CHAPTER

The Collaboration Imperative

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INTRODUCTION

At the Glion IV Colloquium on "Reinventing the Research University", the author contributed a chapter on "Globalization of Research and Development in a Federated World", focusing on opportunities for strategic partnership using the concepts of the "knowledge supply chain" and the "partnership continuum" (Johnson, 2004). This chapter builds on that work, seeking to advance the thinking about university-industry collaborations and building strategic relationships, while recognizing some of the challenges in collaborating.

The chapter discusses the impact of the information technology evolution and its impact on research strategy and innovation from the conventional stand-alone wave, to the systems innovation wave, the network innovation wave and finally the innovation and knowledge exchange or systems of systems innovation wave. This results in the collaboration imperative and the need to manage the knowledge supply chain.

THE RISE OF SCIENTIFIC ACTIVITY AND VIRTUOUS ECONOMIC DEVELOPMENT AND SOCIETAL BENEFITS

During World War II, the Office of Scientific Research and Development oversaw much of the effort that resulted in radar, missiles, radio-controlled fuses, the atom bomb and penicillin. Vannevar Bush, the director of the OSRD, recognized that these scientific advances and new technologies had

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enabled the U.S. and its allies to win the war, but that the margin of success was dangerously small (Zachary, 1997). Since that time there has been a series of events or "wake-up calls" that have emphasized the importance of government, universities and industry working together to create new knowledge and educate a new generation of engineers and scientists:

- World War II demonstrated that we needed sustainable and reliable processes to create scientific advances in order to insure national security, medical advances and economic prosperity. In his seminal report, "Science The Endless Frontier", Bush proposed the creation of a partnership between government, universities and industry to create new scientific knowledge (Bush, 1945).
- Because of Sputnik, Eisenhower supported the creation of the National Aeronautics and Space Administration in July 1958. He also signed the National Defense Education Act that encouraged the study of science.
- When the Soviet Union won the race to put a man into space, President Kennedy challenged the U.S. to "commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth". Kennedy also recognized the importance of education to this effort by starting "a new Manpower Development and Training program".
- The attacks on the World Trade Center on September 11, 2001, created a new national agenda on security, resulting in a partnership among government, universities and industry to advance science and technology in this critical area.
- The advent of the internet has enabled work to be broken down and dispersed throughout the world to where the various pieces can be done most effectively.

The Vannevar Bush model of the involvement of government, universities and industry to insure national security and economic security needs to be updated. New approaches need to be developed for these partners to achieve national security and economic competitiveness in a globalized world. Other countries have faith that America will solve this, but we need to heed the wake-up call. Fortunately, America has significant capabilities. Although America is a nation motivated by individualists, when the task is large, we come together. In doing so, we do what it takes to succeed and we always seem to be able to develop imaginative, creative new ways of accomplishing things.

INNOVATION WAVES IN THE 'IT' SPACE

The information technology ("IT") industry has followed a unique evolutionary history throughout the past five decades. The renaissance which began through the efforts of Vannevar Bush was propelled forward by the national science and technology focus, together with the attendant government funding and investment. In combination with the research activities of many universities and the work of the large industrial central research laboratories (AT&T, IBM, etc.), these elements came together to create the innovation engines and new technologies which gave rise to rapid progress across a variety of fundamental IT areas. The next sections will examine four different waves of innovation activity, together with the underlying research *modalities* or operating modes that seemed prevalent during these times. The first will look at some of the outputs of those waves of innovation, and then working backwards examine a few of the themes, motivations, assumptions and philosophies that underlie the university-industry interactions and partnerships of that time.

THE 'STAND-ALONE PRODUCTS' INNOVATION WAVE

One of the important contributions produced by this first wave of innovation activity was a multitude of individual and proprietary "stand-alone" products. At the time, these products enabled individuals and organizations to be able to do things, both computationally and commercially, that had previously been out of reach.

The prominent research and development *modality* that supported the development of this myriad of products could be characterized as one of *independent exploration* of distributed opportunities across many fronts, with undercurrents of a "go-it-alone" approach to product innovation and development. This mode of operation supported the goal of many companies to put wonderful new products into the hands of end-users as quickly as possible. It also supported the research interests of finding promising new areas to explore, and mapping out relatively unexplored fields to play in. Research and technological innovation delivered the hot new features, integration was deferred to the end-user environment, and any focus on solutions (in today's terminology) was virtually absent from the efforts to get the newest feature-enabled products to market quickly. Some have characterized the contribution focus as technologically-driven "features and functions", "mips and megabytes" or "speeds and feeds".

Looking a little deeper at the underlying research modality, we find a number of interesting subtleties. In the research space, the sponsoring and initiating of many decoupled activities and independent investigations seemed natural, given the ready abundance of problems to be solved and the wide-open spaces of undeveloped opportunities to be worked on. Philosophically, universities were optimizing their desire for open inquiry and basic research, and this was well suited to having an abundance of undeveloped areas to work in. Within universities, work was usually conducted on a departmental basis, and there wasn't a great deal of multi-disciplinary research to be had. Furthermore, the way in which research topics and problem areas were identified and configured among independent research teams also demonstrated a sort of "innocent independence" that was well suited to motivating simultaneous and uncoordinated research work.

In a parallel space, companies were looking for ideas that could contribute to their immediate problems in developing the point products that they were undertaking. They were challenged to attract researchers to focus on specific problems related to their product development interests, hoping to move university researchers beyond basic research interests and focus more of their efforts on solving some of the practical problems of the day. Companies were comfortable engaging their university counterparts only infrequently, and after some discussions and interchanges they would come back at a later time to see what had developed, without great expectations of finding significant practical applications.

In retrospect, both the university predisposition towards basic research and the infrequent industrial interactions and expectations of few practical contributions resulted in an unstated agreement around a serial technology transfer model, where relatively little "after-the-fact" accomplishments were exchanged between researchers and product developers.

THE 'SYSTEMS' INNOVATION WAVE

As technology advanced, research interests became more developed, and products grew more complex and sophisticated. This began the shift to a systems focus, and less on what individual products could do by themselves. For the purposes of this discussion, we'll characterize this second evolutionary wave a focus on "systems".

Notwithstanding the great innovation and substantial progress made in the "stand-alone" products era, end-users became increasingly dissatisfied in dealing with collections of products from different manufacturers that didn't work together. Companies in turn became focused on developing system architectures that would permit sets of products to interface and interact with each other in order to accomplish greater purposes than simply the features and functions that were contained within. This naturally resulted in an increasing need to cooperate across companies in the early planning and design phases of product development (usually via standards bodies) and to share efforts across the industry without giving up too much competitive advantage or early access to undeveloped market opportunities (delicate balance).

At this same time, universities also became integration laboratories for many point products from different companies. As early adopters, they became the testing ground for the latest and greatest advancements that companies were so eager to contribute in order to have the newest product ideas validated and used in interesting ways. As a consequence, universities began to see firsthand the effects of technology feature and function proliferation as they attempted to conduct their research upon a fragmented and ever-changing infrastructure of IT systems, evolutions and upgrades. In some sense, they were caught in the dilemma of both embracing and standardizing on innovations which were essential to support their research work, and at the same time creating the next generation of innovations which would obsolete the very infrastructure stability they so desperately needed.

The underlying modalities upon which research and development were conducted began to shift. Conversations turned to emphasizing cooperation, coordination of activities, and addressing the systems interfacing and integration challenges in the research areas. Standardization and convergence also became a locus for much of the dialogue, and consortia and other cooperative cross-industry structures sprang up as vehicles to focus efforts and give shared context to the multiple independent activities underway. Emerging countries began to challenge the U.S. in specific industries (semiconductors, low-cost manufacturing), and the need to cooperate and orchestrate efforts was felt for the first time across America, in both academia as well as industry.

As funding and investment increased, so did the need to eliminate redundant activities, give more focus to sponsored work, reduce the proliferation of dissimilar architectures and technologies, and to standardize on fewer platforms and infrastructures going forward. All of this propelled government, universities and industries further in the direction of cooperation and set up the conditions for the next wave of innovation.

THE 'NETWORKS' INNOVATION WAVE

The third wave of R & D model innovation can best be seen by looking at the IT infrastructure that resulted from collective efforts. In it, complex "systems of systems" were developed and linked together into "networks of networks", resulting in a broad, highly-capable information infrastructure that is low cost, pervasive, and widely available to individuals as well as companies. Interestingly enough, it is ever-changing, while also being "standardized" at the same time. Many paradoxes which remained unsolved in the second wave (such as how to have both innovation and standardization at the same time, or how to have both quality and low cost in the same item) were solved in the third wave, and the world moved forward tremendously in the development of its compute infrastructure capability.

Probably one of the best examples of this model, though certainly not the only example, was the personal computer. As an extremely useful tool in its own right, it is also both a system that contains components (the processor system, the video system, the memory system, the i/o system, etc.), as well as a component or building block of a larger system (a client, a server, a node, a controller, etc.). In this innovation wave, the understanding of how to effectively make components into systems was developed, as well as how to decompose systems into ever-increasingly sophisticated components. Still, that doesn't paint the whole picture. It is the *networks approach* that makes possible the systems of systems, and the inherent flexibility, coupling and configuration of elements at just the right level in the compute fabric.

In terms of the research and development *modality*, we collectively managed to figure out how to have holographic, recursive development take place at any level in the infrastructure, without impact to either components at the levels below, or the systems at levels above. Without ever making it explicit, unstated agreements were ratified on how to do innovation within standardization, radical change within stability and revolution within evolution.

To further illustrate this new style of value-creation, companies were able to create whole new "sub-industries" in which they fiercely competed with each other while advancing the state-of-the-art for their own "component-systems" and continuing to create new value. Again, using the personal computer as the system-level element for this example, component industries which illustrate this concept would include the video system-component being advanced by companies like NVIDIA and ATI. The processor system world continues to be fiercely fought out by Intel, AMD, TransMeta, IBM and others. Even I/O was split into two distinct sub-industries — disk drives (Seagate, Maxtor, IBM, Hitachi, Quantum), and controller cards (Adaptec, Chips & Technologies, etc.) Without going further, it's easy to see how this unstated, multi-level, stratified architecture provided the framework for intense, distributed, parallel innovation and competition across companies and sub-industries, all the while providing tangible value to the end-users and consumers from the ongoing technological progress and achievement.

What were some of the philosophical orientations that underlie this research and development modality? What were the unstated assumptions that drove this world? It's probably easier to discuss what these were not, more than to identify what they were.

First, consider the interaction model. Independent research explorations, "go-it-alone" product development philosophies and other methodologies which optimize individual activity apart from the whole, did not garner much support in the third wave. The reality was that the world (at least the IT world) had become very interdependent, not independent. The environment would no longer tolerate having unsolved interfacing and integration issues deferred until later from new technologies that were created without some understanding of how they would be used.

Second, each technology player (be they in industry or in academia) knew their place in the multi-level, system-component world. They knew their place and level in the network, and hence where they would focus their research and innovation efforts. They knew who to cooperate with and who to compete with, and they new how to advance their particular part of the ecosystem without causing ripples or claiming territory in other parts.

Third, through the network of human professionals, we somehow learned to "get along" — to both compete and cooperate with each other. This was the age of "co-opetition", where companies both competed and worked together with some of their fiercest competitors at the same time. We also learned how to replace/obsolete and to complement with our technologies, to do research and to do development in the same spaces, and to both lead and to appropriately follow/participate in steering and direction setting. One observer put it this way: "We learned how to humanly interact and sustain the very values that were instantiated into our multi-level infrastructure networked architecture. We learned how to be both 'components' and 'systems' in our own human world of leadership, follower-ship and moving the IT world ahead for all humanity."

This third wave of activity produced the network fabric and know-how that enabled our systems to interact in ways that were previously unavailable in the first and second waves. Not only did it give rise to unparalleled innovation, advancement and prosperity, but it was also highly efficient in this regard. All of this infrastructure innovation set the stage for a fourth wave of advancement which would take us forward into new ways of operating that had not before been recognized.

THE 'INTERACTION AND KNOWLEDGE EXCHANGE' INNOVATION WAVE

The fourth wave isn't so much about raw technology, as it is about thinking, interaction, the flow of ideas and knowledge exchange. Through its networks, the third wave gave us an unparalleled, pervasive global communications capability, which was previously unavailable through telecommunications efforts alone. This in turn provided the foundation on which to develop things like e-mail, voice-mail, file transfer (ftp), and the World Wide Web. As these technology layers were built out, the ability to send almost any information to any place on the planet within a few seconds was created.

Within this information and communications infrastructure, another important capability was instantiated as well. The ability to disjoin space and time emerged. In the old telecommunications world, one had to be at a particular place in space and time to receive a telephone call, a message, or a package. With the advent of e-mail, voice-mail, contact managers, document standards, etc. it has become possible to send a communication or information packet to anyone in the world *wherever* they are, and *whenever* they are. The intended receiver of a message or document, for example, might be travelling to a location on business, yet they can still pick up their messages and documents via the internet from other places remote to where they live, at a time when it's convenient for them to do so.

Simultaneous with these developments, the physical networks underwent major transformation and grew significantly in their capabilities. Companies like FedEx, UPS, DHL and others have effectively dis-intermediated proprietary shipping and receiving, while extending their global reaches in the most competitive of environments. Global supply chains and logistics networks have moved beyond where anyone would have imagined ten years ago, and established companies both large and small now rely on these outsourced, aggregated capabilities for the transportation and delivery of their hard goods and physical items.

Not to be outdone by the advances in other industries, the telecommunications industry made significant strides as well. Cellphone networks improved considerably, prices dropped, 2nd- and 3rd-generation digital data networks came into existence as the underpinnings of cellphone communications and the cellphone boom took off! The desire of humans to communicate with each other frequently and "never be out of reach", together with the technological advances and build-out of infrastructure, propelled the cellphone adoption and subscriber rates to the highest ever. The result was that another building block of the interaction and knowledge exchange wave was put into place.

Through the efforts of the global communication and information interchange networks, the advancement of the physical item logistics and supply chain networks, and the global reach of the cellphone communications infrastructure, the world has indeed become very small and very flat (Friedman, 2005). Packages move around the world almost as easily as information bits and data move over fibre-optic cables. The world is developing along an unrelenting accelerating path to reducing most everything to being transportable, whether it consists of information bits or physical items.

So what does the future hold? What happens when most things of interest either arrive at one's door or are available through the internet? What happens when people can get whatever they want, wherever they are, whenever they are? What will they want next?

One idea is that the focus then moves from information and things to ideas and experiences. People become enabled to interact with things and with each other, with a different purpose in mind and a different intent behind their interaction. As more of the infrastructure gets put into place and global access becomes pervasive, people can become less focused on the mechanics of acquiring and accessing what they want, and become more enabled to reflect on the whys, the wherefores, and the quality of their experiences. Metaphorically speaking, these infrastructure advancements can enable humankind to elevate their attention and focus to have the deeper more personal interactions, the ones about connection, contribution and meaning.

In this new infrastructure-enabled world, human interactions and engagements can become much more personal, simultaneous and parallel. Conversations can focus more on the frequent, synergistic exchange of ideas and concepts to yield new developments and insights. Interactions become much more "real-time" as built-in delays are systematically moved out of the system (for example, not having immediate access to someone because they don't have a cellphone.) And the world becomes much more enabled to literally move "at the speed of thought". So, who will be doing the thinking in this new paradigm?

Another important aspect of this new modality is the non-local nature of human interaction. Given the ability to disjoin space and time in communications, it now becomes possible to have exchanges of thoughts and points-of-view with just about anyone around the globe with whom we have a connection. As an example, an e-mail can be sent from California to the U.K. just before going to bed, and a reply e-mail can be received first thing in the morning after a fresh night's sleep. While people may take time out, dialogue can become almost continuous, and the advancement of thinking and the development of new insights can occur unfettered by the limitations present in the earlier innovation waves. Consider the infrastructure advances in global finance. Due to recent developments in the financial infrastructure, money is now able to move around the world and be invested continuously on a 24-hour basis. The markets of North America, Europe, and Asia provide continuous opportunity for dollars/euros/yen that are seeking to be invested. Why not take advantage of the same opportunity for idea development, for R & D, and in the advancement of research? Somewhere on planet earth, minds are available 24 hours a day to do the thinking that needs to be done.

What has now become possible in this new interaction paradigm is that technological and infrastructure advancement has mitigated distances, has disjoined space and time, has enabled conversations and dialogue to be almost continuous, and has enabled humans to spend less time focusing on the whats and hows, and more time searching out the whys and wherefores. What are the essential characteristics of research and innovation in this world? What modalities emerge as being significant for universities, for industry and for government? And what challenges will we be presented with, as a result?

Given the ability of potentially everyone on planet earth to communicate and exchange information through an inexpensive, global, pervasive information network, access to each others thoughts, ideas, perspectives, energies and efforts becomes radically increased. The world becomes much flatter (Friedman, 2005) and much more of a "level playing field" than at any time previous in human history. Throughout the ages, it used to be necessary to travel to other lands of opportunity to engage in trade, commerce, to be a part of a new social fabric, or access a land of opportunity. Through the infrastructure, these things can now much more easily come to us, wherever and whenever we are. In this emerging paradigm, "goodness" and advancement will be bestowed upon those who can successfully orchestrate greater access to and application of the thoughts and ideas of others that exist throughout the vast world of planet earth. Challenge and difficulty will find their homes with the limited, narrow-scope, protectionist thinkers who strive to draw boundaries around what they already have, and try to keep it from expanding and developing. The future will belong to those who are comfortable with abundance, openness, inclusion, interaction, engagement and diversity.

THE COLLABORATION IMPERATIVE

Given the interactive nature and modalities present in the fourth innovation wave, it's easy to recognize why the need for early-stage collaborative efforts is so vitally important in the research and innovation spaces. Under the modalities of a "flat world", the resource base of human individuals potentially becomes infinite, and the supply of knowledge and information workers becomes unlimited. The community of thinkers and unique perspectives becomes as many as six billion people strong. And somewhere, someone on planet earth is likely to be thinking similar thoughts to mine.

With an advanced global infrastructure it thus becomes possible and even easy to exchange perspectives, share thoughts, synergize concepts and develop thought processes with other like-minded people. Access to and engaging in productive interchanges with other thinkers on a global basis becomes the norm, and accelerates the idea development process considerably. It becomes easier to find the key people through social networks, enabling these people in academia and industry to interact with each other to achieve effective knowledge exchange (Schramm, 2004). After all, isn't that what innovation is all about? The Knowledge Supply Chain provides a high-level understanding of what is possible in this interaction.

What does this mean for those who are reluctant to embrace the open, unlimited flow of ideas and concepts. History has shown, time and time again, that closed systems, protectionist-based ideas, and local-optimizations cannot stand the test of time. While they may provide limited benefits for narrow contexts and relatively short time intervals, ultimately the largest benefits are to be derived from the open, free exchange of information and ideas. In strict competitive terms, those who don't take advantage of the vast supply of knowledge workers, and integrate the best and most innovative thoughts and concepts into their work, will find themselves under-competitive as others pass them by with better concepts, superior innovation, and break-away contributions from their open, collective efforts (Chesbrough, 2003).

Looking back at our four innovation waves, we can now contrast the first wave with the last wave, and make some observations about the underlying paradigm. Technology-transfer was predominantly seen throughout the first innovation wave. It is a serial process that is primarily oriented around the transfer of thoughts and ideas in "relatively finished form", after they are embedded in a technology which is demonstrated as being real or useful. This has both advantages and disadvantages. While the outputs of the technology-transfer process are the most tangible and concrete, they are also only available late in the development process. They are the least able to be targeted at new problems areas (malleable and influenceable), and have the highest probably of being outdated, outmoded or incorrectly aimed.

Collaborative exchanges, predominantly used throughout the fourth innovation wave, are early stage processes that occur at the onset of thought and idea development. While they are the least tangible and least concrete (as they are not yet embodied into a technology), they are also the most malleable, can be aimed at a variety of problems, and are the most easily evolvable. The ideas that are exchanged in collaborative environments usually occur far upstream from technology development, and produce the largest gain and the best match to being applied to many different problems of interest, simultaneously, by multiple independent communities (companies, industries, other researchers, etc.)

The interactions that produce successful innovation and commercialization are not random. It appears that university faculty who are involved in a "cluster" of collaboration, innovation and commercialization also have a high level of experience in industry engagement, consulting and collaboration. While in the earlier waves the knowledge of facts and skills was important, it is in the fourth wave that the knowledge of social relations or networks, the knowledge of "who knows what" and "who can do what" may be of greater importance to innovation than knowing scientific principles (Schramm, 2004). Because of these researchers' involvement in a social network of friends and colleagues who are entrepreneurs, venture capitalists and other experts, their opportunity recognition skills are more keenly developed (Schramm, 2004). Collaboration among researchers with consulting experience and well developed social networks enables them to be more successful as collaborators and entrepreneurs.

Recognizing the forces and contributing factors present in the fourth wave of innovation, the need for early-stage collaboration cannot be overstated. Advances in the global infrastructure, and the increasing migration of innovation into a fourth wave style of interaction and knowledge exchange, necessitates and even demands that people interact early and often, if they are not to be left behind. Without the parallel thought processes, the able to retarget ideas to a variety of implementation and application areas, the ability to access many minds with a global perspective, and the ability to link with and federate with the efforts of others who have been working in the same field, under-competitiveness is the most likely outcome. Go-it-alone idea development, late-stage interactions, serial application of ideas to problems and limited access to a small subset of the vast array of thinkers that are out there, simply won't cut it any longer.

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