

Beyond Risk and Fear: Research Frontiers for Knowledge and Technology Transfer in Internet2

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Abstract

This paper reviews the background and concepts relevant to understanding knowledge and technology transfer in the Internet2 project of UCAID. Drawing from presentations at the Knowledge and Technology Transfer Panel at the Internet2 Sociotechnical Summit, this paper suggests opportunities for research on technology transfer among UCAID collaborators working on new developments for advanced networking.

1. Introduction

The consortium of organizations engaged in developing know-how for advanced networks, known as the University Corporation for Advanced Internet Development (UCAID), was formed in 1997 to develop and implement advanced networking technologies. The driving force which catalyzed UCAID's development was advanced networking technologies growing out of the development of IPv6 as the new IP protocol. This new protocol, made IETF (Internet Engineering Task Force) Draft Standard in 1998 [11] as initially developed in 1994.

The development of the IPv6 protocol grew out of the amazing growth of the Internet and the disturbing fact that the world is running out of IP addresses for networked devices. The fixed 32-bit address length of the commodity Internet would simply have been inadequate for the explosive growth of networks. The next generation of IP, called IPv6, is expected to support applications and services well into the next century [22] will be able to accommodate 128-bit addressing and will carry much more information about the data packets sent over

networks.

New applications such as multicast routing, mobile internetworking, scalable addressing, and support for multimedia applications over the Internet will be possible with IPv6. These applications are possible because IPv6 permits more addressable nodes (expanded routing and addressing capabilities), quality-of-service capabilities (the labeling of packets belonging to particular traffic flows for which the sender requests special handling, such as non-default quality of service or real-time service), and novel authentication, data integrity, and confidentiality capabilities (through new header extensions). [9]

In order to prepare for and fully utilize the potential of the IPv6 protocols as the standard for the next generation Internet, UCAID members have developed the Internet2 project.

The Internet2 project is not a single separate network, but rather a network application and engineering development effort that joins collaborators at UCAID member institutions (150 academic institutions, 50 industry organizations, governmental agencies and international partners) to create advanced and experimental campus, regional, and national networks. UCAID collaborators are using these experimental networks to develop and test new pre-commercial technologies, such as IPv6, multicasting, and quality of service (QoS), that will enable applications—telemedicine, digital libraries and virtual laboratories—that are not possible with the technology underlying today's Internet. [24]

1.1. Technology transfer

The concept of technology transfer was introduced several decades ago by development

economists as a strategy for accelerating the development of Third World countries [5] considered strategically important to economic development and national competitiveness, the concept worked like this. Through the transfer of know-how, new opportunities to use existing resources were created, and new demands for additional resources were developed. As a result, the development of international markets for agricultural inputs was accelerated greatly through technology transfer programs with Third World countries; many of these based on nationally sponsored international R&D programs. NASA and DOD developed efforts, based on similar principles, that targeted dual-use technology development and transfer of technologies developed in the national interest to civilian, commercial applications.

Objectives for nationally funded R&D evolved to include commercial development (Small Business Innovative Research Grants, Engineering Research Centers, etc.) And today across the national research agencies, one finds explicit objectives about, on the one hand, the commercialization of research results and, on the other hand, pre-competitive research in the national interest as a public good. The objectives of the National Information Infrastructure program span both.

Some successes in transferring technology in R&D consortia have been noted [8] and lauded, as have the barriers. But across the many programs that have been created, the development of the Internet itself stands out as a pinnacle example how technology developed to solve a specific and defined problem (redundant communications for national security) was transferred to other domains and adapted for new uses.

1.2. The Knowledge Spiral

The complement of tacit and explicit knowledge and the processes of exchanging knowledge among the participating entities are fundamental to the technology transfer process. Technology transfer, the application of knowledge, relies on the exchange of knowledge between two entities. [7] The knowledge that is being exchanged may not be a fully formed idea. Or it may be a fully formed idea that is not yet ready for application. It may be tacit knowledge — associated with subjective, simultaneous

practice and not easily expressible. It may be explicit knowledge —objective, easily processed, transmitted and stored, rational, sequential and digital. [14, 15]

| | Tacit knowledge | Explicit knowledge |
|------------|---|--|
| Individual | Socialization Sympathetic knowledge | Externalization Conceptual knowledge |
| Group | Internalization Operational knowledge | Combination Systematic knowledge |




Figure 1. The four modes of knowledge creation and the content of knowledge created in them (Nonaka et. al., 1995, p.72.)

1.3. The UCAID collaborators

UCAID s collaborators include people working at the GigaPoPs (network operations centers that provide expertise and access to this experimental networks), development teams working on application demonstrations that require the use of these advanced networks or the services of the GigaPoPs, and people (in test, primary and secondary markets) who will deploy the applications being developed.

The GigaPoPs and network operation centers at UCAID member universities play a central role in the nature and the speed of these technology developments. The Pacific/Northwest GigaPoP, for example, serves leading-edge organizations throughout the region by providing robust, highest-speed access to current state-of-the-art Internet; Next Generation Internet services and technology. It serves and provides essential expertise to the R&D testbeds where IPv6 technologies are being developed. [4] The GigaPoPs are educating new generations of users of advanced networks and advanced networking. They are important arenas for knowledge and technology transfer.

Academic networks such as the Metropolitan Research and Education Network (MREN), which includes the network operations centers at several institutions, are UCAID collaborators

also. The International Center for Advanced Internet Research (iCAIR), for example, participate in UCAID through its affiliation with MREN, through its affiliation with Northwestern University, and through its affiliation with national and international partners who also participate in UCAID. Technology transfer in a program such as iCAIR is modeled through a spiral that includes partnerships, research and development, commercialization, and privatization. [12] These partnerships are formed around interests —NGI, objectives —CANARIE and NORDUNet, and specific projects —STAR TAP. Across the range of mutual interests and shared resources, these alliances, partners and projects form a virtual laboratory [Russell]

Collaborating UCAID academic partners and corporate sponsors support and participate in the creation of testbeds, producing a new generation of testers and users, and generating an understanding of the requirements needed for next generation hardware, software and applications. Two of the primary goals of technology transfer —motivating the expression and stimulating the demonstration of the know-how —are directly tackled in the GigaPoPs and in collaborating networks.

Project-based applications of tacit know-how in new ways — how to make networks function — make that knowledge explicit and help people articulate and share what they know. As people externalize this tacit know-how and demonstrate it to others, the knowledge is transferred. UCAID's focus on application demonstrations is targeted toward this very objective. The presentations technical meetings and at the Internet2 Sociotechnical Summit, as well as this book of proceedings, address this need as well.

Following the externalization of knowledge among collaborating researchers, the applications are adapted, refined, re-applied and combined for new situations and wider audiences. As the appropriateness of the applications is recognized and accepted, the applied know-how becomes standard operating procedure within the group or the organization, creating a community of practice. The knowledge is taken again to an implicit dimension, incorporating it into the organization's culture and norms.

In today's Internet environment, we have witnessed this spiraling cycle in browsers, in email, in ecommerce, and more. The cycles create a spiral, as new innovations take the previously transferred technology or its

application to a new level. Organizations themselves have changed as the network-based new knowledge has become an organizational resource and asset. Continuous redevelopment processes that use networked information to share constructions of reality, build self-reference and organizational identity, and nurture conflicting versions of reality [23.] are changing the goals sets of organizations, causing systems to be under constant development. Educational institutions, in particular, have felt the impact of the Internet on administrative, instructional and research activities.

The internal and external activities that create knowledge help to fuel the continuous innovation needed for competitive advantage. Changes occur along the spiral. Innovations in standard operating procedures, made consciously or not by individuals create new know-how that becomes standard operating procedure, and the knowledge spiral begins again. Emergent organizations in which knowledge is continually being applied and exchanged, are characterized by rapid spirals. Slow spirals characterize well-established and highly bureaucratized organizations. [23] Continuous innovation requires continuous communication and results in continuous change. With the transfer of know-how from the Ipv4 dimension to the new Ipv6 dimension and the development of new technologies [25] one can anticipate the organizations, as well as individuals, will continue to develop new applications for the know-how.

Personal and interpersonal communications are the basis of the exchanges through which transfers take place. [7] In order to be applied, that new knowledge, that transferred technology, must be transferred several times again on its pathway to organizational acceptance, product development, marketing and adoption by the end user.

1.4. The Internet2 technology transfer challenge

Sometimes individuals find each other, identify a mutual objective, are spontaneously motivated to collaborate, find the resources to do it, and transfer know-how successfully — completely on their own and without external intervention. More often than not, the exchange of know-how and the transfer of technology are

established as goals at an organizational level. Leaders and managers are tasked with the accomplishment of the objectives.

The Internet2 project includes both routes. People learn about the opportunities available through advanced networking, imagine something novel that could be done with it, and seek out UCAID collaborators to help them realize their dreams. In other situations, organizations have joined UCAID and have assigned people to investigate how they can participate in early stage advanced networking. In this case, collaborating UCAID organizations take on the task of mobilizing the knowledge of individuals — often tacit but rich with understanding about the value the knowledge has for a solution —for exchange or adaptation into another form and with other people.

So, while we can define the technology transfer challenge of UCAID to be a question of learning and communicating more broadly than on the personal level. [10] Making it happen is an organizational issue, usually between members of small to medium-sized groups, united by common goals of some type. The members of the groups (often not geographically co-located) need to develop a communication structure in order to function. They must operate within one or more organizational environments whose cultures and priorities may vary. Although they depend on each other's work, they take home separate paychecks. And at the end of the day, their professional competency is likely to be judged by several different disciplinary groups that do not communicate with each other. [17] The organizational environment, the management of the creative and design processes, feedback mechanisms, and human resources are all critical to creating the vision, the motivation and the interpersonal glue that that fuels and sustains successful technology transfer endeavors.

2. Organizational environments

The enduring paradox of R&D consortia and technology transfer initiatives continues to be that the very organizations set up to create technology transfer also set up very effective barriers.

2.1. Paradox of incentives and barriers

The duality of great strengths becoming weaknesses applies to technology transfer efforts and to the influence of organizational structures and management practices on communication and exchange. A company organized by quasi-autonomous divisions (with R&D, marketing, sales and manufacturing for one division all within one building) might be very good at building products that solved problems for the customer. The various divisions, although they report to the same Group VP, could be expected to excel at producing product solutions allowing them to work inside their division, but have a very difficulty time producing an integrated set of compatible products that require their working across divisions. [10]

Another company, because it is organized by functional units that have a critical mass of all the sub-systems designers in one building (engineers co-located, marketing people co-located, etc.), could be expected to more efficient at building systems. However, when the requirements of those systems came from someone in sales, who had to go to engineering, who had to go to R&D, and eventually had to come back to marketing in order to develop a complete order and deliver the final solution, a sustained effort that resulted in a marketable solution was difficult. [10]

It is indeed a great advantage that UCAID is not the first initiative created for the purpose of technology development and transfer. The experiences of other organizations —businesses, universities, R&D consortia and collaborations — have provided worthwhile and relevant knowledge which can be articulated, adapted, and applied to the Internet2 projects and its objectives. In a word, know-how that can be transferred. Since the National Cooperative Research Act of 1984, when the antitrust regulations in the United States were liberalized to permit wider latitude in pre-competitive research collaboration among companies in the same industry, many initiatives have been mounted.

Internet-based tools have opened new networks for exchanging and managing the information resources necessary for technology transfer. The nonlinear flow of information over these networks, the open and immediate access to

information, and the ability to make information widely available have had profound impacts on the way people expect to use information. [1] Former conceptions of technology transfer as linear information flows from R&D through Development through Engineering through Marketing through Sales to the Customer have been replaced with conceptions that acknowledge the random, sporadic, episodic, eclectic, evanescent, anywhere origination of knowledge that needs to be captured effectively, codified, catalogued and distributed in order to become a knowledge resource that the organization can use. [10]

Among the personal and organizational dimensions that can serve as incentives or barriers to the communication needed for technology transfer, and among the new tools that can be used to manage and exchange key information, some important questions are presented for technology transfer in the era of advanced networking. Nonaka and Takeuchi refer to this knowledge-sharing space as *ba*. [14] In some cases, the *ba* is a physical place; for some it is a shared mental space. Advanced networking is likely to enable new types of *ba* that will significantly influence how knowledge is shared and technology is transferred using advanced networking technologies.

- What are the requirements for creating shared spaces for knowledge exchange and technology transfer for advanced networking initiatives? How are these requirements influenced by personal and organizational dimensions of advanced networks and by the know-how itself? What do we need to know about the *ba* of advanced networks?
- What are the critical dimensions for the metadata necessary for shared knowledge in a distributed global environment?
- What is the effectiveness of formal and informal means used to collect, distill and disseminate knowledge generated through Internet2 projects about advanced networking and new applications of this know-how?

2.2. Multi-level strategies and mechanisms

Technology transfer involves serendipitous interactions as well as deliberate intervention strategies. Experience and research have shown

[7] that for optimal effectiveness, these mechanisms need to be targeted to all levels of an organization—the individual, the program or project, consortia, alliances or business partnerships and top management or shareholders. Active communication mechanisms—such as face-to-face meetings, emails and other forms of interactive communication—and passive mechanisms—such as reports and articles—are mechanisms through which both explicit knowledge and tacit knowledge can be exchanged to fuel change. Both are needed to fuel the exchange.

As an example, the Microelectronics Computer Corporation, located in Austin Texas, was one of the largest and most complex consortia in the U.S. The MCC experiences were studied over its life span with careful collection and analysis of: interviews with those that founded the MCC, MCC managers and scientists, and member company representatives; archival documents, personal records, scholarly articles, and mass media accounts; and with surveys of MCC scientists, managers, and member company representatives, provide many lessons for other R&D consortia.

At its inception, MCC was motivated by fear—concern about the survival of a strategic industry, about international competitiveness, about limited financial resources, about scarce and costly talent, about increasingly short product development cycles, and about the proliferation of new technologies. Yet, while fear was an important motivator for public/private collaboration, such motivation did not sustain the cooperative/synergistic activity required to make that alliances work effectively over time. [7]

Flexible and adaptive systems that provide predictable and dependable mechanisms for sporadic and sometimes unexpected flows of information are needed along side of well-organized and routine mechanisms. MCC used a variety of techniques to move know-how along the knowledge spiral. Passive technology transfer mechanisms were used—non-proprietary technical reports, proprietary technical reports, refereed journal articles, newsletters, as well as videotaped overviews and demonstrations. Computer-based technology transfer—video conferencing and E-mail consulting—were used. And active means such as face-to-face interactions, created through scheduled meetings and scheduled committees, as well as

designation of shareholder representatives and assignees, visitor programs, on-site demonstrations, shadow projects and research collaborations were used.

Advanced technology will not cause institutions, organizations, and people to become more collaborative, cooperative, or synergistic. Advanced technology is merely an additional tool that can facilitate or exacerbate the process. The real challenges are behavioral and managerial. [6] MCC's first ten years demonstrated how significant the organizational and behavioral challenges are to establishing and maintaining inter-organizational collaborative alliances.

Communication and exchange are the basis of technology transfer. Other organizations, other collaborations have provided lessons about the different modalities that are used to accomplish meaningful work and the importance of multi-mediated communication. They have also provided some experiences that reveal that communication tools do not make up for dysfunctional organizational, institutional, or personal behaviors. As spirals of socialization, externalization, combination and internalization operate across both physical locations and in cyberspace, what makes them work?

- What are the success factors among the UCAID partners for the continued development of a collaborative mission? What keeps collaborative efforts on target?
- What approaches to research management are most successful in setting, guiding and adjusting shared goals, priorities and resources in the emergent organizational units that are collaborating in Internet2 development projects? How can they be managed?
- What are the critical success factors in organizational infrastructures that have emerged among the users and providers participating in the Internet2 initiative? GigaPoPs? Network operation centers? Inter-institutional project teams?

2.3. Balancing risk and reward

By definition the results of experimental work includes uncertainty. Evaluating the risk, estimating the reward, and maintaining the balance takes place at each of these levels. Regardless of the unit of analysis — the

organization, the division, the work group, the individual -- conducting experimental activities includes risk. At the beginning of the project and at each point at which new resources commitments are required, some evaluation of the return on investment is made. Will it be break-through? Will it help us? How many projects and what kind of budgets are needed to accomplish a given rate of successful innovation. And how will we know if we have succeeded?

Some organizations keep internal records and continually evaluate their own R&D and advanced development efforts. Productivity evaluations of national agency-sponsored R&D attempts to create and pass on knowledge about the elements of successful research, education, outreach and technology transfer programs. But like a defensible evaluation of an interdisciplinary program, [20] the assessment of consortia-based technology development and transfer programs is complex and difficult to quantify.

Finding appropriate peers to evaluate an interdisciplinary project is difficult. In the corporate setting, as well as in the academic milieu, a new project that is truly *break-through* probably falls outside the realm of concepts for which support can be garnered, for which resources can be justified, for which a publisher can be found. Evaluation of Internet2 technology development and transfer activities also poses challenges.

Studies of innovation in fields of agriculture, in microelectronics, and in biotechnology have provided a basis for understanding how critical factors such as team size, organizational structure and leadership influence the rate of innovation in R&D teams. Studies of various approaches to R&D collaborations linking small, medium and large manufacturing technology companies with universities give us a basis for understanding the relative strengths offered by different types of technology transfer partners. Studies of national research programs illuminate how institutional and international relationships have influenced technology transfer. Many of these same principles can be applied in the Internet era of R&D. But at the same time, there have been changes that could be substantially influential on the rate of R&D innovation.

Concurrent competition and collaboration is an important dimension of current organizational environments. Much can be learned about this period in time, as well as about management

principles used to balance risk and optimize return on investment in that risk — from studying the way that Internet2's academic and business and government partners have justified, tracked, optimized their participation in Internet2 activities to studying the impact of advanced networks on the way that the needs of users are understood and communicated to the technology development teams. Organizations that have succeeded in creating and maintaining the flexibility and responsiveness needed to continually redefine their best opportunities have pioneered the new emergent organizational structures [23]

Much can be learned from these organizations. Some relevant research questions might be:

- What are the determinants of the revenue, pricing and cost-sharing models that successfully sustain mutual dependencies in public and private sectors?
- What critical aspects of the development and maturation of advanced networking initiatives fall outside member organizations' willingness to risk and therefore require continued nurturing and support from the consortium or from public agencies?

2.4. Cross-cultural influences

One of the objectives of the Internet2 Sociotechnical Summit was to stimulate greater collaboration among the social scientists who have been studying the individual and group dimensions of computer-based and networked communication and technologists working on Internet2 projects. Significant groundwork for this was laid at the I2 ST Summit. But as presentations were given and led to discussions, it soon became evident that a great deal of cross-fertilization was also taking place among the different disciplines that comprise the social sciences.

Cultural differences do exist among the scientific disciplines; they exist among institutions, even from one university to another.

The epitome of cultural differences relevant for technology collaboration may be the interface between academe and industry. Considered off-limits by many academics, the foundation of patent literature and troves of market testing conducted through industry research programs often goes unrecognized and underutilized by

academic researchers. The extremely limited availability of on-demand, just-buy-it-then resources in university labs and the required accommodation of the academic instructional calendar are often off-putting to industrial researchers. It often takes raw courage to cross the line into the unknown, into the forbidden zone for collaboration.

Understanding the cultural differences among people who could be collaborators on advanced networking initiatives is an important consideration and a significant opportunity for research that can support knowledge and technology transfer. The results of such studies would also have important benefits for the application networking technologies for those markets. Cultural differences that stem from academic disciplines, organizational units, and national points of view are knowledge resources in a global community. The development of insights for enabling synergistic collaborations must consider cultural issues such as time zones and languages but they must also include expectancies about sharing, ownership, respect and acknowledgement. Importantly, they also include the cultural gap between academic institutions and the marketplace, which Porter calls the forbidden zone between industry and academe. [16]

- What cultural differences among collaborating disciplines, nations, and organizational vision and mission that require special consideration and attention in building global knowledge networks? What best practices can be understood and deployed to build strong bridges? How does timing influence the conditions?

3. Design management

Social scientists can contribute a great deal to the understanding of technology transfer. They also have important contributions for the development of the technologies themselves. Other white papers in this series delve more deeply into the specific perspectives that can be contributed and the roles that social scientists can play on technology development teams. In the context of technology transfer, however, it is important to at least mention the variety of functional roles that social scientists can play and to mention the need to understand how those roles can best be integrated into technology

development efforts.

In many circumstances social scientists are brought into a technology development team as one of the final stages of new product development. The technology has been proven, prototyped and productized. One final check must be taken —does it fit the needs of the end user? Social scientists are brought in to test this before it goes to manufacturing or to market.

From its design, this type relationship starts out adversarial and does not promote collaboration. The user tests conducted by the social scientists are the last barrier that stands in the way of the product going to market. Nothing short of complete approval will be received with enthusiasm. And this is particularly unlikely if the user has not been considered before this point. Insights for refinement, much less major design considerations, are received as criticisms, delays, bad grades. The likelihood of such an engagement producing collaboration is slim.

Alternatives exist. Social scientists are sometimes involved at the initial phase of projects — in defining the user experience in order to understand the requirements of a product or service solution. Through the regular collaboration of social scientists and technology developers a shared, consistent vocabulary can be developed to describe the persistent and consistent human behaviors that run throughout use situations, as well as the practices, issues and values likely to be associated with the use of the application. [2] Prototypes, models and simulations can be developed reflect user and customer needs and values.

But like going to a bank for money, the one-shot, gimme what cha got approach to utilizing the input of social scientists benefits from experience, exposure and repeated use —in short, a relationship. A quick response to a human factors or user interface question is likely to be better if some ground work has been laid before —if there is already an account at the bank. The reverse is also valid. The credibility, or currency, of a social scientist to take an applications idea to a technology development group depends significantly on the trust and confidence established in previous interactions. Collaboration in solving problems requires first sharing the problems, and the real problems are more likely to be shared in an atmosphere of genuine interest and trust. For this reason, organizations such as Nortel Networks and the

National Science Foundation have established programs to encourage interaction between social scientists and physical scientists or technology developers. [2, 3]

More can be known about effective ways to facilitate this collaboration. Some candidate research questions concern the following:

- What ratio of behavioral scientists to technologists is advised for companies that make product used by people and organizations?
- How can social scientists interact with technology development teams to make the optimal impact? How can they interact with many technology development teams at a time in order to optimize their numbers?
- How can individuals working on many different and changing teams over time be appropriately and meaningfully recognized and rewarded?

4. Feedback mechanisms

One of the most important dimensions of successful knowledge and technology transfer programs consists of the mechanisms that are used for feedback. Setting objectives is important. Communication and decision-making channels through which they can be changed are critical.

During the 60s and 70s, the hope chest model of technology transfer, in which resources go into a project, while sponsors resort to patience, hope and providence to produce the outcomes, was satisfactory. It is not sufficient today.

Again, examples from other R&D collaborations provide some useful experience. In the early, formative years of MCC, the organization's approach to technology transfer was focused on the researcher with a candy store, come-and-get-it attitude. Later, as fear of international competition subsided and the collaborators anted up the second round of resources, the focus shifted to the consumer; and third party licenses became the mode. Following that, the focus shifted to profits, return-on-investment, new ventures and spinouts. [7]

Through these eras, MCC leaders commented on the organization's attitudes toward technology transfer. Admiral Inman, the first president, commented in 1987, Some companies get in [the MCC] and they aggressively pull the

technology out. Other companies lean back and sip through a long straw. Later in 1991, the second president, Grant Dove, reflected, Early in the game there was the feeling that we would deliver ideas, concepts, prototypes, etc. The companies would then invest to put it to work. That didn't happen. And then as the return on investment became crucial, the third president, Craig Fields, said, Up front we have technology transfer plans because I believe that it's bad management to wait for the middle or until the end, and then come back and figure out how you're going to transfer it. [7]

One would not be surprised that expectations for outcomes of R&D activity will vary across individuals, organizations and institutions. Doing state-of-the-art research will motivate some, whether it is used or not. Others are inspired to see that a targeted user accepts the technology. Still others strive to see that the technology will be implemented. For some, the driver is that the technology will be commercialized and provide a return on investment. Market penetration and diffusion are the payoffs that others seek.

What constitutes a successful outcome may be specific to the particular situation, the specific project or the program. But across situations and across motivations for technology transfer, some collaborations are more successful than others. Studies of the characteristics of successful technology transfer programs have identified the importance of supportive organizational contexts, highly interactive and early communication among collaborators, high cultural proximity, and low technical ambiguity as key indicators. [7]

The program development, project management and funding mechanisms of UCAID are structured to require continual feedback concerning objectives and outcomes. Flexible structures that enable reconfiguration reflect the advanced networking technologies that are their focus. In this novel approach, many lessons about constructing feedback mechanisms for R&D collaboration wait to be articulated and shared.

- How is customer satisfaction defined at various links in the chain of relationships that are necessary to implement the Internet2 initiative? How is responsibility for those relationships assumed, assigned, and shared?
- What factors describe the best practices for providing centralized/decentralized service

and support for the distributed computing and networking activities of Internet2?

5. Building the human resource

A few years ago, only a few people knew how to make Internet networks. There are more network engineers now and they know more, but they are still in short supply. Far more are needed, in the days ahead, to enable the expansion of the commodity Internet, to develop the basis for the next generation Internet, and to convert appropriate dimensions of current use for the next generation.

Developing the new advanced networking technologies is only one part of the challenge. The availability of people who know how to use it remains a critical dependency. And to this end, a crucial dimension of technology transfer in the Internet2 project requires knowledgeable, skilled people — implementers, doers, makers.

The flow of scientific personnel as a technology transfer and diffusion mechanism has been studied before. Transnational flows of scientists are an objective of the scientific community. Their exchange of perspectives adds vitality, broadens intellect, and promotes peace. [13] Likewise, flows of new scientists from academic institutions into the work place carry new skills and motivations into the labor pool. The migration of technical talent from one company to another creates personal linkages across which new ideas and business relationships flourish.

The human resource objective of UCAID is strong and clear. Collaboration through UCAID offers an opportunity to build this pool of talent, in spite of the competition among organizations for the best and fastest and most nimble network engineers. The recruitment and development of network engineers who will help to build and operate the next generation is a necessity—in the academic institutions and throughout industry.

Additionally, it seems evident that the people needed for technology development and transfer must be good communicators, able to work with others, able to see problems from the perspectives of another discipline, flexible in the face of changing teams and shifting priorities. Findings from the study of interdisciplinary research management are extremely relevant to the preparation of researchers and leaders who are

developing the next generation of advanced networking. We can draw upon studies begun in the 70s as the evaluation of large scale research projects stimulated a focus on interdisciplinary research management [19] and continued through an era that re-introduced mission-focused funding by national agencies. These studies emphasize interdisciplinary endeavors involving groups of physical scientists drawn from several disciplines or the combination of scientists and engineers. But additional research is needed on how the interface between the social scientists and the engineers, physical scientist or technologists needed for Internet2 developments can be understood and facilitated. And the important issue remains of identifying and integrating into academic instruction the fundamental intellectual and skill components required to train and educate the next generation of network engineers.

To that end, some important questions warrant study in order to get and keep good people and to optimize their roles in the Internet2 project.

What best practices can be identified for recruiting, training and retaining a quality workforce for advanced networking in academic and business centers?

- How can the influx and outflow of participating researchers be leveraged for synergy between academic and business partners in Internet2 projects?

6. Sharing the vision

To accomplish the objectives of UCAID requires clearly communicating the nature of the Internet2 project to potential participants. Current UCAID collaborators need a continuing flow of communications and opportunities to interact with each other. Potential collaborators need to know how they can be involved. Potential users need to understand the promise of advanced networking and how the Internet2 project fits into this.

The perception (or misconception) of Internet2 as a fatter, faster connection to the World Wide Web is surprisingly prevalent among well-educated, decision-making leaders. When can I get Internet2? is a frequently asked question. Many of the people whose intellect and energies are needed for the next phase of the Internet2 project do not yet understand what it is and why it's important. An informed constituency is essential to build advocates for the availability of

resources for further research, the creation of informed markets, and development of policies that support realization of the benefits that can be delivered.

In this still emergent stage of advanced networking and the conversion to IPv6 protocols, the next users of the new applications may be another academic network operations center. They may be the research team that is just forming, or a professor with a need to communicate. Identifying and connecting with the next users are critical steps for the Internet2 endeavor. Their interest and ability to utilize the applications developed to date provide important information about the next development that needs to be done. Their articulation of opportunities for advanced networking to provide solutions to their needs is an important resource and a vital element of the knowledge spiral.

Fruitful explorations of knowledge and technology transfer for the Internet2 project should include questions about identifying and reaching the next users.

- What does Internet2 represent and how does the communication of that position define the initiative for its users and for other constituencies (e.g., elected officials, university administrators, journalists, etc.)

The growth driver of the Internet, served by the current IPv4, has been computers connected to various small networks in the large business, government, and university education markets. Growing at an exponential rate, the computers in these networks are generally at the endpoints of Internet communications, generally attached to Local Area Networks (LANs.) Most are not mobile. While this market is expected to grow, it is likely that new, extremely large markets will develop and bring with them a new set of requirements.

For example, Hinden describes networked nomadic personal computing devices (devices that replace cellular phones, pagers, personal digital assistants) that will need a variety of types of network attachments. With requirements to alternate between RF wireless networks when disconnected, infrared attachments when in networked facilities, and physical wires when docked, these devices will be an ideal candidate for internetworking technology. They will need a common protocol that can work over a variety of physical networks. [9]

He describes networked entertainment, with

the possibility that every television set will become an Internet host, diminishing the differences between a computer and a television as the world of digital high definition television approaches. As in the previous example, this market will require an Internet protocol that supports large scale routing and addressing, and auto configuration. [9]

Markets of the future, yes, possibly, but rooted in present technology developments — technology developments that could emerge from Internet2. In a way that may be different from previous technology developments, the Internet arena offers opportunities for customer requirements to be quickly communicated to developers and for new developments to be quickly tested by potential users and disseminated to markets.

The Internet2 project offers a journey in which, like the Center for the Performing Sciences at the Houston Advanced Research Center, science emerges from the laboratory to perform for society —where an audience can gain access to and benefit from it. [16] This journey will likely have a few bumps along the way. Other R&D collaborations have demonstrated that advanced technology will not in and of itself cause organizations and people to be collaborative or productive. Interorganizational alliances do not in and of themselves produce synergy. While the technology challenges are not insignificant, the behavioral, organizational and managerial challenges are often the most critical. The ranks of social scientists include many with the courage and appetite to join this journey. Their methods and tools stand ready to help construct the road maps.

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