially great for start-up firms and to a somewhat lesser extent, pre-existing small businesses. Firms must also pay universities for technology use, according to the terms of their licensing agreements. An MIT study estimated the ratio of induced investment to licensing revenue to be 24:1 (Pressman et al., 1995).

The breadth of macro-level information obscures that university TTOs often focus their efforts on revenue generation and the transfer of 'homerun' technologies. It is still a common practice for many university TTOs to patent and subsequently make available for licensing only those technologies they feel likely to generate significant revenues. This narrow perspective fails to account for licensing's much greater impact (a ratio of 24:1) in the private sector, or the broad mandate that federally sponsored research should benefit society (Table 2). The Bayh-Dole Act of 1980 also encourages "maximum participation of small business firms." A narrow university policy to maximize TT revenue (licensing, equity buyouts) is likely to be in direct conflict with this sub-objective. Specifically, the Bayh-Dole Act notes:

It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development; to

encourage maximum participation of small business firms in federally supported research and development efforts; to promote collaboration between commercial concerns and nonprofit organizations, including universities; to ensure that inventions made by nonprofit organizations and small business firms are used in a manner to promote free competition and enterprise without unduly encumbering future research and discovery; to promote the commercialization and public availability of inventions made in the United States by United States industry and labor; to ensure that the Government obtains sufficient rights in federally supported inventions to meet the needs of the Government and protect the public against nonuse or unreasonable use of inventions; and to minimize the costs of administering policies in this area. (Title 35, Part II, Chapter 18, § 200 Policy and Objective)

In addition to university resources, the private sector (AT manufacturers) can tap into federal laboratories through Cooperative Research and Development Agreements (CRADA) or contracted research. CRADAs were first created under the Stevenson-Wydler Technology Innovation Act of 1980, as amended by the Federal TT Act of 1986 (Federal Laboratory Consortium, 2006). There are two types of CRADAs. For *cost-shared* CRADAs the government owns the original intellectual property (IP) and the firm wishes to co-develop commercial applications that are based on this IP. For *cost-in* CRADAs the firm owns the original IP and wishes to co-develop commercial applications. In both cases, firms gain access to and leverage the federal laboratory's extensive technical infrastructure and expertise. The firm and government normally share joint-ownership

of any new IP produced under either CRADA. The firm retains exclusive rights to use the new IP for commercial applications. The federal agency has rights to use the new IP for internal use and cannot sub-license the new IP to another commercial partner (T<sup>2</sup>RERC, 2005).

CRADAs generally apply when new IP is likely to address an agency's mission-critical needs. The firm pays for work carried out under the CRADA at a negotiated rate. From a lab's perspective, the negotiated rate is impacted by the value of the original IP (for cost-in CRADAs), the new IP developed under the CRADA (shared or cost-in) and the firm's technical contribution. Under contract research, the federal laboratory simply carries out research activities as specified by the firm. The firm retains ownership of any old or new IP and pays for all work carried out by the federal laboratory. Negotiated rates for contract research are likely to be higher than negotiated rates for CRADAs because contract research does not address mission-critical needs, there is no joint ownership of new IP, and the lab does all of the work.

Data is lacking, however it is likely that few AT manufacturers have worked with federal laboratories through CRADAs or contract research (DOC, 2003). As a potential explanation, original IP owned by an AT manufacturer, or new IP developed under a CRADA for this manufacturer, is unlikely to address an agency's mission-critical needs. An AT manufacturer's expertise in applied research for product development is unlikely to be valued by federal laboratories whose focus is basic research. As a consequence, federal labs are likely to have little interest in working with AT manufacturers and negotiated rates for CRADAs or contract research are likely to be high.

In principle, technology licensing provides another avenue for firms to access

technologies developed in the federal laboratory system. The Federal Laboratory Consortium (FLC) Locator Service is the principle gateway to laboratory technologies. In using the FLC Locator Service, firms are asked to provide background information and to describe their technology needs. Full and detailed disclosure helps to narrow the search and to ensure that whatever technologies are found closely match the firm's described needs. The Locator Service and federal laboratory ORTA treat each firm's requests as proprietary and confidential (Federal Laboratory Consortium, n.d.).

The FLC Locator Service is an excellent resource for all manufacturers. However, laboratory technologies generally need additional research before an application idea can be embodied as a proof-of-concept prototype (proof of product, commercial product). The originating laboratory is likely to have the expertise and capacity (including the scientist who conducted the research) to assist the firm. However, this assistance can only be obtained through CRADAs or contracts. The drawbacks for these mechanisms, especially for small businesses, have already been outlined.

#### *Micro Scale*

In analogy with microeconomics, TT at the micro level looks at activities of individual actors within a TT system. Activities are considered for their impact on that actor's TT performance. In terms of the TT model, individual activities often lead to intermediate outcomes consequent to major events. For example, prior to a technology patent being issued a TIO might solicit technology disclosures, screen technologies (patent searches, public benefit, commercial potential, etc.) and prepare patent applications. Examination of intermediate outcomes and how they are achieved can indicate why the

performances of individual TTIs are exceptional or unexceptional.

For example, data gathered from the AUTM 2006 Annual Survey suggests that the University of Minnesota is a leader in both research and TT outcomes. According to this survey, in 2006 the University of Minnesota ranked fifth in license royalties (\$57 million), twenty-sixth in new patents issued (n=28), ninth in new licenses and options (n=83), and fifteenth in research expenditures (\$594 million). Given the relative success of the University of Minnesota, other university TTO might benefit from their insights pertaining to effective TT strategies (Association of University Technology Managers, 2007).

At the AUTM 2006 Annual Meeting, the University of Minnesota presented their findings on TT activities most valued by manufactures. In rank order manufacturers valued: (a) access to undergraduate students, (b) access to graduate students, (c) faculty consulting, (d) continuing educational opportunities, (e) university-industry consortia, (f) industry-sponsored research, and (g) technology licensing (Sommerstad, 2006).

Interestingly, undergraduate and graduate student placements and continuing education help manufacturers to assimilate new knowledge and build capacity for research and development. Industry-university consortia, faculty consulting, and industry-sponsored research are demand-side strategies, which is to say that manufacturers identify market needs and business opportunities *before* establishing university collaborations to develop technology solutions. In each case, intellectual property rights, licensing, non-disclosure, and delayed publication can be negotiated between the manufacturer and university up front. Technology licensing, a supply-side strategy, was least valued by manufacturers.

Erik Sander, then at the University of Florida, wrote an excellent overview pertaining to industry and or university research centers (Sander, 2000 September). In this overview, he argues that manufacturers benefit from participation in industry and or university partnerships through (a) their access to bright energetic students, (b) gaining early looks at emerging research and technologies, (c) leveraging of industrial investments, (d) faculty mentoring, (e) access to the university research infrastructure, (f) capacity building through industrial-academic researcher networks, and (g) obtaining favorable intellectual property rights as a center participant. Many USDE-funded RERCs and the NSF funded Quality of Life Technology [Engineering Research] Center conduct collaborative research and development activities with AT manufacturers (Quality of Life Technology Center, n.d.).

Industry and or university collaborations allow university faculty and students to work closely with practicing engineers and scientists solving real world technical problems while exposing them to the culture and constraints of business. Collaborations enrich the students' educational experience and help to prepare them for future employment in the private sector. Collaborations also provide a practical education to faculty, enhance course curriculums, and serve as catalysts for future research and grants.

University TTOs must understand and be responsive to the cultures and values of both business and academe. At some risk of overgeneralization, firms conduct applied R&D to develop products and services; they protect knowledge through non-disclosure, patents, trade secrets, and copyrights; they generate revenue through sales, service contracts, and warranties; and they operate with tightly structured management, organization, scheduling, and timeframes. Firms differ in their resources, R&D capacity,

product portfolios and markets, aggressiveness developing new and improved products, interest in technologies from external origins, use of SBIR and other funding sources, and use of sub-contractors.

Academes (a) conduct basic research to develop new knowledge; (b) disclose knowledge through journal publications and conferences; (c) acquire revenue through grants; (d) mentor, train, and educate students; and (e) operate within loosely structured management, organization, scheduling, and timeframes. Faculty tenure and promotion is often tied to research publications, teaching, grantsmanship, and service rather than technology disclosure, patenting, licensing, or revenue.

To bridge the gap in values and cultures between the private sector and academe, TTO activities must be responsive, transparent, accessible, efficient, consistent, fair, and professional from the perspective of both manufacturers and academe. A university and its TTO might increase faculty awareness of business culture and TT processes and policies through education and training. A university and TTO may also adopt strategies to foster entrepreneurship, tie tenure and promotion to technology disclosure, patenting, and licensing, and reward faculty through license revenue sharing. Universities might strive to optimize their combined TT

(licensing, equity buyouts) and research (state, federal, and industry) revenues rather than treating them as separate and independent.

During its 2003-to-2008 funding cycle, the T<sup>2</sup>RERC conducted three TT projects to facilitate product development and commercialization, benefiting persons with disabilities and elders. A qualitative comparison of the Demand Pull project, the Supply Push project and the Corporate Collaboration project is presented in Table 3.

It is useful to compare these projects. Both the Demand Pull and Corporate Collaboration projects employ demand transfer strategies. Demand transfer strategies can be compared to discharging a rifle. If you chose your target well and aim carefully, you have a high likelihood of hitting your target.

The Demand Pull project has long transfer latency with somewhat lower transfer efficiency. As explanation the Demand Pull project (typically) works with innovations 'leftward' on the TT model with many barriers to overcome. The (typical) small companies participating in the Demand Pull project have limited resources with which to overcome these barriers. In many cases, the T<sup>2</sup>RERC co-developed SBIR grants with these firms to help overcome these barriers.

The Corporate Collaboration project works

**Table 3**  
**Comparison of T<sup>2</sup>RERC TT Projects**

Project	Technology Status (source)	Transfer Strategy	Technology Source	Technology Destination	Transfer Latency	Transfer Efficiency	Exemplar Technologies
Demand Pull	<i>Technology Research to early Product Research</i>	Pull	federal labs, universities, small companies	AT small company	Long (~3-4 yrs)	Mid	VisiPrint print management software, PowerCheq™ battery string equalizer
Supply Push	<i>Product Research</i>	Push	Independent inventors, small companies	AT small company	Mid (~2-3 yrs)	Low	Strong Arm™ Cane, Bumpa Coloring Book
Corporate Collaboration	<i>late Product Research</i>	Pull	knowledge transfer from T <sup>2</sup> RERC	collaborating large corporation	Short (~1 yr)	High	Black & Decker Jar Opener

with large corporations developing innovations already very close to the marketplace and with few barriers to overcome. The collaborating corporations (typically) have tremendous resources with which to overcome barriers and commercialize products. In addition, large corporations in highly competitive markets will (typically) have shorter product development cycles than small companies serving less competitive AT markets.

The Supply Push project used a supply transfer strategy, which can be compared to a shotgun approach. You aim at *likely targets* and fire. In terms of an analogy to a shotgun, some of your shot will hit the target, but much of the buckshot is likely to fly astray of the target. The term likely targets is critical. TTI very familiar with their corporate partners, their markets, technology needs, product portfolios, capacities, and inclinations will be much better at identifying likely targets. Such was the case with the Supply Push project. This project had the lowest transfer efficiency and intermediate transfer latency. As an explanation, the Supply Push project (typically) worked with innovations at a proof-of-product, or more 'rightward,' stage of development.

The effectiveness of the T<sup>2</sup>RERC as a TT intermediary derived from a number of factors. However, the most influential of these factors was the project personnel's broad knowledge and experience related to development and commercialization activities. First, the team employed its marketing expertise to conduct primary market research using interviews, focus groups, and surveys. It also applied this expertise to perform secondary market research by analyzing competing products, markets, demographics, legislation, and reimbursement. Second, the team utilized engineering skills to apply customer-centered, universal and transgenerational design principles while

engaging in collaborative product development. Finally, business management skills were called upon for brokering activities such as negotiations, contract development, and licensing.

Primary market research (i.e., focus groups, panels) was conducted in a state-of-the-art facility at the Western New York Independent Living (WNYIL) center. WNYIL facilitated sampling and recruitment by maintaining a large database comprised of elderly people and people with diverse disabilities. Several personnel were expert in scripting, running, and analyzing data derived from panels and focus groups. Primary market research was integral to customer-centered design and subsequent product validation.

Customer-centered design (CCD) is a best practice. It entails involving consumers in all phases of product definition, design, development, evaluation, and marketing. CCD maximizes commercial potential by helping to ensure that products are well designed, properly priced, and that they serve broad markets. CCD reduces design iteration, saving the manufacturer time, resources, and costs during product development. CCD was commonly used in the Supply Push and Corporate Collaboration projects.

The Demand Pull project transferred technology solutions to AT manufacturers to address critical market needs. Comprehensive primary and secondary market research was conducted to identify critical needs. That research was subsequently compiled into industry profiles — on learning disabilities, wheeled mobility and low vision and blindness — and published online (T<sup>2</sup>RERC, n.d.c). Demand Pull project personnel also co-wrote about a half-dozen funded SBIR proposals with partner manufacturers. Funding from SBIR grant awards helped (and is helping) to bring several AT products to market.

Project personnel were members of major trade and professional associations and participated in their annual conferences, including Assistive Technology Industry Association, MedTrade, International Seating Symposium, American Academy of Audiology, and the Rehabilitation Engineering and Assistive Technology Society of North America. Membership and participation helped personnel to maintain awareness of emerging technologies, products and markets, and to build an extensive network of responsive contacts.

Project personnel were also members of, or participated in, the annual conferences of the AUTM, FLC (national, regional), and the TT Society. Here membership and participation also provided an opportunity to acquire and to disseminate TT knowledge and practices.

As a TTI, the T<sup>2</sup>RERC made micro-level adaptations to address the specific needs of its transfer partners. For example, AT manufacturers underutilize primary market research and CCD in product design, development, testing, validating, and marketing. Both AT manufacturers and mainstream manufacturers lack access to people with disabilities. In the U.S., published primary and secondary research pertaining to disability markets and industries is fragmentary and/or costly to obtain. This dearth of data stultifies private sector innovation, new product development, and the ability to attract investment. AT manufacturers underutilize SBIR grants to fund product development. Mainstream manufacturers have not taken full advantage of transgenerational design as a strategy by which to broaden, deepen and retain markets. Finally, AT manufacturers underutilize universities and federal laboratories as technology sources (DOC, 2003). The three T<sup>2</sup>RERC transfer projects were conceived and refined to address these gaps and needs (T<sup>2</sup>RERC, n.d.a.).

## Outcomes and Benefits

This article reviews Lane's TT model. A case study (LC Technologies Eye Gaze System) demonstrates model concepts that include critical events, activities, stakeholders, and resource providers. TT intermediaries and resource providers play central roles as facilitators to TT processes. Examples of TTIs (*with principle activity impacted*) include federal granting agencies (*Technology Applications*), agencies administering small business innovation research grants (*Technology Research, Product Research*), angel investors (*Product Research*), and venture capitalists (*late Product Research to Product Commercialization*).

This model does not address the dynamic aspects of TT, which relate to transfer efficiency and transfer latency, transfer scale (micro, macro); nor does it fully develop the role of TTI. Lane views demand pull and supply push as forces that initiate TT activities. The current paper proposes that TT intermediaries employ demand pull strategies or supply push strategies to *facilitate* TT activities.

Working definitions were given to common terminology including: innovation, context (source, destination), and transfer mechanisms. Using this terminology, TT was defined as the movement of an innovation from a source context to a destination context via some transfer mechanism. Major concepts discussed include transfer efficiency, transfer latency, push transfer and pull transfer strategies (employed by TTI) and micro- and macro- scales. AT-related examples were used to illustrate important concepts.

Studies have been conducted to evaluate large and important TT systems (U.S. universities, federal laboratories, small business innovation development programs and RERCs). In these studies, transfer efficiency was discussed for universities (AUTM, 2007) and SBIR

programs (Wessner, 2008, DOC, 2003) and transfer rate was discussed for universities (Pressman & et al., 1995; T<sup>2</sup>RERC, n.d.d).

TT was also examined at different scales. Discussions around the studies by AUTM, NRC, MIT, and RERC all focused on macro-scale issues. Discussions around the University of Minnesota Pulse Survey of manufacturer interests and T<sup>2</sup>RERC project descriptions focused on micro-scale issues.

Data gathered and analyzed in macro-scale studies does not address or substitute for a clear understanding and practice pertaining to micro-scale issues. The AUTM (2007) study presented aggregate data on intermediate outcomes (disclosures, patent applications), the proof-of-concept event (patents granted) and intermediate outcomes subsequent to patenting (exclusive, non-exclusive licensing). However, it is unclear what percentage of licenses result in proof-of-products or commercial products. Economic impacts (product sales, induced investment) are also unclear. Data regarding the average latency from disclosure to patent application, patent application to patent, or patent to license are lacking.

The MIT (Pressman et al., 1995) study suggested that induced investment (ratio of private investment to licensing revenues) consequent to university technology licensing is 24-to-1. However, the AUTM (2007) study neglects the broader economic and social impact of transfer activities (as required under the Bayh-Dole Act). Instead it focuses on revenue generation (primarily) as a consequence of licensing and equity buy-outs. In particular, firms serving small disability markets may not fully benefit from university licensing activities.

A number of strategies might be adopted to balance a university's narrow interests against society's broader interests. Here are a few

examples. Universities could reduce or eliminate license royalties (and other fees and payments) for small market technologies. Patent applications could be filed for all novel (screened for due diligence) technology disclosures. This suggestion is not particularly radical, given that more than 62% of university technology disclosures currently result in patent applications. A 'timer' could be employed whereby intellectual property rights are waived back to the inventor if a technology is not licensed in some reasonable period. Societal metrics could be employed to justify transfer policies and practices. State and local revenue sharing might reward universities for positive economic outcomes consequent to their TT activities (and fund subsequent efforts). Universities could adopt metrics that emphasize both total research revenue and industry-based research revenue. Public legislation could require university TT performance be judged (at least in part) against economic impact.

The MIT study (Pressman et al., 1995) discussed transfer latency in terms of the average age of MIT technology licenses. The average MIT technology license was about four years old while product commercialization was expected to take about eight years. In general, university TTOs should adopt and be rewarded for practices that both maximize transfer efficiency and minimize transfer latencies (pre- and post-patent). To shorten post-transfer latencies, universities should adopt policies and practices to support (by speeding and reducing costs of) the licensee's efforts to develop (new) proof of concepts and proof of products. The University of Minnesota Pulse Survey and subsequent discussion of industry and university research centers identified (exemplar) services and support sought by manufacturers.

The RERC study (T<sup>2</sup>RERC, n.d.b) showed that USDE-funded Rehabilitation

Engineering Research Centers (sample of 11 former centers studied) have low transfer efficiencies. Most RERCs are university-based and TTOs serve as their TT intermediaries. RERCs typically conduct their research, development, and utilization activities in a linear and dependent sequence (a push transfer strategy). These activities normally correspond to needs (technology, service, diagnostic) identified for small disability markets.

RERCs have a five-year funding cycle and utilization activities normally take place in the last year or two of the cycle. With an average post-transfer latency of eight years from a university technology license to the consequent commercial product, one should expect to find (and does find) little evidence for successful utilization. A TTO can exacerbate low transfer efficiency several ways. It may fail to provide outreach or support to their faculty; it may allow (or cause) long pre-patent and pre-license latencies; its transfer strategies may be inflexible or too narrow; and it may demonstrate an exclusive, or predominant, focus on 'homerun' technologies.

RERCs should be a critical knowledge resource, a research and development partner and a technology source for AT manufacturers. To improve transfer efficiency and reduce transfer latency, five strategies might be employed. First, universities should not receive RERC awards until they commit to expedite the transfer of RERC generated intellectual property. The USDE should gain this concession at the grant award site visit.

Second, RERCs should abandon the 'normal' research, development, and utilization sequence. Instead, utilization (market needs, business interest) should be established prior to conducting research and development activities (a pull transfer strategy).

Third, AT manufacturers should be partners on all research and development projects whose intended outcomes are transfer and utilization. AT manufacturers should be active and significant partners from project inception (during proposal development and thereafter), help to establish project objectives, collaborate on research and development activities, and serve as the primary and preferred technology licensee.

Fourth, RERCs should negotiate with their TTOs while preparing their grant proposals. The proposal should include a summary of the negotiations, and it should specify how intellectual property will be handled subsequent to the grant award. In particular, the IP rights and licensing terms and conditions for partner manufacturers should be addressed.

Fifth, RERCs should be required, or strongly encouraged, to work closely and intensively with the Disability Rehabilitation Research Project on Knowledge Translation for TT (Center on KT for TT). The center embodies, and will extend, the micro-level knowledge, experience, and practices of the former and successful RERC on Technology Transfer, which operated over two five year cycles from 1998 to 2003 and 2003 to 2008 (T<sup>2</sup>RERC, n.d.e).

The NRC study (Pressman & et al, 1995) evaluated the five largest SBIR programs (DOD, NIH, NASA, DOE, and NSF). Transfer efficiency was stated in terms of the number of commercial products consequent to Phase II grants. The NRC study found a very high transfer efficiency of 49% (minimum) to 71% (maximum) for the five agencies studied. Significant follow-on funding was also consequent to receipt of a Phase II SBIR grant. The NRC study provided the status (ongoing research, discontinued, sales expected, sales not expected, and sales) for technologies

developed with SBIR funding and sales revenues generated.

The NRC study did not provide the average transfer latency from firms' receipt of a Phase I or II SBIR awards to the introduction of commercial products. The NRC study did not classify SBIR awards by type of technology being developed. Sampling biases may have skewed transfer efficiency upward. Firms without a working email address (30%) and their awards were not included in the study. Firms with working email addresses had (only) a 42% response rate. As a consequence, the strong positive findings of the NRC study are somewhat weakened and it is unclear whether findings generalize to AT manufacturers and industries.

The federal laboratory system should be another important knowledge resource, research and development partner, and technology source for AT manufacturers. The FLC locator service is an excellent means by which AT manufacturers can find or pursue development of needed technology. The principle mechanisms available to AT manufacturers include technology licensing, cooperative research, and development agreements and contracts. It is likely that most work carried out by federal laboratories with, or for, AT manufacturers will be through cost-in CRADAs or contracts.

Further study is needed to gauge interactions between AT manufacturers and the federal laboratory system. Future studies may attempt to answer questions such as these: From which federal agencies do AT manufacturers license technologies? With which federal agencies do AT manufacturers enter into CRADAs (cost-in, cost-shared) and contracts? What types of technologies are licensed or developed (requires a classification system)? What factors (barriers, facilitators) influence AT manufacturers licensing, CRADAs, and contract decisions? What factors influence the

terms and conditions of CRADAs and contracts?

Most of the studies considered in this paper addressed (albeit incompletely) the macro-performance of large TT systems. However, TTI activities take place at a micro-scale. In order to evaluate the impact of TTI activities on TT outcomes, it is necessary to expand the resolution of the current TT model. The new Disability Rehabilitation Research Project on KT for TT is working to address this need. Specifically, the DRRP is overlaying and synchronizing the Product Development and Management Association (PDMA) product development model to the TT framework. The Product Development and Management Association (PDMA):

... is the premier global advocate for product development and management professionals. Our mission is to improve the effectiveness of individuals and organizations in product development and management. This is accomplished by providing resources for professional development, information, collaboration and promotion of new product development and management. (PDMA, 2010, para 1)

The *PDMA Handbook of New Product Development* embodies the state of the art (Kahn, 2004). The KT for TT is formally mapping carriers, barriers, and best practices to the individual (micro-level) steps of the PDMA model. This work was made publicly available in late 2009 through an online database (<http://kt4tt.buffalo.edu/>) that is accessible to AT manufactures, TT intermediaries, and other relevant stakeholders.

Finally, where TT processes are concerned, TT intermediaries should be active experts

and facilitators, rather than passive benefactors of TT outcomes. For example, stakeholders served by university TT offices include faculty, students, the university, businesses, the community, and society. However, most stakeholder interests are grossly ignored by applying performance metrics that are narrowly focused on return-on-investment from research dollars. Community, state, and national resources have created university and federal laboratory infrastructures. Scientists working in these institutions are the creators of intellectual property and educators of future members of the workforce. Businesses are the consumers of intellectual property, creators of products, employers and engines of the economy. As a consequence, communities, states, the nation, scientists, students, and business are all critical stakeholders. TT intermediaries have a responsibility to recognize the criticality of these stakeholders and facilitate TT in manner that is maximally responsive to their interests. New and re-enacted TT legislation might reflect these priorities and require the use of more appropriate metrics by universities, federal laboratories, and other covered entities.

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