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Convergence of assistive devices and mainstream products: Keys to university participation in research, development and commercialization

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Abstract. Development and commercialization activities for assistive devices and mainstream products are converging. Aging and disability demographics, rapid technical innovation, healthcare costs, intense market competition and public policy all drive this trend; while trans-generational design suggests new business strategies and product solutions. The university research community can play an important role in industry research and development activities leading to new products. Business is the gateway through which all new products enter the marketplace. University researchers are advised to engage business partners prior to the inception of their own research activities, and early in the corporate product development cycle. Successful university-business partnership requires that university researchers and other stakeholders recognize business' lead in product development and commercialization; and understand and practice business culture. University contributions may include: technical research and development; identification of customer and technology needs; product definition; prototype testing; product validation; clinical trials and external funding through grant activities. Five keys to successful university-business partnership are discussed.

Keywords: Assistive technology, universal design, trans-generational design, design for all, university private sector partnership, collaboration, smart homes, aging in place, market research, technology licensing, technology transfer

1. Introduction

Why are development activities for assistive technology (A/T) devices and mainstream products converging? Aging demographics are creating a burgeoning market demand; with explicit recognition that people age with and into disability. Mainstream manufacturers, always attuned to large market trends, are positioning themselves to respond to this demand. However they are often unfamiliar with disability and aging markets; assistive technology, and trans-generational ("universal," "design for all") product concepts. As a consequence, they may be disinclined to build or acquire the requisite expertise and infrastructure needed to develop and commercialize products for these markets. They may also lack access to people with and aging into disability, needed to identify product needs; to validate markets; to define and evaluate product concepts.

Assistive technology device manufacturers must often develop technically sophisticated products for small disability markets, populated by individuals with complex needs. They are mostly very small companies and therefore lack the financial and technical resources of mainstream manufacturers. A/T manufacturers are typically very familiar with their segment of the disability market, assistive technologies serving these market segments, competitors; as well as distribution, marketing and payment issues.

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Public policies are mandating the inclusion and equal participation of people with disabilities; requiring the provision of assistive and accessible products; financing the development of these products; and providing revenue for their purchase. Exploding health care costs are driving a paradigm shift for our elders. Under the old paradigm, sick elders are treated and maintained in centralized, specialized and costly health care facilities. Under the proposed new paradigm; environment modification, innovative technologies and caregiver support will allow elders to remain healthy as they "age in place." Rapid technological innovation and convergence is enabling the development of low cost, sophisticated, and high-quality assistive technology and trans-generational products. Universal and trans-generational design ("design for all") place aging and disability, needs and products within a common framework.

Mainstream product and A/T device manufacturers are entering into new collaborative relationships that leverage the A/T manufacturer's specialized knowledge of disability markets, people with disabilities, public and private insurance, and assistive technologies. In turn, the A/T manufacturers draw upon the technical, financial, marketing and distribution capabilities of mainstream manufacturers to produce high quality, new and improved products, in shorter timeframes, with broader distribution. In this context, there are many opportunities for university researchers to collaborate with mainstream and A/T manufacturers on the development and commercialization of assistive and trans-generational products.

The United States Department of Education, National Institute on Disability and Rehabilitation Research (NIDRR) funds Rehabilitation Engineering Research Centers (RERC's) to carry out disability-related research and development activities. RERC's can be roughly divided into centers with a disability focus (hearing, vision, communication, wheeled mobility, aging) and centers with a cross-disability, technology focus (telecommunications access, information technology, workplace ergonomics, universal design). Most RERC's are based at a research university and each RERC must demonstrate the utility of its research by transferring technology to the private sector. Transfers mechanisms include, but are not limited to: intellectual property licensing; standards and protocols; clinical instruments; non-commercial products available by order (hardware) or download (software); licensing of intellectual property for commercial use; and contract research and development.

The RERC on Technology Transfer (T^2RERC) is a technology-focused center whose mission is to facilitate the introduction of new and improved products, benefiting people with disabilities, and people aging into disability. The T^2RERC provides technology transfer assistance to other RERC's and runs a number of technology transfer projects. Across these projects, the T^2RERC supports technology transfer between industries; from private inventors to industry; and from research universities and federal labs to the private sector. T^2RERC activities include but are not limited to: serving as a technology transfer broker; prototype design and development; collaborative product development with manufacturers; primary market research; secondary market research; collaborative grant development with manufacturers [14].

At the 2002 International Conference on Computers Helping People with Special Needs (ICCHP) held in Linz, Austria, Joseph Lane proposed "Keys to successful collaboration" between university researchers and the private sector for the purpose of product development and commercialization. This paper expands upon and updates that presentation.

2. Background

Assistive technology manufacturers are often categorized into "industry segments" serving broadly defined disability markets (vision, hearing, mobility, communication, cognition, education). Most disability markets are small however, and the corresponding industry segments tend to be populated by fewer than a hundred companies and dominated by at most a few dozen. The vast majority of A/T manufacturers are very small companies, with the largest companies having sales revenue on the order of $1B US (Invacare Corporation, Sunrise Medical in the mobility industry). A few large mainstream manufacturers have AT product divisions (Siemens AG and the Gennum Corporation in the hearing industry). A few large original equipment manufacturers (OEM) specialize in assistive technology (Knowles Electronics supplies components to hearing aid manufacturers) while AT manufacturers are small customers for many other OEM (wheelchair batteries and controllers). AT manufacturers are often in the difficult position of having to design, develop and test costly and sophisticated products for small, highly specialized markets.

Market demand spurs product development and refinement; shapes business planning; attracts competi-

tion and investment, and induces manufacturers to improve their marketing, distribution, sales and service. Disability markets are generally small and highly fragmented; and include people with an extraordinary range of functional abilities and needs; across all ages and life situations. Many disability markets (as defined above) have yearly sales of less than $100M US while a few AT markets have sales exceeding $1B US (usually characterized as "mid-sized" markets). Hearing (hearing aids, assistive listening systems) and wheeled mobility (power wheelchairs, scooters, and manual wheelchairs) are certainly mid-sized markets.

The United States Department of Commerce conducted a survey of A/T manufacturers in 1999 and published the results from this survey in 2003. There were 359 survey respondents including 287 AT manufacturers. Participating manufacturers had $2.87B US in total sales; for average yearly sales of $10 M US. Only 11 manufacturers had yearly sales in excess of $60 M US and 1 manufacturer had sales in excess of $800 M US. About 23% of sales ($660 M US) were to export markets; with Western Europe being the largest non-US market at $282 M US. In terms of innovation, 62% of participating manufacturers obtained consumer input for product design; 14% had applied for a Small Business Innovation Research grant from 1997 to 1999; and 14% had worked collaboratively with non-A/T manufacturers, universities or federal laboratories. The Department of Commerce estimated that 3000 US manufacturers were producing some 17,000 assistive technology products [15]. The hearing and mobility industy segments are illustrative.

In 2004, about 7.38 M people in the US owned one or more hearing aids out of 31.5 M people with hearing difficulty; and 6.2 M people used their hearing aid(s) at least once in the previous year. Market penetration reached an historical low of 20.4% in 1997; down from 23.8% in 1984; but has steadily increased back up to 23.5% in 2004. There are 12.52M hearing instruments owned by people; and 74.1% of new hearing aid users purchase instruments for both ears. The average price for a single hearing instrument has increased from $1215 US in 2001 to $1369 US in 2004. Average price in 2004 by instrument type: behind the ear ($1514 US); in the canal ($1361 US); and in the ear ($1306 US). Some 41.7% of all hearing instruments are less than 2 years old suggesting that at about 25% of all US hearing instruments (some 3.13 M) were purchased in 2004; generating sales of about $4.3B [10]. Industry leaders for hearing instruments include: Siemens Hearing Instruments, Oticon, Phonak, GN Resound, Starkey Laboratories and Widex. Other important manufacturers in the hearing industry produce earmolds, hearing aid components and assistive listening systems.

Cooper provides a good overview of the US mobility industry in 2000. About 2 M people in the US used manual wheelchairs, power wheelchairs or electric scooters on a daily basis. Broken down by type there were 1.36 M manual wheelchairs (depot, lightweight, bariatric, standing, specialized); 0.32 M power wheelchairs (lightweight indoor, lightweight indoor/outdoor, active indoor/outdoor, bariatric, standing, push rim power assist, and specialized seating) and 0.35 M electric scooters. Cooper reports that 170 US wheelchair manufacturers had total reported sales of $1.33B US; with $880 M US for manual wheelchairs, $205 M US for power wheelchairs, and $245 M US for electric scooters. Only five companies had sales in excess of $100 M US [4]. Other mobility products include seating and positioning; walkers, canes and crutches. Major mobility manufacturers include: Invacare, Pride Mobility, Sunrise Medical, Graham-Field Health Products, Otto Bock Healthcare, Permobil, Hoveround, Amigo Mobility International and Electric Mobility.

The growing senior's market is a major driver for innovation and is attracting the attention of major manufacturers of telecommunication, computer, health care, and consumer products. In 1975, there was 216 M US citizens with 10.6% aged 65 or older. By 2025, these figures are projected to increase to 350 M US citizens with 18.2% aged 65 or older. Similar trends hold worldwide with 357 M seniors in 1990 projected to increase to 761 M by 2025. Health care costs for seniors are growing at a staggering rate and already exceeds $1.5T in the US. The current centralized, crisis driven health care paradigm cannot be sustained. Intel's Proactive Health research group suggests that a health paradigm emphasizing "aging in place" is needed. To this end, Proactive Health is focusing on four research areas: promoting healthy behaviors, early disease detection, improved treatment compliance, and support for informal care giving. Proposed solutions rely upon technologies such as: network infrastructure, sensors, computers, software data analysis and "smart agents;" and upon the capabilities and commitment of informal caregivers. The Intel Proactive Health Group funded "aging in place" research projects at six US universities [5].

In 2003 and 2004 Microsoft published two studies examining computer usage among today's workforce; and disability trends among today's seniors. The under-

lying premise of these studies is that today's computer using workforce will be tomorrow's computer using retiree; but only if retirees can readily access their computer. Among study participants aged 65 or older, 33% were characterized as having a "mild" disability and 40% as having a "severe" disability. Modes of disability and percent of respondents having such disability (mild, severe) include: vision (11.7, 4.4) manual dexterity (11.7, 4.4), hearing (11.9, 1.6) cognition (11.0, 1.4) and speech (1.6, 2.4). These are very important studies and have, I believe, direct relevance to manufacturers of telecommunication and consumer electronics products [1,17].

Microsoft provides resources, training, and technical support to about 100 A/T manufacturers and research universities. "Members of Microsoft's Assistive Technology Vendor Program (MATvp) must have a proven track record in designing, building and supporting assistive technology products to meet the needs of customers with disabilities/functional limitations and schools and businesses that are responsible for making accommodations" [12]. By supporting AT manufacturers, people with and aging into disability are provided with timely and high quality access to Microsoft's operating systems and software applications. At the same time, Microsoft needn't become expert in diverse and complex disability populations and corresponding assistive technologies.

Technological innovations developed for specific mainstream, aging or disability applications often have considerable cross-market relevance. Way-finding products developed for people with visual impairments may serve the needs of elders with Alzheimer's disease or other cognitive impairments. Beam-forming directional microphones developed for hearing aids have been used to improve the performance of automatic speech recognition. Classroom sound field systems enable full and effective participation for many children with hearing impairments; and may also improve the focus and educational performance of most other children. Wireless networks with unbounded mainstream potential; may provide the information backbone for our elder's smart homes; and contextually relevant information to augmentative communication devices. Bluetooth (and future generations of wireless technologies) provides a wireless link between cell phones and headsets; and may be used to link bilateral hearing aids; or hearing aids and cell phones. Adaptive electric motors were developed for electric vehicles; and would be a major improvement over the motor technologies now employed in power wheelchairs and scooters. Internet accessibility and usability pioneered for and driven by the needs of people with disabilities; will serve the elderly as they "age in place;" and also serve the interests of our students, our workforces and our governments. Smart homes and trans-generational products developed for people aging with and into disability will have general relevance for people with disabilities. There are of course, many other examples of technological convergence.

Universal design (also known as "trans-generational design" or "design for all") is a powerful concept: to make products that work better, with less effort, with lower risk of injury, and more intuitively. It makes products usable for people with a greater diversity of abilities; in a wider range of environments; for a longer period of their lives; and as their abilities change. People intuitively recognize the logic and value of curb cuts, kitchen appliances and tools with ergonomic grips and controls, and computer operating systems that have built-in accessibility options. The universal design lineage can be traced back to farm worker ergonomics; industrial worker productivity and safety; and the battlefield performance of soldiers and pilots. The disability rights movement fostered the concept of "accessible design," and led to accessibility standards and enforcement of these standards through public policy. Universal design generalized classical ergonomics, and addressed shortcomings in the concept of accessible design. Basic guidelines for universal design are easy to state, but not always easy to implement; and universal design continues to evolve. More recently, mainstream manufacturers began recognizing universal design (more comfortably referred to by industry as "trans-generational design") as a business strategy; a means by which to access new markets, increase market penetration, and retain customers.

Given this context, what are the keys to successful university-business collaborations leading to product development and commercialization?

3. Keys to university-private sector collaboration

3.1. Key #1: Know your goal

We assume that the common goal is "to introduce products into the marketplace, addressing important needs of people with disabilities and aging into disability." The path to this goal is necessarily through A/T and mainstream manufacturers interested in serving a disability or trans-generational market. Traditional

academic research produces new knowledge (basic research), new technology (applied research), publications (knowledge dissemination) and new researchers.

Private sector application of this research generally takes place through various types of technology license agreements. In the US, technology transfer offices will preferentially disclose, patent and license research with the greatest perceived market potential. There is likely to be an unintended bias against (assistive technology and other) research serving small (disability and other) markets.

Technology transfer offices were established in response to the Patent and Trademark Act (1980) and broker the transfer of university research to the private sector. The Association of University Technology Managers conducts yearly surveys of technology transfer activities from federal funded institutions. In 2004, 381 institutions were surveyed including: 232 US research universities and 69 US research hospitals and institutes; 76 Canadian institutions; and 4 third-party investment firms. There were 232 survey respondents including: 164 US research universities and 33 US research hospitals and institutes; 35 Canadian institutes; and 1 third party investor. Respondents (192 of 232) reported $41.2B US in total research expenditures with $27.7B coming from "federal sources," and $3.0B US coming from "industrial sources." The 192 US respondents reported 14,025 intellectual property disclosures and 10,517 US patent applications (13,803 including international patents). There were 3,680 US utility patents awarded representing (only) about 2.2% of the 170,637 utility patents granted by the USPTO in 2004. US respondents reported 4783 new licenses or license option renewals on 27,322 active patents covering the period 1991 through 2004 [2].

US research universities have a major economic impact in the US private sector. US universities were responsible for 3928 new licenses or license option renewals distributed among start-up companies (618), small companies (2133) and large companies (1177). Most start-up companies locate close to the licensing institution; thereby contributing to the local economy. In 2004 US universities reported $1.03B US in gross license income from running royalties, cashed in equity and other sources. However, a relatively small percentage of all university research is patented (35% of new disclosures in 2004); and licensed (18% of active patents); while in 2004, the average research expenditure for each new patent was about $11 M [2]. Technology transfer offices have good reason to adopt practices that: increase the number of patents and patent licenses, license revenue or number of company start-ups; or decrease research expenditure leading to patents, license royalty or other revenue opportunities.

The rules under which university researchers can engage manufacturers vary across countries and universities. In the US, technology transfer offices (in conjunction with university administration) control all rights to intellectual property derived from university research; dictate how university researchers can conduct research for the private sector; and whether university facilities can be used for this research. University researchers should negotiate these issues with their technology transfer offices (or analogous entities outside of the US) before engaging manufacturers in collaborative research efforts. Proposals for university-business research collaborations should address intellectual property, staffing, and facilities issues and should address how the university might obtain financial and other benefits. Technology transfer offices should be given regular updates on the status of university-business collaboration; and especially the research outcomes from this collaboration. Analogous considerations are likely to apply for most countries and universities.

Recommendation: The goal of development projects is the eventual transfer and use of some tangible output by others. The majority of those outputs are commercial products, so the transfer path goes through private sector manufacturers. It is not enough for university researchers to develop technology and hope for a fortuitous patent, license, transfer and commercialization. Instead, researchers should engage manufacturers early, establish the collaboration, and work to maintain it. Researchers must work closely with their technology transfer offices (or analogous entities) at all times.

3.2. Key #2: Know your customer

If the goal is to commercialize products, then manufacturers are your customers. University researchers mistakenly assume that the end-users are their customers. They are not. End-users are the intended beneficiaries, but the benefit is only packaged and delivered to them through manufacturers. Only manufacturers have the capacity to produce, distribute and support products in the marketplace, including those designed for use by people with disabilities. This outcome will only occur if the manufacturer seeks and gains rights to the researcher's intellectual property. Government funding agencies, university administration, colleagues and students, research collaborators, clinicians

and consumer advocacy groups are stakeholders who may influence the research activities and commercialization outcomes, but they are not the target customer.

What factors should be considered when seeking out a partner manufacturer? Tech Link a technology transfer subcontractor to the US Federal Laboratory Consortium developed a checklist to identify "promising" manufacturers for technology transfer. Factors on their checklist include: small-to-medium sized companies (50 to 250 employees), growing and hiring, history of new product introduction, history of licensing externally developed technology, manufacturing capacity, established market channels, financially sound, and experienced management [6]. The checklist may differ somewhat for university to private sector technology transfers but the idea will be the same.

Supporting Tech Link's position, small businesses appear to be more aggressive than large companies in their efforts to develop and commercialize new products. In the US, small businesses employ 53% of the private work force; generate 47% of national sales; 55% of all patents; and in recent years have produced most of the new job growth. R&D engineers and scientists constitute 6.41% of small business' employees but only 4.05% of large business employees. Large businesses appear to focus their resources on marketing, distributing, sales and service for established product lines [13].

One must be careful not to over-generalize however. There is great variation amongst small and large manufacturers regarding their aggressiveness to develop new products; willingness to partner with university researchers (or other "external" partners); and resources they might be willing to commit toward university based research. The most important considerations for establishing a successful partnership will be a good match of university research capabilities and interests, to the manufacturer's needs and interests; and the ability to establish and maintain a healthy working relationship. The T^2RERC has successfully collaborated with very small A/T manufacturers and with very large mainstream manufacturers.

On a micro-level, corporate vice-presidents or senior managers in charge of development, production and marketing are "key" decision makers for new product development; and whether or not to involve external partners. It is important to win support from people within a company who can serve as "internal champions" for your research capabilities and interests. It is equally important to avoid antagonizing people who can take on the role of "internal assassins."

Businesses are risk averse; a "no" answer is more readily achieved than a "yes" answer. New projects are often approved through a chain-of-command and every link in the chain has decision authority. A "no" ends the process whereas a "yes" only moves it to the next link of "yes/no" scrutiny. Internal contention over limited company resources is perpetual. If no one inside the company will defend "your project" with their reputation or career, it will generally lose out to projects supported with greater commitment.

Recommendation: The partner manufacturer is your "customer" while funding agencies, university administration, students, colleagues and others are "stakeholders." Research activities should address manufacturer needs as expressed by corporate decision makers, but supported by your own detailed analysis of the end-user, marketplace and technical factors that will determine commercial success or failure. Use profiles to identify potential corporate partners but remember that profiles are advisory not determinant. Cultivate internal champions to advocate for your research capabilities and interests. Conversely, be careful to not alienate anyone within the company, as they may play a role in the decision-making in unexpected ways.

3.3. Key #3: Know your market

Manufacturers will only have interest in university research and technology leading to products that have: a competitive advantage; a significant market; a promising return on investment projection; a reasonable research and development path; and fit the manufacturer's strategic vision and product portfolio. Corporate decisions on whether to pursue new product development are often informed by upper management (strategic vision, product portfolio, market potential, and competition); design and engineering (research, development, design, and production); marketing and sales (perceived market needs, customer feedback). New product development competes with other projects and activities for corporate resources and attention. Manufacturers have many paths by which to develop or acquire new technology including technology licensing, internal R&D, subcontracted R&D, and licensing from original equipment manufacturers – and university based research and technology development.

Alignment (to whatever extent) between university research interests and capabilities; and the manufacturer's needs and interests takes place during the identification of and engagement to the corporate partner. Manufacturers value the contributions of their univer-

sity partners. However, university research and development will necessarily be focused on the manufacturer's needs and interests. The manufacturer will be the customer and decision maker for the goals, objectives, deliverables and timeframes of the partnership. The university researcher loses some autonomy. However this loss is compensated for by having an efficient path to market; and saving the time and effort invested into activities having no value to the manufacturer. In some cases, the corporate partner may even provide financial or other resources to support your efforts.

Engagement to a corporate partner prior to conducting research and development activities is the ideal path for technology transfer. Nonetheless, the majority of university research is still conducted prior to establishing the market potential for research outcomes; obtaining patent protection; identifying and negotiating with potential licensees; and closing a license agreement. As discussed, this path has a very low throughput. What considerations might improve this situation?

Given that a potential licensee has been identified, an "externally developed" technology must pass the same scrutiny as a manufacturer's "internally developed" technology. In the US, university technology must actually pass a higher level of scrutiny because the university technology transfer office seeks royalties and other payments from the licensee; and often introduces unacceptable delays. Manufacturers own the intellectual property rights for internally developed technology; avoid licensing costs and have immediate access to the technology. In order to license your technology to a manufacturer, you must think like the manufacturer; anticipate their tests of scrutiny; and pass these tests.

Important tests include the technology's state-of-development (idea only, concept drawings, simulations, working prototype), intellectual property (no patent, patent pending, provisional patent, patent); business opportunity (market and market size, competing products and their deficiencies, purchase intent and price points); research and development (product requirements; cost, expertise, infrastructure and timeline for additional research and development); as well as considerations for production, marketing, distribution, sales and support. Generally, your technology and derived products must fit the manufacturer's product portfolio (similar products for similar markets).

Manufacturers especially welcome reasoned arguments that establish the market potential for your technology and derivative products. These arguments should be well supported by primary and secondary market research. Primary market research draws upon expert interviews, panels, surveys and focus groups; and is used (among other things) to identify customers and unmet needs; define product requirements; and estimate purchase intent and price points. Secondary market research draws upon published literature ("secondary sources") to identify markets segments and size, competing manufacturers and their products, marketing and distribution, and laws and regulations relevant to the purchase, recommendation or financing of the proposed product. In the US, university technology transfer offices are supposed to carry out this work but often lack the time and resources to do a thorough job. On the other hand, most academicians lack the expertise, experience and resources to undertake this work. It may be advisable therefore to employ graduate students or colleagues with business backgrounds to carry out these activities.

Manufacturers often follow fixed cycles during which: proposals for new product are submitted, reviewed and screened by management; product development is initiated; and new products are introduced. Twenty-four month cycles may be typical and new product introductions often take place at a yearly industry trade show. For example, product proposals might be submitted and screened in fall 2004, product development might start in winter 2004, and the new product be introduced at a fall 2006 tradeshow. Missing the window for product proposal submission could delay a promising transfer opportunity by at least 12 months and may derail the opportunity entirely.

Recommendation: Identify and engage a corporate partner prior to initiating your research and development activities, to ensure they align with the company's intended path. This dialogue begins early in the corporation's product development cycle, and ideally prior to the cycle's initiation. The corporate partner will then establish the role for university-based research and development activities. When university research activities have been carried out prior to seeking a corporate partner, it is important to anticipate and prepare for the "tests" that a corporation will apply to your development output to assess its viability. You should know the market potential of your technology and be aware of corporate product development cycles.

3.4. Key #4: Know your role

When pursuing the uptake of university research by business, the research enterprise holds a subordinate role to the business enterprise. These relative roles

must be accepted by university researchers; and this acceptance clearly communicated to the business partner. Other stakeholders (funding agencies, research collaborators, consumer advocates, and university administrators) must also accept the lead role of the corporate partner.

Joining an ongoing business' research and development project; is similar to joining an ongoing conversation. Work will have preceded university involvement; and commercialization activities will continue after the university research team has concluded their role. University researchers are advised to first listen to and become very familiar with: project goals; project management; completed work; project members (internal and external); future tasks and their role in these tasks. Once the role of the university research team is established, your business partner will embrace your expertise and capabilities. You have effectively joined the conversation.

University culture is focused on academic research, grants, teaching, service, mentoring and publication. Business culture is focused on identification of new markets and business opportunities; product development and introduction; marketing, distribution, sales and revenue generation. To work with business, the university researcher must understand and accommodate business culture. Business plans; new product development and introductions; ongoing research activities; unprotected intellectual property; trade secrets; marketing plans and other sensitive information must be held private and confidential. Research team members will typically be asked to work under and respect non-disclosure agreements. Manufacturers will often want intellectual property rights to research and technology produced by their university partner. In the US, university researchers will need to work closely with their technology transfer office to ensure that they are working in accordance with federal law. While differing in particulars, similar intellectual property concerns will likely hold for other countries and universities. Finally, the university research team should always support and complement the business' engineering, marketing, or design personnel assigned to the project. Any perception that a university research team is competing with, or undercutting any portion of the business' project team will quickly generate animosity, undercut cooperation, and endangers the collaboration.

University research projects should be led by someone familiar with business culture and expectations; with a professional demeanor; and with decision-making authority for the university side of the collaboration. University research projects should be staffed by faculty, students and other professionals who understand and will adhere to the demands of collaboration. Communication via email, mail, teleconferencing, or videoconferencing should be regularly scheduled, and properly prepared for; project timelines should be adhered to; project reports, studies, drawings, prototypes and other deliverables should be on time, to specification and of high quality.

Many countries provides funding for university-private sector research collaborations leading to commercial products. Such resources should be leveraged to attract business partners and focus on activities best suiting the researcher's interests and capabilities. Most importantly, businesses may perceive externally funded research as having less risk.

The US Small Business Innovation Research (SBIR) program provides funding to small businesses (less than 500 employees) for product development and pre-commercialization activities. Small businesses must be located in the US, at least 51% US owned, and independently operated; and the principle investigator must be employed by the small business. The small business must do at least 67% of the work; and permits up to 33% of the work to be done by universities or other non-profit research organization. The SBIR program typically has two funded phases and one unfunded phase. Phase I is typically 6 months at up to $100 K US; while Phase II is typically 2 years at up to $0.75 M US. A Phase II award cannot be applied for without having already won a Phase I award. Ten federal departments and agencies participate in the SBIR program, and set aside 2.5% of their extramural funding to support this program. About 29% of all applicants receive a Phase I award; while about 40% of phase I award winners, apply for and secure a Phase II award [8,13,16].

About one-tenth the size, the US Small Business Technology Transfer (STTR) program is similar in most respects to the SBIR program. Under the STTR program, the principle investigator *need not* be employed by the small business. At least 40% of STTR research must be done by a small business; and at least 30% *must* be done by a university or other non-profit research organization. The STTR program also has 2 funded phases and one unfunded phase. Phase I is typically 12 months at up to $100 K US; while Phase II is typically 2 years at up to $0.75 M US. Five federal departments and agencies participate in the STTR program, and set aside 0.3% of their extramural funding to support this program. In fiscal year 2003, federal departments and agencies contributed about $1.6B to the SBIR and STTR programs [16].

A university researcher is not precluded from co-authoring an SBIR proposal that reflects their research interests and capabilities, while also addressing a business' interests and needs. In fact, co-authoring an SBIR proposal is a great service to the business; and business' will rarely turn down an offer in this vein. In their role as SBIR subcontractor or STTR principle investigator, the university researcher is in a strong position to negotiate favorable terms for intellectual property rights and use of university research facilities pursuant to winning an SBIR or STTR grant. The university researcher has a much weaker position to negotiate these issues with their technology transfer office after the grant has been awarded.

Recommendation: Business has the lead in any university-business partnership; and defines the university's role in this partnership. The university research team often joins an ongoing project about which they must learn. Academic culture and business culture differ greatly. The university research team must learn and practice the business culture; and be led by someone experienced in this culture. University researchers should pursue external funding such as SBIR and STTR grants. External funding gives the university researcher leverage with potential business partners; and leverage with university administration.

3.5. Key #5: Broaden the concept of research

Limiting "research" to "technology development," and limiting "technology transfer" to "licensing" is unnecessarily restrictive. Business can benefit from many university "research activities" that support the development and commercialization of products. University research can include: basic and applied research; prototype development and testing; market research (needs identification, establishing product requirements, product evaluation); and clinical trials. An effective university-business partnership provides many benefits to business including: access to research infrastructure; access to technical, business and clinical expertise; skilled labor (graduate students) and financial resources through grant opportunities. University researchers often have access to human subject populations (elders, people with disabilities) that manufacturers have difficulty reaching. University researchers will generally cultivate different strengths, and each manufacturer will differ in its needs. Researchers should not be discouraged that many manufacturers will not be interested in what they have to offer.

The Center for Future Health at the University of Rochester is an example of a university-private sector collaboration focused on healthcare research and technology. The Center for Future Health "is a national catalyst for the creation and validation of non-invasive personal health technology for self care, mobile care, and home care." Areas of active research include: automated health assessment; molecular modeling and smart bandage technology; conversational personal medical assistant; motion understanding (in vivo gait capture and analysis for health assessment); continuous health data gathering and assessment; and sensor network middleware. The Center for Future Health is an academic-private sector consortium which includes consumer organizations, national institutes and foundations, medical advisors, and product developers [3]. The Center for Future Health is one of six Proactive Health university research projects supported by the Intel Corporation [5].

The T^2RERC Fortune 500 Project is an example of a university-corporate collaboration built around market research and trans-generational product design. The Fortune 500 Project works with the largest and most influential US corporations, producing new mass-marketed household products. These corporations continually redesign products and introduce new products in response to changing customer demands; and to stay competitive in the marketplace. The Fortune 500 team works with partner corporations to identify the product needs of elders, people with disabilities and the general market; and then to define, develop, and validate new and improved products serving these markets. Trans-generational design is at the heart of the Fortune 500 Project and all consumers are involved in all phases of product design and development.

Our message to the Fortune 500 companies is that they can expand their markets by considering the needs of people with various levels of functional limitations when designing new mainstream consumer products. Corporate partners in the Fortune 500 Project include: Applica Consumer Products Inc., Whirlpool Corporation, Kodak, and the White-Rogers Division of Emerson Electric Corporation. Several products have entered the marketplace through this project including the Black & Decker Lids Off? jar opener and Toaster Oven; with other products in development [14].

Universities can follow market and product development trends to identify new research opportunities. Knowing what your customer wants is essential to delivering it. Semi-annually for more than a decade, Knowles Electronics (a leading manufacturer of hear-

ing aid electronics) has contracted comprehensive surveys of the US hearing disability market [11]. Hearing aid manufacturers responding to this information will improve customer satisfaction, increase market share and increase demand for Knowles electronics components. From a sample of 1764 hearing aid users (sampled across degree of hearing loss and instrument type) only 59% of users (with units up to 6 years old) are "satisfied" while 18% are "dissatisfied." In particular, users were dissatisfied with: ability to hear soft sounds (23%); comfort with loud sounds (27%); feedback/whistling (27%); use in noisy situations (38%); telephone access (30%), cell phone access (30%); [communication in] large groups (44%) or restaurants (25%), and [listening to a] concert (22%). While not the explicit intention of this survey – a range research targets are identified [10].

The T^{2}RERC Market Research Project identifies market opportunities and technology needs for A/T "industries" serving people with mobility, hearing, vision, communication and educational impairments. Primary market research (expert interviews, consumer focus groups) is used to identify: market needs (performance, feature and functions, safety, durability), technology needs (state of the art, future technologies) and business opportunities. Secondary market research is used to identify: markets (segments, definitions, size); disabilities (description, diagnosis); competitors (manufacturers, products, featured, prices), technologies (state of the practice); distribution channels, payment vehicles (out of pocket, public and private insurance), legislation impacting the prescription, recommendation and purchase of products; and marketing channels (conferences, tradeshows, publications). Market information is compiled into "Profiles" for each industry and can be purchased through the T^{2}RERC website. Technology needs and supporting market information is also summarized into "problem statements" and posted on the T^{2}RERC website. The market information developed by this and other T^{2}RERC projects has attracted about 70,000 corporate visitors each year [14].

Recommendation: Broaden the definition of "research" to include all activities that can facilitate product development and commercialization. Review public market research to discover the private sector's research interests, and then offer your expertise in literature, methods and metrics to address their needs.

4. Conclusion

Market factors; rapid technological innovation and convergence; and new design concepts are creating great opportunity for research and development collaboration between mainstream manufacturers, A/T manufacturers, and university researchers.

Aging demographics, burgeoning health care costs, intense competition and other factors are drawing or forcing mainstream manufacturers to the trans-generational market. In response to market complexity of people aging with and into disability, and the technical complexity of products and systems addressing their needs; A/T manufacturers and university researchers have much to offer mainstream manufacturers.

Assistive technology manufacturers can provide the mainstream manufacturer with expert knowledge of disability, assistive technology solutions, distribution channels, and payment. High-tech "smart homes" and trans-generational concepts will never meet all of the needs, for everyone, in every environment and at all times. Assistive technology products will necessarily be components of "aging in place" solutions; used to adapt the living, working, and recreational environment to the individual needs of elders.

Irrespective of collaborations with mainstream manufacturers, people aging with and into disability represent a growing business opportunity for A/T manufacturers. While most A/T markets are small to mid-sized, they are not insignificant. Assistive technology markets are served primarily by small companies but also by a growing number of mid-sized companies and large-sized companies with A/T divisions.

Collaboration with university researchers provides many benefits to A/T and mainstream manufacturers. University research can include: basic and applied research; prototype development and testing; market research; and clinical trials. The collaboration provides the manufacturer with access to research infrastructure; technical, business and clinical expertise; skilled labor, financial resources through grants, and human subject populations. Unfortunately, a number of factors interfere with such collaborations.

If the goal of research is product commercialization, and product commercialization only takes place through manufacturers, then manufactures are the customers of researchers. Business will understandably want the lead in any university-business partnership; and will want to define the university's role in this partnership. Researchers are reminded of their responsibility to disclose all intellectual property to their technology transfer offices.

The ideal scenario for university-business collaboration is for the university researcher to identify and engage a qualified corporate partner prior to initiating re-

search activities, and at the earliest possible time in the corporate product planning cycle. Intellectual property rights for likely research outcomes should be negotiated between the researcher and their university prior to entering into collaboration. The researcher should pursue external funding to gain negotiation leverage with both the university and potential business partners. Negotiations between the researcher and business are facilitated by internal champions. Willingness on the researcher's part to broaden the notion of "university research" will uncover many novel opportunities for collaboration. Once collaboration is established, the university research team should learn its role project and adopt a "business culture." The university research team should avoid competing with or antagonizing any member of the business team at all costs.

Conducting research; seeking patent protection; identifying potential licensees; and securing a license agreement that leads to a commercial product is the most common but much less effective path to market. Nonetheless, this path can be optimized by "thinking like a business" and anticipating "tests of scrutiny" applied to any new product proposal. The university research team should consider employing or partnering with business graduate students or colleagues to provide market research and other support.

Many opportunities exist for university-private sector collaboration for the development and commercialization of assistive and trans-generational products. Effective university-business collaborations provide important benefits to all parties. To achieve a successful collaboration, university researchers must bridge the gap between academic and corporate culture; and work closely with their university technology transfer office at all times.

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