Building an Institute for Triple-Helix Research Innovation

Leigh W. Jerome, Ph.D.

University Clinical, Education and Research Associates (UCERA)

John A. Burns School of Medicine, University of Hawai'i

Patricia J. Jordan, Ph.D.

Pacific Telehealth & Technology Hui

Tripler AMC, HI

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Corresponding Author: Leigh W. Jerome, Ph.D., Director, Institute for Triple Helix Innovation, John A. Burns School of Medicine, University of Hawaii, 651 Ilalao Street, Honolulu, Hawaii, 96813; e-mail: JeromeL002@hawaii.rr.com

Abstract

A paradigm shift is now underway that promotes new patterns of collaboration among industry consortia, university linkages and government agencies, with an emphasis on the integration of commercialization, empirical knowledge and the public good. Moreover, a triple helix of overlapping spheres of university-industry-government is a process increasingly at the core, rather than the periphery, of national, regional, and multinational innovation systems (Etzkowitz, 2003). This paper describes a program of research designed to investigate the impact of triple-helix research ventures compared with other types of collaborative research models, and determine specific criteria associated with successful projects, and flourishing innovation systems. The development of an institute for triple-helix research offers a basis from which to explore critical interfaces, quantify new collaborative models, investigate new paradigms for innovation, and develop strategies to address the risks associated with collaborative research relationships. To generate new knowledge, transfer tacit knowledge, and successfully manage knowledge, a triple-helix CoP will be established to begin to define a consensus language for cross-disciplinary, cross-cultural and cross-organizational research; to organize appropriate methodologies for investigation; and, moreover to promote a virtuous cycle of international knowledge diffusion. It is hypothesized that the creation of the institute and corresponding community of practice will result in evidenced-based exportable models for triple-helix collaboration, significant knowledge spillovers for Hawai`i, and fertile international linkages for all participating partners. The development of a Hawai`i-based institute for triple-helix innovation is posited as a new framework for understanding collaborative potentials and facilitating Pacific region innovation. An evidenced-based approach to triple-helix collaborations will delineate the benefits and challenges of university-industry-government collaborations and enumerate essential factors for new paradigms of innovation to be developed and validated. A robust and enduring research program will allow for broad data collection and analysis, longitudinal examination of diverse factors, and a perpetual feedback loop to continually refine our understanding of the knowledge base while informing new projects and collaborative designs.

"An innovative society needs more research driven by societal need…performed under conditions of imagination, flexibility and competition associated with traditional basic science."

Lewis Branscomb
Former Director of the Science, Technology and Public Policy Program
Harvard University, Kennedy School of Government (1999)

BACKGROUND

Until the beginning of the last century, research in the United States was accomplished almost exclusively within the university environment, drawing upon a rich tradition of intellectual freedom, specialization, and scientific independence. In the early 1900's, when industry began to initiate its own R & D programs, profit was introduced as a new research driver. The National Institute of Health was conceived during this same period and formal programs of research were initiated. Following World War II, a system of federal laboratories was established to achieve government projects focused on national missions and the public good. Academia, industry and government were thus established as the three primary sponsors of research.

Over time, the independence of each of these entities has shifted to create evolving and overlapping relationships. Government plays an increasingly important role in providing a regulatory environment and encouraging innovation; and academia is increasingly involved with industry, not only through consulting and contract research but in forming companies from university-based research (Leydesdorff & Etzkowitz, 2001). This triple helix of university, industry, and government relations is demonstrated in new organizational mechanisms that promote innovation and new collaborative endeavors (Lissenburgh & Harding, 2000). This structure differs dramatically, in both function and role, from the innovation model that existed prior to the emergence of knowledge-based economy.

The program of research described herein is designed to establish an ongoing effort for data collection and analysis, and to advance the quantification of triple-helix models and methodologies. An evidenced-based approach to triple-helix collaborations will delineate the benefits and challenges of university-industry-government collaborations and help enumerate the essential factors for new paradigms of innovation to be developed and validated. Quantifying triple-helix methodologies means defining variables associated with project effectiveness, efficiency, and success, as well as documenting best practices, lessons learned, failed enterprises, conflicts of interest, and how barriers to collaboration have been successfully removed. A robust and enduring research program will allow for broad data collection and analysis, longitudinal examination of diverse factors, and a perpetual feedback loop to permit the continual refinement of our understanding of the knowledge base while informing new projects and collaborative designs.

The Triple Helix Model of Collaboration**:** An international paradigm shift is underway that promotes new patterns of collaboration among industry consortia, university linkages and government agencies, with an emphasis on commercialization (Asheim & Coenen, 2004; HAL Corporation, 1999; Leydesdorff, 2005; Leydesdorff & Etzkowitz, 2001; Shapira, 2002). Mounting evidence attests to the fact that controlled collaboration of government, academia and industry facilitates innovation and creative development while providing balance between knowledge, social benefit and profit motivations (Asheim & Coenan, 2004; HAL Corporation, 1999; Leydesdorff, 2005). Trilateral collaborations energize partners to address local and national concerns through funded research programs, thereby leveraging human and material resources to generate solutions while furthering the acquisition of new knowledge.

Partnerships can significantly facilitate the transfer of scientific knowledge in the development of tangible products and processes. Over the past decade, consensus has been growing regarding public-private partnerships. Emerging literature that examines university-industry-government networked infrastructures supports these triple-helix collaborations as the key to improving the conditions for innovation, productivity, and wealth in a knowledge-based society (Campbell, 2005; Campbell, Koski, & Blumenthal., 2004; Etzkowitz, 2002; Leydesdorff, 2003; Shapira, 2002; Sutz, 1998). Triple helix research partnerships are considered the best promise for establishing long-term organizational structures that allow for short-term intensive collaboration experiences (Campbell, 2005; Etzkowitz, 2003; Langford, Hall, Josty, Matos, & Jacobson, 2005; Leydesdorff & Fritsch, 2005). The majority of literature in this field to date concentrates on the accrual of institutional benefits resulting from triple helix collaborations, specifically research funding and increased productivity (Campbell et al., 2004). Another recent focus has pointed to the potential risks associated with industry relationships, including bias in the reporting of results (Bekelman, Li, & Gross, 2003), impacts on education and training (Gluck, Blumenthal, & Stoto, 1987), and financial conflicts of interest (Campbell et al., 2004). The emerging roles and priorities of universities, corporations, and government agencies are becoming closely linked on several levels (Campbell et al., 2004). Moreover, a triple helix of overlapping spheres of university-industry-government is increasingly at the core, rather than the periphery, of national, regional, and multinational innovation systems (Etzkowitz, 2003). Innovative and ethical trilateral partnerships must minimize barriers to collaboration; increase the exchange of science and technology resources; and, proactively address possible threats to the integrity of empirical investigation.

According to Shapira (2002), there are three compelling reasons to establish flexible partnerships with university-industry-government networked infrastructures: Social benefit, economic efficiency and sustainability. The construction of an institute for triple-helix innovation would provide both a mechanism for facilitating these trilateral relationships and the means to investigate the impact of these relationships on domestic and international innovation. This is important because innovation requires more than the emergence of a good idea or a promising prototype. The efficacy of new developments must be substantiated through empirical research and then pushed out as a product or codified knowledge within a societal context. Increasingly, innovation is considered to be an event at the organizational level, and is noted as a social precondition for creating technological innovations. Bringing the benefits of new products, new processes, and new knowledge to the market is a key challenge for an innovation system. Today's innovations are more than ever the result of collaborative approaches to research (Best et al., 2003). The construction of an institute for triple-helix research offers a new paradigm for understanding and leveraging these interfaces and facilitating local, regional, national and international systems for innovation.

One of the main ideas behind the concept of innovation systems is that innovation is more likely to occur at the interfaces of economics, politics, and science (Leydedorff & Fritsch, 2005). Collaborations can thus be realized that straddle these ambiguous trilateral boundaries and internalize the flexibility and innovation inherent in each (Guston, 2000). Technological innovation has traditionally been viewed as the application of an existing knowledge to develop a specific product, such as the microprocessor chip. Increasingly, however, innovation is recognized as a complex event, responsive to contextual factors, organizational structures, and multiple dynamic processes. In other words, knowledge production is a necessary but not sufficient condition for innovation (Rogers, 1995). Knowledge production creates an innovation potential that can then be realized through networks where users, producers, entrepreneurs and policy-makers collaborate in transaction spaces (Nowotny, Scott & Gibbons, 2001). We are in the midst of a growing preeminence of knowledge capitalization; economic growth is dependent not only one a new cycle of innovation but on new structures for innovation (Sutz, 1998).

Systems for Regional Innovation*:* The 'region' has emerged as a central tenet in theories of innovation and economic development. Regional differences are noted in the types and quality of systems and the ways systems and processes are developed and sustained (Leydesdorff, & Fritsch, 2005). Innovation is associated with the regional clustering of resources and activities (De Bruijn, 2004). Regional clustering tends to spark innovation and boost productivity levels, competitive strength and prosperity. The focus on regions as the best geographical scale for an innovation-based learning economy stresses the importance of regional resources in stimulating the innovation capability and competitiveness of firms.

According to Doloreux and Parto (2004) 'regional innovation systems' are private and public organizations that function via relationships and organizational arrangements that are conducive to the generation, use and dissemination of knowledge. A regional innovation system is characterized by competition and cooperation between knowledge creation and knowledge diffusion organizations (e.g., firms, universities, training organizations, R & D organizations, technology transfer agencies) and the innovation-supportive culture that enables these systems to evolve. A regional innovation system promotes innovation activities in two ways: 1) The availability of inputs in a region makes some innovation projects possible that would otherwise not be started or accomplished; and 2) Heightened efficiency and productivity of innovation processes can occur, especially in local environments where a high degree of labor division is stimulated (Fritsch, 2002). Doloreux and Parto (2004) describe the following three key features of regional innovation:

1. Innovation is a geographical process and innovation capabilities are sustained through regional communities that share common knowledge bases and localized resources (e.g., specialized labor market, suppliers, local learning processes, local traditions for interacting etc.).

2. Innovation is embedded in social relationships that develop over time along culturally determined lines. The regional context prevails over the set of rules, conventions and norms that prescribe behavioral roles and shape expectations. These are often informal social relationships determine a specific image and specific representation and sense of belonging which enhances the local innovative capability through synergic and collective learning processes.

3. Innovation occurs when geographical concentration and proximity are present.

Globalization is changing both the concept of proximity and the scope of innovation. Global geographical dispersion of knowledge, technology, and industry is rapidly co-occurring with agglomeration to create concentrated handfuls of specialized clusters (Ernst, Guerrieri, Iammarino, & Pietrobelli, 2001). International linkages appear to be an essential to continuous growth of an enterprise cluster (Ernst et al., 2001). Partnerships offer expanded opportunities for financial flows, technology transfers, information flows and the interpenetration of business activities. Moreover, international linkages have been noted to recharge regional activity through opportunities for international knowledge sourcing (Saxenian & Hsu, 2001).

Regional innovation occurs within the context of urbanized clustering, or agglomeration, and the localized learning that occurs within an agglomeration economy. There are three essential components of regional innovation systems:

1. <u>Clustering</u>: A cluster is a geographic concentration of competing and cooperating companies, suppliers, service providers, and associated institutions. Clusters tend to occur in agglomerations. Clusters provide access to a maximum flow of information and ideas; opportunities for collaboration; availability of specialists, subcontractors and suppliers; efficiency of particular local services; development of local pool of specialized labor; less risk; and, greater options and customer choice (Harmaakorpi, 2004). The most recognized innovation cluster is Silicon Valley.

   As innovation moves outside of a single organization, lateral relationships across boundaries are of primary importance, rather than more traditional hierarchical bureaucratic structures.(Etzkowitz, 2001). Innovation clusters are the linkages, interactions, relationships and development of different but inter-dependent entities (i.e., education, research and development, industries, financial institutions) to form a virtuous cycle of innovation and entrepreneurship. In innovation clusters, there is a strong and consistent interaction between many individuals and organizations, on both formal and informal levels. Clustering is seen as a key means of driving regional development by building private and public sector partnerships to mutual benefit through government and regional investment in innovation incubators, science parks and cities, and technology transfer offices. It has been noted that regions that have been able to achieve a clustering effect, by accident or design, have achieved and sustained greater success in the global marketplace.

2. <u>Knowledge Spillovers</u>: Knowledge, once created, is difficult to contain and may therefore spill over to benefit others who are vigilant and able to recognize its potential (Aharonson, Baum, & Feldman, 2004). Knowledge spillovers reflect a flow of salient knowledge from sources such as the labor market; the fluctuation of employees between different employers; cooperative relationships; trade; publication; and, purchased goods and services (Fritsch, 2002).

   Knowledge-generating activities do not occur in isolation, but depend on access to new ideas. Thus, co-location and geographic concentrations of innovative activity facilitates knowledge spillovers by providing opportunities for both planned and serendipitous interactions potential. This, in turn, promotes networking of firms engaged in related research (Aharonson et al., 2004). The cumulative nature of innovation manifests itself at the organization and industry levels, but also at the geographic level. This creates an advantage for firms locating in areas of concentrated innovative activity, and leads to pronounced geographic clustering. These factors can generate positive feedback loops or virtuous cycles as geographic concentrations of innovative activity attracts additional labor, trade, research, development and a greater exchange of ideas (Krugman, 1991).

3. <u>Absorptive capacity</u>: Absorptive capacity is an organization's ability to develop or adopt

innovations; the ability to perceive opportunities; and, the ability to use the information to develop products or processes (Greve & Salaff, 2001). Greater absorptive capacity becomes available with exposure to a larger pool of ideas; so, firms also benefit from the strategic alliances of their neighbors. The benefit an organization derives from co-locating and developing strategic alliances is dependent on the firm's ability to capitalize on available spillovers. This stresses the importance of absorptive capacity and of the characteristics of the environment within the cluster to generate positive opportunities (Aharonson et al., 2004).

Interdisciplinary Research: While many contemporary research problems span a number of scientific disciplines (Metzger & Zare, 1999), it is the fusion of disciplinary perspectives that is essential for scholarly innovation and discovery of new health technologies and technology-mediated health care. In recent decades, rapid growth in science and technological knowledge has compelled scientists to begin addressing complex problems from multiple perspectives. Interdisciplinary partnerships between universities, industry, and government are increasing in scale and diversifying in scope. Regulatory and statutory legislation have also evolved in support of these relationships. Today, many of the country's most valuable intellectual resources have migrated to private enterprises that offer progressive research environments where individuals are rewarded for creativity and innovative design. U.S. business research investments already approach the levels of basic university research funding (Campbell, 2005).

Collaboration is becoming a requirement in response to the interdisciplinary nature of more advancement in basic science in bioinformatics, bioengineering and structural biology (Sherman & Miyataki, 2004). In fact, the recognition of synergy between two or more disciplines has led to the advent of a number of new fields of study, including biochemistry, cognitive neuropsychology and more recently, bioinformatics, genomics, and photonics. Parallel gains are also being achieved through innovative information and medical technologies. The interdisciplinary nature of basic science research today requires a shift in the working culture of collaboration to a degree not found previously within or across most institutions (Sherman & Miyataki, 2004). According to Metzger and Zare (1999), there exist several barriers to promotion of interdisciplinary research collaborations, including institutional, environmental and practical considerations. Institutions foster an isolation of disciplines (Dauphinée & Martin, 2000) that leads to difficulties in promoting collaboration in research and development. On a more practical level, there is a broad range of issues that can make it difficult for interdisciplinary teams to establish common understanding. For example, unifying disciplines where scientists don't speak the same language can be difficult (Robertson, Martin, & Singer, 2003; Zeleznik, Agard-Henriques, & Schnebel, 2003) — making it virtually impossible to achieve consensus on a common problem of topic for study. There also exist issues of data recording, language, coding and analysis (Treloar & Graham, 2003); difficulties monitoring quality assurance (Zeleznik et al., 2003); and publication implications, such as authorship (Treloar & Graham, 2003). Such differences heighten the need for models or frameworks to guide important steps and processes of collaborative research (LeGris, Weir, Browne, Gafni, Stewart, & Easton, 2000).

Interdisciplinarity provides a way to address topics and formulate questions that are too complex to be adequately explored by a single discipline. The points where multiple disciplines converge provide opportunities for leveraging knowledge and expanding the utility of emergent tools. "Radical" interdisciplinarity suggests there is untapped value in the development of mechanisms to facilitate integrated explorations between disparate research spheres such as computer science, economics, public policy, medicine, engineering, entertainment media, communications and public health (Evans & Marvin, 2004). Diverse networks can capture and exploit the richness of information from new and complex perspectives. The promotion of interdisciplinary research through communities of practice holds promise for the sustainability of innovative approaches to common areas of inquiry and generating applied solutions to multi-faceted healthcare concerns.

Communities of Practice: The emergence and perpetuation of innovation clusters is dependent on knowledge flows and information spillovers. The rapid and dynamic pace of innovation is making traditional hierarchical structures for knowledge flow obsolete. More flexible mechanisms are required that allow fluid changes within emergent organizational forms. Such flexibility allows for responsiveness to on-demand problems, in real time (Fontaine & Millen, 2004). In this project, an interdisciplinary, triple helix Community of Practice will be established in order to facilitate new knowledge flows between researchers in various locales. This Community of Practice will work to better understand and quantify collaborative research models and regional innovation.

A Community of Practice (CoP) is a special type of network that emerges from a desire to share knowledge more effectively or to build systems among members of a particular discipline. The community of practice is the essential component of a perspective on knowledge networks that informs the creation of learning systems at various levels of scale, from local communities, to single organizations, partnerships, cities, regions, and globally (Preese, 2004). Communities of practice, whether spontaneous or intentional, bring specific scientific capabilities together in distinctive but functionally related local and global locations (Cooke, in press). A CoP consists of individuals bound to one another through exposure to a common class of problems, with a common pursuit of solutions and thus the embodiment of a particular store of knowledge (Hildreth & Kimble, 2000). Wenger and Snyder (2000) define a CoP as one where people share their experiences and knowledge in free-flowing creative ways so as to foster new approaches to problem solving, to develop new strategies, to transfer best practices, develop professional skills and to recruit and retain staff.

Communities of practice are considered essential building blocks of the knowledge economy (Teigland & Wasko, 2004) through which knowledge has been noted to flow best and fastest (Gelauff, 2003). According to Brown (2005), CoPs are characterized by: 1) The Domain: an identity defined by a shared domain of interest; 2) The Community: the environment where members engage in joint activities and discussions; and, 3) The Practice: the development of a shared repertoire of resources including experiences, tools, solutions, rituals, and so on. There is a geographical stickiness to knowledge, particularly tacit knowledge. In today's market environment, codified knowledge travels the world with very little friction (Bathelt et al., 2004). The acquisition and transmission of tacit knowledge, however, is often locally embodied in routines, expertise and skills that are largely acquired by learning-by-doing or learning-by-interacting (Poon & MacPherson, 2003). Only when locally embedded tacit knowledge is combined in novel ways with codified and accessible external knowledge can new value be created (Bathelt et al., 2004). CoPs are particularly useful in building communal resources and mechanisms that allow for the exchange of tacit information. Tacit information and collective learning represent critical components in intraregional knowledge spillovers.

Like any other organic entity, CoPs evolve and change over time (Preese, 2001; Wenger, 2001). Members join, others leave, and new foci of interest emerge that modify the CoP's direction. . This malleable nature is a key feature that differentiates CoP from traditional, task-driven teams or workgroups and allows efficient tacit knowledge flows. Lesser and Storck (2001) assert that it is the social capital inherent in CoPs accounts for the outcomes that are most valuable. Social capital can be defined in terms of the processes between individuals, groups, communities and organizations that potentially influence mutual social benefit. Social capital has been described as “the glue” that holds a community together; it is the shared knowledge, understanding, skills and offers of help needed to achieve shared goals, or solve common problems (Putnam, 2000). Unlike financial capital, social capital is usually not tangible; consequently it is less well understood and its power is (Wenger, 1998). Research suggests that social capital is created through purposeful action and resultant knowledge can be transformed into conventional economic gains (Sobel, 2002). Networks rich in social capital, such as CoPs, have members who will more easily share knowledge amongst one another and build new knowledge together (Gelauff, 2003). Fundamental to, and underpinning these processes, are: a) norms and values which form the basis of the group’s identity; b) the networks and social interactions that provide the vehicle for productive output; and c) trust and cooperation which provide the necessary cohesion in the social context to ensure that collaborative efforts are integrated in a sustained, mutually beneficial outcome (Guenther & Falk, 1999). According to Cox (1998; Cox & Caldwell, 2000), social capital can be expressed in terms of trust. Research supports the view that trust is foundational in the production of social capital, and consequently mutually beneficial social outcomes (Fukuyama, 1995; Falk & Kilpatrick, 1999; Kilpatrick, Bell, & Falk, 1999).

While CoPs are central to the maintenance of tacit knowledge, most referent literature describes only co-located communities (Kimble et al., 2001). But, Communities of Practice can be physically located, locally networked (e.g., within a company via an Intranet), virtual (i.e., networked across distance) or, any combination of these (Preese, 2004). Virtual Communities of Practice are becoming more important as a means of sharing information within and between organizations (Adamic & Adar, 2003). The globalization of business means that many organizations now function in a distributed environment; and the literature suggests CoP might ably be developed and maintained within a distributed international environment (Kimble, Hildreth, & Wright, 2001).

One major challenge with establishing virtual CoPs is the traditional notions of how information quality is achieved, limiting our thinking about the non-linear potential of collaboration (Neus, 2001). A distributed community of practice (CoP), like the one being described in this study, consists of a group of people who communicate with each other synchronously and/or asynchronously, concerning a knowledge domain of common interest (Snyder & de Souza Briggs, 2003; Wenger, 1998, 2001). As the community develops its members share expertise and support by interacting to solve problems. By using the same dynamics that made open source goods possible, distributed CoPs are challenging this notion as well, suggesting that a loosely knit network of experts can produce comparable or better quality information in a collaborative paradigm than traditional solitary authors, institutions, or organization are able to create. Various computer-mediated communication structures and tool allow “virtual communities” to work together online, not only communicating about specific activities but also building a form of collaborative knowledge base (Bieber et al., 2002). Gradually shared solutions and insights emerge that contribute to an accumulated common knowledge base. This knowledge base may be facilitated by and held externally in databases (effectively rendering it codified knowledge) or it may become tacit knowledge within the community or held in the minds of long-term members.

The promotion of a distributed triple-helix community of practice holds promise for inspiring applied solutions to complex healthcare concerns and innovative approaches to common areas of inquiry. Within the context of this project, a triple helix CoP will be initiated to create a consensus language for cross-disciplinary, cross-cultural and cross-organizational research; to organize appropriate methodologies for investigation; and moreover to promote a virtuous cycle of international knowledge diffusion. Any network requires a versatile mechanism by which to synchronize its efforts. This project seeks to establish a triple helix CoP towards generating new knowledge, transferring tacit knowledge, and successfully managing codified knowledge.

One current area of focus in the CoP literature relates to understanding how to enable these communities of practice to emerge, flourish, become productive and then transform. Emerging knowledge models assume Virtual CoPs have the opportunity to redefine how high-quality information is created and shared in an organization (Neus, 2001). This project will therefore establish an initial CoP from which to learn but with the understanding that it will eventually transform, in the flexible manner it is intended to embody. The CoP will generate knowledge related to the specific aims of the Triple Helix project as well as how to best utilize CoP in subsequent endeavors. It is hypothesized that the creation of the institute and corresponding triple helix CoP will result in evidenced-based exportable models for triple-helix collaboration, significant knowledge spillovers for Hawai'i, and fertile international linkages for all participating partners.

A Regional Innovation System in the Pacific Region: The Asia-Pacific region is vast, stretching northward to Mongolia, southward to New Zealand, eastward to the island states of Oceania, and westward to Pakistan. The countries and territories of the Pacific region are at various stages of economic growth. While Australia, Japan, Republic of Korea, New Zealand, and Singapore are categorized as highly industrialized countries, Bangladesh, Cambodia, China, India, Pakistan, and Vietnam are regarded as low-income countries. Indonesia and Philippine could be categorized as middle income countries, and Thailand and Malaysia be as high income countries (The World Bank, 2006). The major financial centers in the Pacific Rim are Tokyo, Hong Kong, Singapore, and to a lesser extent, Sydney. These centers also serve as the primary points for the administrative control and coordination of a firm's Pacific Rim activity. As a result, the concentration of multinational service activity in these centers is far more intense and dynamic than other Pacific Rim cities (Moss, 1986).

Over the past several decades, Asian economies have experienced rapid expansion of industrial production and trade and have become central in the global production and export of Information Technology (IT) products. The IT services market in the Asia-Pacific region is projected to grow at an annual compound rate of 8.9% from 2004 to 2009, outpacing the global rate of 6.1% (Young, De Souza, Datar, & Tramacere, 2005). Two factors have fueled these expansions: growth in IT demand, worldwide; and, relocation of labor-intensive production stages to lower-wage Asian countries (Bonham, Gangnes, & Van Assche, 2003).

The continued expansion of U.S. and Asian technology markets is spawning the emergence of new regional innovation systems. Biomedical sites in Singapore, Hong Kong, China, and Japan's cities of Kyoto and Kobe have revealed a growing interest by Asian organizations to reach across international boundaries to collaborate on biomedical research (Sherman & Miyataki, 2004). On the other side of the Pacific Ocean, Silicon Valley firms have developed and brought to market some of the most important electronics and biomedical technologies seen in the second half of the Twentieth Century. The rise of Silicon Valley from the 1930s to the 1990s reflects a complex process shaped by successive waves of innovation and entrepreneurship; the emergence of new forms of financing, such as venture capital; and the evolving military and commercial demand for electronic and biomedical products (Lécuyer , 2001). In 2000, high-tech firms in Silicon Valley employed more than half a million engineers, scientists, managers, and operators in industries ranging from electronic components to computers. The United States still accounts for almost three-fourths of global biotech revenues, but elsewhere the industry is growing faster, as Asia-Pacific nations target biotechnology as a core economic development engine for the future.

New regional systems require novel structures that align with salient goals, strategies and cultural values. The essential traits of each regional system are idiosyncratic and thus face a big risk in attempting to adopt designs or policies just because they have worked in another location. Any particularly successful regional approach is aligned with the characteristics of that region and will almost certainly be ineffective in creating success when transferred to a new region (Cooke, in press). Since the values and goals for each regional network differ significantly, a suitable social and cultural environment is essential for achieving common goals and coordination of action (Harmaakorpi, 2004). The current project establishes a distributed, regionally compatible networking structure comprised of interdisciplinary researchers from six Pacific region locales. The initial goal for the institute of triple helix research innovation will be to quantify the value of triple helix and other research models while creating a working community of practice that recognizes and integrates the unique geographic characteristics, cultural values and the complementary goals of the locales in the Pacific region. As a broader goal, the institute will test the application of derived models and explore longitudinal impact in terms of knowledge spillover, knowledge diffusion and regional development.

Hawai`i's Place in an East-West Innovation System: The global knowledge economy is impacting our notions of proximity and the scope of markets and competition. Globalization brings an increased pressure for the quick delivery of superior performing technologies at the lowest cost and ahead of the competition. A necessary prerequisite for competitive survival in a global market is the capacity to foster the co-evolution of local and international networks, and to develop new modes and structures for knowledge creation and knowledge diffusion (Pietrobelli, 2002). New innovation systems must form, adapt and develop strategic alliances with both domestic and foreign partners (NAP, 1999).

While innovation systems are often thought of as large, ever-expanding clusters like Silicon Valley, some important transactions are more effectively and efficiently accomplished in small scale urban areas where things like shared vision and mutual trust can be more easily achieved. A region can be geographically defined as a network of organizations that interact with innovative outputs of regional firms on a regular basis. Alternatively, a region can describe the cultural aspects of the region, homogenous in terms of specific criteria and possessing some kind of internal cohesion (Doloreux & Parto, 2004). So, there is room for smaller agglomerations that specialize, based on location economies or more diversified small agglomerations. Here, the advantages of smallness can be intentionally exploited by establishing a sound institutional organization of regional decision-making, learning, leadership, networking and innovation processes and social cohesion in order to overcome the disadvantage caused by lacking the benefits of economies of scale (Harmaakorpi, 2004). The institute for triple helix research innovation will consider regional development from this perspective in seeking to quantify research models and in establishing new structures for collaborative endeavors.

As innovation ventures seek to develop a global networking capacity, two variables are considered essential: cultural harmony and managerial compatibility (Shaw, 2001). Cultural harmony is characterized by effective cross-cultural understanding and cooperation. Managerial compatibility is the organizational communications and style of interacting that allows a mission to be developed with supporting strategy, tactics, and goals. To be effective, new partnerships need to be properly constructed and ably led. This requires that a shared cultural perspective be in place. The development of international partnerships is no exception. All partnerships work best when there are clear goals that align with a mutual vision; shared contributions; and, regular evaluations based on agreed upon core criteria. Well-structured and well operated partnerships that reflect cultural harmony and managerial compatibility are more likely to succeed; and, will serve as valuable intermediary organizations able to bring together key partners to develop new products and processes of value to society as a whole (National Academies Press, 2003).

Hawai`i, by virtue of its geography and multi-cultural population, is a suitable place for facilitating knowledge, networks and systems pertinent to Asia, the Pacific Islands and the Pacific Coast of the United States. With respect to regional and international partnering, Hawai`i has many strengths upon which to build, including geographical centrality, technological infrastructure, and a rich social and cultural heritage. Hawai`i's mid-Pacific location and the diversity of local culture provide a natural alignment for compatible partnering with Asia-Pacific markets. Hawai`i is a logistic hub in the Pacific region and has established a high technology development sector. Further, Hawai`i's size provides reasonable access to all levels of government and the capacity to model systems that would not be possible in larger urban areas. But, Hawai`i does not have the geographic clustering necessary to compete with more established systems of innovation. A new paradigm for innovation development must therefore be envisioned in order to take advantage of the region's particular strengths while recognizing the limitations and challenges of scale.

Building the institute for triple helix innovation research in Hawai`i provides ideal positioning for bridging Asia-Pacific markets and for providing new kinds of competitive linkages for technology-based endeavors. The institute will act as a catalyst in developing an 'innovative milieu,' for Pacific region collaborative development. An innovative milieu is a whole of relations, occurring in a geographical area, which has networked beyond the area itself and increases the unity of economy, industry and culture to create collective learning and act as a mechanism that alleviates insecurity within the innovation process (Harmaakorpi, 2004). This project recognizes the opportunities for building unique regional systems and linking existing innovation systems in new ways. The creation of an institute for triple helix research innovation seeks to develop new models of research and knowledge transfer that optimize social missions such as healthcare and education while facilitating regional development. Hawai`i is situated, both in place and time, such that the institute for triple helix innovation research will establish a facilitative mechanism for the emergence of new regional innovation systems in the Pacific region.

HYPOTHESIS

The roles and interests of universities, corporations, and government are increasingly intertwined in a complex combination of financial, intellectual, personal and legal relationships

(Campbell et al., 2004). These relationships offer new collaborative opportunities where perspectives from various disciplines, organizations, and firms collide within novel interfaces. The triple helix thesis is that the interaction among university, industry, and government is the key to improving the conditions for innovation in a knowledge-based society (Etzkowitz, 2002). While the formation of new strategic alliances is believed to be a good means to source knowledge and overcome geographic issues, there has been limited investigation of how this strategy relates to geographic location, regional innovation and whether strategic alliances can provide substitutes or complements for co-location (Aharonson et al., 2004). Hawaii's geographic centrality and cultural compatibility offer a suitable setting for facilitating domestic and international linkages. The development of a Hawaii-based institute for triple-helix innovation will explore strategic models of research development in the Pacific region.

This project seeks to investigate the impact of trilateral research collaborations compared with other types of research models, and to identify some specific criteria associated with successful collaborations and innovation systems. Further, a distributed triple helix community of practice will be established to provide guidance, establish a communal language for enabling this cross-disciplinary, cross-cultural and cross-organization research and, moreover, promote a virtuous circle of international knowledge diffusion. It is hypothesized that the creation of the institute and corresponding triple helix community of practice will result in evidenced-based exportable models for triple-helix collaboration, significant knowledge spillovers within the Pacific region, and will activate fertile international linkages for all participating partners.

OBJECTIVES

1. Are triple helix research collaborations more successful than other types of research models?
    a. Do triple helix research collaborations generate more innovations (e.g., products, theories)?
    b. Do triple helix research collaborations lead to greater public health impacts?

2. Are triple helix research collaborations the most efficient type of research model?
    a. Do triple helix research collaborations require more or fewer resources?
    b. Do triple helix research collaborations produce more outputs?
    c. Do triple helix research collaborations average greater financial returns?
    d. Do triple helix research collaborations provide more equitable outcomes?

3. Do triple helix research collaborations result in significantly more outcomes (e.g., licenses/patents, publications/presentations, CRADAs) than other types of research models?

4. Are there specific criteria that are associated with the successful performance of triple helix research collaborations?
    a. Can standardized indices be utilized to evaluate models on a comparable metric?

5. What are the essential components of a distributed a triple helix community of practice?
    a. Can a triple helix community of practice act as a distributed cluster that promotes regional knowledge diffusion?

MILITARY SIGNIFICANCE

A primary component of U.S. military strategy is to achieve military advantage through technological superiority (Paarlberg, 2004). Maintaining technological superiority is expensive, and the continuing decline of the military's science and technology budget and the recently announced restructuring of laboratory, research, development, and test facilities will make it more challenging than ever to achieve this goal (Jones, 2006), . Moreover, the recently announced Base Realignment and Closure (BRAC) actions pose additional challenges to the military's ability to carry out its military mission; BRAC will reduce the military's infrastructure, forcing it to rethink its strategies for maintaining the flexibility it needs to uphold its readiness posture. To meet these formidable challenges, the military must seek innovative ways to conduct its R&D to maintain technological superiority and explore concepts that can optimize infrastructure utilization (Chang et al., 1999).

Collaborative research endeavors offer the best hope for developing new science and technology advances and solving critical problems facing the military today. Spending on research and development by non-defense agencies and private industry has steadily increased since the early 1980s, while federal research and development is slowing (Baker, 2000). Triple-helix partnerships can fortify organizational capabilities and harness complementary expertise so that new synergies between academia, industry and government are realized. Such partnerships can orchestrate research funding that targets public missions with specific local and national concerns, while simultaneously conducting virtuoso science (Guston, 2000). Partnerships that are appropriately constructed and carefully evaluated offer society a proven means of enhancing technological developments, the welfare of U.S. citizens, and the security of the nation (National Academies Press, 2003).

Collaborations represent opportunities to leverage resources. Cost-sharing is important as the DoD faces decreasing R & D dollars. Further, international partnering offers the potential for exploiting technological leads, thinking in new ways about requirements and providing new sources of supply for products and services (Wong, 1998). By combining government expertise, assets, and resources with complementary contributions from the academic and private sectors, triple helix research partnerships offer a variety of benefits for those involved (Chang et al., 1999). For the military benefits include opportunities to:

- leverage its assets, reduce capital investments, reduce costs, or decrease outlays to achieve infrastructure, intellectual property, or financial arrangement goals;
- increase the value of its property or other assets;
- create new capabilities or assets that help accomplish the military's mission;
- influence technology early and thereby get equipment fielded earlier and/or possibly at lower cost;
- improve its readiness posture; and
- receive a stream of revenue to fund projects that help to accomplish the military's mission.

Globalization is changing the ways that government, industry, and academia relate. There are a myriad of new designs for collaboration. The Institute for Triple-Helix Innovation described herein recognizes that knowledge-based development is an endless transition of innovation rather than a single model for all economic, research and societal partnering. As exportable models and strategies for flexible partnering are continually developed and refined, the Institute for Triple Helix Innovation will become a national resource for analyzing the best potential for a particular development project in specific regional locale.

Learning how best to remove barriers to co-operation, support collaborations, and facilitate the exchange of science and technology personnel will focus the orientation of military research efforts on societal and mission specific needs. Triple-helix research will provide information for local, national and regional decision makers relevant to a diversity of technological advancements impacting security, military healthcare, and economic development. Outcomes will be specifically aimed towards dual-use products, improving informed decisions for policy makers, and the implications of technology and national security.

PUBLIC PURPOSE

Triple-helix innovation is predicated on the elements of a free society. The ability of individuals and groups to organize freely, to debate and take initiatives without permission from the state, are a necessary condition for the development of a triple helix dynamic. For example, only after the collapse of the military regime in Brazil were university science and technology researchers able to introduce the concept of the state incubator in order to encourage the systematic creation of start-ups (Etzkowitz & Brisolla, 1999). Further, triple-helix innovation facilitates the realization of a knowledge based society through strategies to facilitate the progressive transformation of theoretical knowledge to innovation to wealth to national well-being (Larson & Brahmakulam, 2002; Dambrowitz, Champ, & Davidson, 2005). The transfer and subsequent application of academic research results has demonstrable benefits for health care, researchers, universities, companies, and local economies (Campbell et al, 2004). Knowledge is no longer a superfluous input into an industrial and market-oriented economy; rather, the codification of information into knowledge provides a way that production systems can change over time through the further development of their knowledge infrastructure (Cowan & Foray, 2000). This model drives socio-economic benefit by enabling effective technology transfer developed through basic research at academic institutions to commercialization with industrial partners in a manner that returns value to regional and national economies and government.

Technology development has important international and regional dimensions. As such, initiatives in international benchmarking of national and regional technology research are strategically important. Analyzing the source of relationships helps us learn about what other participants in the global economy believe are necessary and effective. Cooperative comparison allows for exchanges of experience, research, and sometimes solutions to issues and questions common to many technology programs. Collaboration among firms and facilitative agreements among governments can help to further the progress of innovation.

Specifically, this project proposes the development of a resource through which triple-helix mechanisms and processes can be evaluated and domestic and international linkages can be facilitated. Collecting mutual information in the three dimensions of the triple helix enables the dynamic evaluation of regional networks (Leydesdorff, 2003). The formation of optimal trilateral relationships with international linkages means harnessing a wider breadth of intellectual resources and synthesizing individual capacities in order to leverage new health innovations. The accumulated knowledge in the public-private arena will accelerate the development of new technologies from idea to market and will create efficiencies translation of empirical data into usable products and processes (National Academies Press, 2003). The resulting network will create a virtuous circle of international knowledge diffusion.

METHODOLOGY

Developing a Triple Helix Institute for Research Innovation: In order to address emergent needs and set a direction that will allow future expansion capabilities for government, industry and academic partners, we propose that efforts related to international collaborations be coordinated through the creation of a Triple Helix Institute for Research Innovation positioned to initiate and facilitate triple-helix research and promote new paradigms for innovation. The Triple Helix Institute provides a mechanism that will promote local inclusion, encourage national and international partnerships, thereby stimulating the essential activities for the emergence of a system for Pacific region innovation. Currently, there are no organizations in existence devoted as a singular resource to sourcing, amalgamating and analyzing data generated by triple-helix and other collaborative research models. Further, the Triple Helix Institute aims to evaluate benchmarks of performance, and determine successful policies related to knowledge generation and innovation.

The creation of the non-profit Triple Helix Institute is conceived as a center for performing research and analysis funded by contracts, grants, fees and contributions. The Triple Helix Institute will be based on an interdisciplinary perspective, employing technological innovation analyses to evaluate triple helix methodologies along complex, multidimensional pathways. The long-term vision for the Triple Helix Institute is that it will act as an international resource, offering a range of products, processes, and policy research from which enduring contributions of innovation and economic development can follow. Through the development of an international database for collaborative partnership information, the Triple Helix Institute will be able to analyze complex tripartite collaborations and generate exportable models for successful research innovation. Further, the Triple Helix Institute will promote partnerships that consider social values alongside profit considerations. Finally, the database will grow to provide a significant contribution to Pacific region knowledge management with the capacity to leverage research, partnerships, cultural capital and technology innovation.

Our longitudinal program of research aimed at triple-helix quantification will establish a functional trajectory, with vast expansion capabilities, for government, industry and academic partners toward the promotion of new paradigms for innovation. Such an exploration of collaborative research is conceptualized in four overlapping phases: 1) a time-series megatrend analysis; 2) a research models evaluation; 3) the formation of a distributed community of practice; and 4) establishing a testbed for evaluation and validation.

PHASE ONE — Time-series Megatrend Analysis (MA)

A Time-series Megatrend Analysis, the first step in the development of Triple Helix Institute for Research Innovation is a major undertaking from both a data collection and data analysis perspective. This first phase of the project is required in order to understand the environment which will be served by the Triple Helix Institute, and gain credibility with those regional innovation centers that are representative components of the Pacific Region. A Trend Analysis is traditionally used as a way to detect, compare, and analyze changes in given data items over a period of time (typically one to five years). Trend analysis has broad applicability in preparing future development scenarios, and is widely used in many sectors (e.g., economics, demographics, health) for forecasting purposes (Canadian Environmental Assessment Agency, 2002). By using the term “megatrend” we can also include an emphasis on important tendencies in social capital that can be observed and predicted over a longer timeframe.

There is a historical and political tendency toward regionalization and toward strengthening the resource base of regional systems. If innovation is not assessed at the regional level, these resources may be used ineffectively. Assessing regional innovation environments is an essential first step further developing regional systems, and avoiding unnecessary regional disparities (Harmaakorpi, 2004). This MA will collect descriptive data (see Section G.1.b.) on selected locales within the Pacific Region. The information cycle will be defined as the decade commencing with January, 1995 and ending December, 2004. This 10-year cycle is the most recent decade on which complete data is available for each measured variable.

Selection of Locales: Six locales in the Pacific Region have been selected a *priori* for inclusion in Phase One of the MA — Hawaii, California, Washington, Japan, China and Singapore. Each locale has its own innovation networks and institutions with regular and strong internal interaction that promotes innovativeness and is characterized by embeddedness (Harmaakorpi, 2004). Each one of the locales has demonstrated strong ties to the medical technologies sector, substantial economic growth in emerging technologies, and represents a broad range of partnerships in its business innovation systems. The locales were chosen to represent both national and international nodes, developed and developing medical technology markets and as locales that are somewhat geographically centric and culturally resonant. These locales will contribute the first project information for analysis at the Institute for Triple Helix Innovation. Locales will be added as appropriate to further explore and define optimal models for successful national and international collaboration; to expand the network of researchers in the Community of Practice; and, to answer questions and conduct research in specified areas of interest.

- *Hawai`i:* Hawai`i consists of 137 islands located between the mainland and Asia. Hawai`i is often informally referred to as the “Healthcare State” — more than 85% of its citizens are insured through health care plans that compete to provide high-quality personalized care, employing leading-edge health care concepts and technologies. With its mild subtropical climate, multicultural environment, multiple tourism attractions, and state-of-the-art medical facilities, Hawai`i also provides a congenial venue for patients from all over Asia and the Pacific, as well as an attractive, less stressful environment for their families. Hawai`i’s trans-Pacific fiber optic and satellite connectivity make it an increasingly important node on the global information superhighway. High-speed data processing and supercomputing facilities give Hawai`i parallel processing capabilities that can serve a broad range of industries. Strong partnerships between the private and public sectors have emerged based around Hawai`i’s existing technology resources and competitive advantages. Hawai`i is an attractive location for new business ventures due to its strategic mid-pacific location, time zone advantage, advanced telecommunication infrastructure, growing technology leadership, multicultural-multilingual-educated-productive workforce, rising venture capital funds and angel financing, exceptional research facilities, state-of-the-art business and technology parks, strong infrastructure and first-rate incentives. Hawai`i will provide the physical site for the Institute for Triple Helix Innovation and the hub for the distributed community of practice.

- *<u>California</u>:* California is well known as a center for high-technology and innovation, and is home to a broad range of technological leaders including Intel, Apple Computer, EDS, Oracle Corp., Sun Microsystems, Sony Electronics. There are 37 Federally Funded Research and Development Corporations (FFRDCs) in the U.S., nine of which are located in California. California's is at the cutting edge of global technology, and leads the nation in biomedical research and commercialization. According to the Milken Institute (DeVol, Koepp, & Fogelbach, 2002), California's is the most diversified high-tech economy in the U.S. (fifth largest in the world), including industry clusters in biotechnology, defense and aerospace, medical devices, pharmaceuticals, and environmental technologies. California employs more than one million high-tech workers, produces $48 billion in high-tech exports, and boasts an annual industrial and academic R&D budget of more than $50 billion.

- *<u>Washington</u>:* With a population of approximately six million, Washington State is a leader in research and development and technology-intensive industries. From a total state economy of $220 billion (FY2000), R&D accounts for 4.78% ($10.5 billion) of the state's GSP, ranking it third nationally. Approximately $1.3 billion of federal R&D funds are spent each year in Washington. The University of Washington (UW) has an international reputation for research excellence as well as several Nobel laureates. Other technology development organizations are Fred Hutchinson Cancer Research Center, the Washington Technology Center and the Human Interface Technology (HIT) Laboratory. In the private sector, several hundred firms conduct research in Washington State across a broad range of technologies, including aerospace/transportation (e.g., Boeing), biotechnology and biomedical equipment (e.g., Immunex/Amgen), computer equipment and software (e.g., Microsoft), electronic components/semiconductors, and instrumentation (e.g., Siemens). According to an *Index of Innovation and Technology* report (2000), Washington ranks 9th for all states in R&D expenditure and eighth in innovation capacity, an index measuring relative shares of high-tech jobs, scientists and engineers in the workplace, number of patents generated, industry research and development, and venture capital.

- *<u>Japan</u>:* The Japanese economy is the second largest market economy in the world. In 2003 it recorded a gross domestic product (GDP) of $3.58 trillion. Per capita national income in 2003 was $28,131, ranking Japan 15th in the world. The Japanese market for the overall biotechnology industry expanded by 7.5% from 2001 to $12.8 billion in 2002. Of the total, the biomedical market accounted for $7.3 billion, 7.3% more than the previous year. This biomedical market breaks down into biotech pharmaceuticals worth $4.8 billion, and biomedical treatment and drugs-related products and services worth $2.5 billion. The market has been growing for the past five years at an average annual rate of 6.7%, compared with a U.S. growth rate of 4.6%. The world market for medical equipment was roughly $169 billion dollars in 2000. The Japanese market was second in size only to the U.S., and accounted for roughly 15% of the world market.

- *<u>China</u>:* The emergence of China as a major economic power is one of the most important developments of the 21st century. Measured on a purchasing power parity (PPP) basis, China stood as the second-largest economy in the world after the US in 2005. China is the United States' third largest trading partner, with overall U.S.-China trade reaching $285 billion in 2005. And by most relevant measures, China's GDP is roughly $2.3 trillion, the world's fourth-largest economy after the US, Japan, and Germany . Still, in per capita terms, the country remains lower middle-income ($6,800) and 150 million Chinese falls below international poverty lines. China has benefited from a huge expansion in computer Internet use, with more than 100 million users. Foreign investment remains a strong element in China's expansion in world trade and has been an important factor in the growth of urban jobs. Challenging global players, China is destined to become a science-and-tech superpower. China has size, the will, the economic growth, and the desire that provides a greater opportunity than ever before (McCormick, 2006).

- *Singapore:* Singapore is a highly developed and successful free-market economy in which the state plays a major role. It has an open business environment, stable prices, and one of the highest per capita gross domestic products (GDP) in the world. Exports, particularly in electronics, chemicals, and services provide the main source of revenue for the economy Singapore's port infrastructure and skilled workforce allow easier access to markets for both importing and exporting (The World Bank, 2006). In 2005, A. T. Kearney rated Singapore the "Most Globalized Nation." Manufacturing and financial business services drive Singapore's economy and account for 26% and 22%, respectively, of Singapore's gross domestic product. The electronics industry leads Singapore's manufacturing sector, accounting for 48% of Singapore's total industrial output, but the government also is prioritizing development of the chemicals and biotechnology industries. Singapore's skilled workforce, and advanced and efficient infrastructure have attracted investments from more than 3,000 multinational corporations, account for more than two-thirds of manufacturing output and direct export sales. The government aims to establish a new growth path that will be less vulnerable to the external business cycle and will continue efforts to establish Singapore as Southeast Asia's financial and high-tech hub. Fiscal stimulus, low interest rates, a surge in exports, and internal flexibility led to vigorous growth in 2004, with real GDP rising by 8%, the economy's best performance since 2000.

Archival Data Collection for Locales: Empirical investigation is a basis for the development of any regional innovation system. Investigation of the aspects of regional innovation capability is necessary in order to understand the main elements that characterize the various components of the system. Further, it requires evaluation of the profile of the region by characterizing the innovation performance with indicators such as education, research and development, technological bases, and measured outputs (e.g., patents). Additionally, it describes regional uniqueness in terms of innovation activities and competitiveness — components that could transform the region into an innovative system (Doloreux & Parto, 2004).

The MA will commence with the collection of descriptive data on each locales. Graf (2002) recommends the collection of data across six dimensions in order to conduct a megatrend analysis (i.e., economic trends, ecological sustainability, technological progress, demographic development, political framework, social fundamentals). This research project will focus on the first four of these six dimensions across a 10-year span (1995 through 2004). Data will continue to be collected annually so that existing and emerging trends can be isolated and tracked.

- *Economic Trends:* An economic trend is a statistical record of some economic activity, whereby the data measured at regular time intervals. Examples include median income, labor force, import/export, GNP/GSP, GNP/GSP per capita, and rates of unemployment.

- *Ecological Sustainability:* Ecological sustainability traditionally measures the ability of ecosystems to maintain its structure and function in order to continue to develop and sustain life. For the specific purposes of this research project, "ecosystem" = locale and "life" = health technologies research. Examples of data collected include number hospitals, operating budgets, service delivery infrastructure, number of health technologies companies, range of medical services, manufacture of medical equipment, and development of health technologies.

- *Technological Progress:* Technological progress is essentially the development of new and better ways of producing goods and services and the development of new goods, services, and/or processes. In order to determine whether a trend is progressive or regressive, data must be collected over an extended period of time. Examples include research and development areas, investment funds, funding sources, number of universities, number of private research firms, and annual patents/licenses.

- *Demographic Development:* The composition of a population affords insight not only into present conditions within the population, but also into the potential for change in the future. Patterns can be observed in characteristics that define human populations such as age, sex, race, ethnicity, rural/urban distribution, social integration, and other relevant indicators of population composition, including literacy, language, mortality, and so on.

The data collected for each of the locales will also allow us to calculate a Summary of Innovation Index (Sajeva, Garelli, Tarantola, & Hollanders, 2005). The Summary Innovation Index is composed of two main factors: Innovation Input and Innovation Output. The relevant elements of innovation input are captured by three subgroups: i) *innovation drivers*, the structural conditions required for innovation potential; ii) *knowledge creation*, investments on human factors and R&D activities; and iii) *innovation & entrepreneurship*, efforts towards innovation at the microeconomic level. The relevant elements of innovation output are captured by two subgroups: i) *application*, measurement of performance in terms of human capital and business activities, and their impacts; and ii) *intellectual property*, achieved results in terms of successful knowledge advancement, especially in high-tech sectors.

PHASE TWO — Research Models Evaluation

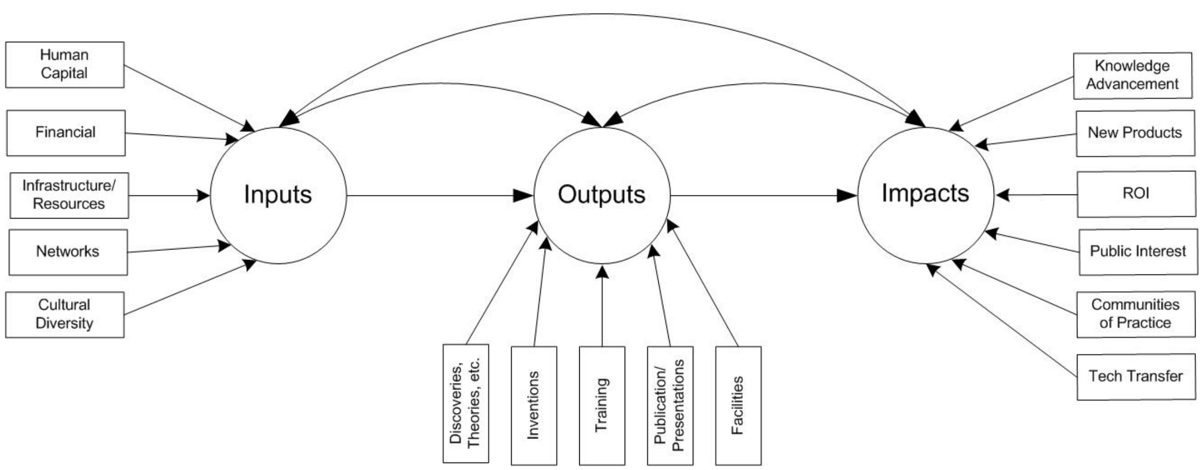
In order to compare various types of research models and the strengths/advantages of each, we will examine seven types of models from each of the previously described locales in a Research Models Evaluation. The seven types of models are defined as: 1) Triple helix (university-industry-government); 2) I-U (industry-university) partnerships; 3) U-G (university-government) partnerships; 4) G-I (government-industry) partnerships; 5) Industry only; 6) Academic only; and 7) Government only. Using the trend data representations from the MA, one or two advanced health technology areas (e.g., biosensors, photonics, genomics) will be selected as the focus of the research models evaluation

The selection of this advanced health technology area (e.g., biosensors, photonics, genomics) will help to reduce the scope of research projects selected for evaluation, and will allow for more a valid comparison between models. In order to build a comprehensive set of data that can help us explore the optimal components of collaborative research, 21 research projects will be selected from each locale, stratified by type of research model (i.e., 3 projects for each of the seven models). Assuming participation from all six locales, we will recruit a total of 126 projects. Additional selection criteria will be established with input from members of an established Community of Practice (see Phase III).

Determining appropriate indicators of success for each of the seven types of collaborative research models is challenging. Jaffe (1998) categorizes performance measurement indicators as "inputs," "outputs," or "impacts." Emphasizing and understanding these measurement indicators will require targeted data collection, measurement development, strategic selection of performance measures, flexible assumptions about each type of innovation model, and expert feedback at various stages of assessment. Our primary aim is to find indicators that can be widely accepted and that function as proxies or correlates for the various paths of knowledge flow associated with each type of model (see Figure 1).

Input measures have obvious limitations, particularly because they are concerned with intent rather than success (Technical Objective 2). For example, the awarding of competitive peer reviewed research grants are perhaps a good input proxy, but are still a measure of promise and not a guarantee of output. Similarly, input measures such as industry sponsorship of research can be used as a proxy for industry-driven collaboration, as well as a correlate of knowledge transfer (see Table 1).

Figure 1. <u>Hypothesized Relationship Among Inputs, Outputs and Impacts in Collaborative Research Models</u>



Outputs are more easily measured as products or deliverables of each collaborative research model, such as patents, licenses, scientific publications, degrees awarded, and CRADAs (Technical Objective 3). *Impacts* focus on the effects that can be directly or indirectly traced back to each organization as a result of its research innovation. These measurements include things like commercialization of research, venture capital financing, employment, license royalties, new product announcements, new product sales, paper citations, patent citations, ROI, and business spin-offs (Technical Objective 3).

Measurement: In order to measure the categories of inputs, outputs and impacts, an in-house measure — the Innovative Research Models Questionnaire (IRMQ) — has been created by adapting existing validated measures that focus on innovation and preparing additional items for assessment based on feedback from experts in each area. The IRMQ is composed of three parts: Part One focuses specifically on the identified research project; and Part Two asks for information about the composition of project's research team; and Part Three asks for additional information about the respondent and her/his experiences with various types of research models.

In addition to the project-specific data provided by the lead investigators on each project, the Investigators' Experiences Questionnaire (IEQ) will be randomly distributed to five members of each of the 126 research project teams with a view to learning more about each individual's experience on the research project. Both the IRMQ and the IEQ will be formatted for either online data collection or manual input using return of pencil and paper questionnaires. Both versions of the questionnaires will be made available to respondents via a password-protected website.

PHASE THREE — Establishing a Distributed Triple Helix Community of Practice

The project aims to develop a distributed triple helix CoP in order to achieve specific project goals and, moreover, to facilitate desired knowledge spillovers within a new regional system. The distributed triple helix CoP will draw together a team of culturally diverse, multi-disciplinary researchers from academia, industry and government to provide insight, expertise and partnering in the Triple Helix Institute. In exchange for their involvement and leadership, CoP members will be provided with a modest stipend as either a percentage of salary or consulting fee for the first year of their commitment to the project. Broadly, the CoP must supply content for the project and interactively participate in the community (Pickles, 2003). This project will establish public and private spaces and provide a range of tools to facilitate triple helix CoP collaborative work (e.g. a discussion forum, digital repository, WebEx, etc.). The triple-helix CoP will network through distributed and face-to-face meetings in order to achieve several specific objectives:

1. The triple helix CoP will refine the variables and measurement tools that will be used to collect data about locales, projects and outcomes.

2. The triple helix CoP will identify projects, provide essential linkages with other researchers and facilitate the collection of relevant project data.

3. The triple helix CoP will develop mechanisms and processes for facilitating the success of the CoP; the cross-pollination of ideas and research; and, the facilitation of new triple-helix partnerships. Specific topics for exploration will include negotiating distributed networks; the development of a trans-disciplinary vocabulary; and, the identification of resources and challenges inherent in tri-lateral partnerships.

Initially, the triple helix CoP will be composed of a small but diverse core of researchers representing a broad spectrum of disciplines from academia, industry and government. The community of practice will expand as the network expands to include lead investigators from research projects; scholars with expertise in methodology, theory, policy, applied research of various technologies (i.e., medical technologies), triple helix partnerships, interdisciplinarity, regional innovation systems, and other salient areas.

The goal is to create a community of practice that fosters information exchange, builds new networks, promotes interdisciplinary relationships, and generates knowledge spillover toward the creation of new innovation systems.

Trust, empathy and reciprocity are the building blocks for relationships that unite members (Preese, 1999). They provide conduits for the knowledge exchange and learning needed to solve problems and achieve shared goals. Research by Guenther and Falk (1999), which examined outcomes of trust in communities, identified eight different components of community trust. These eight components include: social identity, leadership, confidence in leadership, insecurity, information sharing, external ties, information sharing; and perceptions of fairness.

This suggests that the multidimensional nature of trust is built on a combination of factors, as well as various levels of relationships among social communities. At the conclusion of each session, CoP members will be asked to complete the questionnaire as part of their responsibility as a principal member. In addition to its focus on social capital and trust, the questionnaire is designed to evaluate the perceived value of the community of practice, the progress made during the session, levels of relationship development, and to provide recommendations for improving the CoP.

Both qualitative and quantitative data provided by the CoP members will be analyzed. These data will be utilized to improve the content and structure of subsequent sessions. Furthermore, longitudinal data will allow us to explore that magnitude and rate at which knowledge spillover can be generated.

PHASE FOUR – Establishing a Testbed for Evaluation and Validation

Phase 4 will focus on the creation of a testbed for the validation of selected derivative models, indices, processes, and outcomes within an applied platform. Codified knowledge and the core database (derived from Phases 1, 2, and 3) are envisioned as a foundation for spawning multiple strategic tools, including exportable models of triple helix innovation, knowledge solutions, policy synergies, diverse project collaborations, and innovative technologies development.

Real life situations will be sought out as opportunities for naturalistic testing and validation for the tools and measures that emerge from the project research. Collaborative initiatives that appear likely to benefit from the application of these new tools will be identified; and, when appropriate, tools will be deployed and tested within these initiatives to compile efficacy data. Alternatively, pilot collaborations may be initiated to specifically target opportunities for the testing and validation of emergent models, tools and indices.

A pilot initiative will test the capacity of triple helix strategies to promote rapid commercialization of new products; generate industry spin-offs; identify economic returns, proxies of innovation and knowledge (e.g., patents, licenses, publications, etc.); and evoke collaborative partnerships that transform knowledge and innovation into social and commercial benefit.

The Institute for Triple Helix Innovation Research will amass large data sets. But, information is irrelevant without the ability to focus on patterns of information that matter. The data gathered throughout this project will be used to inform a relational database that can be increased in both scope and scale to expand the number of locales included, increase the number of research projects and variables included for comparative analysis, and expand the distributed community of practice. Relationships and context transform static pieces of information into codified knowledge. The development of a robust relational database will provide an efficient architecture to collect, organize and manipulate large sets of relevant data variables. By storing specified data elements in a systematic and sustained way, increasingly complex questions can be answered using an electronic database management system. Further, this will allow the data to be organized and displayed to reflect the relationships between models, projects, people, locales, and other relevant variables.

For example, retrospective assessments on completed triple helix research projects would include the identification of those variables identified in Phase 2 as an integral part of successful triple helix collaborations. Prospective outcomes will be assessed by examining and evaluating the following components of new triple helix initiatives: 1) sustainable development framework; 2) research and development strategy; 3) innovation strategy; 4) action plan; and 5) predicted growth patterns based on input and outcomes.

Ultimately, the database will be used to inform a broad range of knowledge models, such as the emergence of "Best Practices" for collaborative research and/or assessment strategies for immediate and long-term value associated with triple helix collaborations.

The mapping of relationships, using a graphical representation of information, will provide an integration of diverse data and an opportunity to see how the information is created, connected, accessed and used. Further, the data is made available in a way that can reflect patterns and relationships, depending on the question(s) being investigated for particular Triple Helix projects. A knowledge model can be created by analyzing the patterns, identifying the types of information that is involved and specifying the ways that the data is related. For example, some of the items of particular interest may be the kind of research model being utilized (e.g. University; Triple Helix); cultural aspects (e.g. urban/rural; ethnicity of participants/investigators); Specific outcomes (e.g. Dual-use product; codified scientific knowledge); kinds of dollars invested (e.g. grant; government; R & D); Discipline(s) involved in project (e.g. Medicine; Engineering; Software development). Moreover, once a repository of data is made available, each piece of information can be connected to any other item, including those from other repositories.

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