Chapter Four

CATALYZING PARTNERSHIPS TO ENABLE INFRASTRUCTURE AND BROADEN PARTICIPATION

When we first set about designing the PFI program, we had many hours of lively debate about how it should be structured. What guidelines should we develop for prospective grantees? What parameters should we require of the partnerships? We all knew that PFI would best serve its purpose if it attracted a wide variety of institutions, partnerships, and proposed experiments and innovation.

In the end, we decided to place very few restrictions in the proposal description. We wanted to provide the maximum freedom possible for grantees to be innovative about innovation. . . . We've reached out to find the capable people with the best ideas to begin the extraordinary process of transforming our innovation system to meet the needs of the 21st Century.

Joseph Bordogna, Deputy Director, National Science Foundation

To paraphrase one breakout session's plenary report: "The PFI aims to catalyze innovation, and partnerships are how we go about doing that." This chapter accordingly describes workshop discussions regarding three further aims of the PFI program that are related to partnerships and their growth: catalyzing partnerships, catalyzing enabling infrastructure, and broadening participation in the national innovation enterprise.

CATALYZING PARTNERSHIPS FOR INNOVATION

More often than not, workshop participants described genuine partnerships as dynamic and growing relationships based upon shared interests, trust, and an evolving technical relationship.[1] Participants described these relationships as necessarily multifaceted, including senior researchers, students, business people, and others who could find common ground and purpose, and as long term in nature.

Attendees identified a number of characteristics that were associated with successful partnerships that can be thought of in terms of discrete steps. These steps incorporate both broad issues of the partnership's ends and narrower ones of means, ultimately leading to a fuller understanding of the essential interdependency of all partners.[2] Although the following discussion suggests a top-down—and sequential—process, there is obvious concurrency and interdependency among the steps.

Establishing a Vision

First, successful partnerships have a vision that provides an image of what constitutes success in fairly concrete terms (e.g., an incremental innovation that can improve a product or process or a radical innovation that can enable a new one).[3] This can provide a basis for further specifying goals and objectives, for establishing a roadmap for realizing the vision, and for providing incentives to agents of change.

Workshop attendees placed a great deal of emphasis on the development of a vision for each partnership, one that in many cases would be the work of a single champion who could provide the lead-

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[1]Participants in one breakout session contrasted a partnership in which the parties want the partnership to grow and sustain itself with a "marriage of convenience" in which one party just wants something (e.g., money). Mowery (1998) describes key elements of collaborations and proposes features that are associated with better performance.

[2]Some participants even believed that there was a cyclical component in the partnership process: As initial goals were achieved, members of the partnership would establish new ones.

[3]As E. Roger Novak of Venture Capital for Partnerships put it in his talk: "Ideas are plentiful, visions are powerful."

ership and overall coordination necessary to ensure that the partnership was a success. This vision would need to set a tone that embraced the most important aspirations of all of the partners, while providing a coherent statement of the overall end state to which the partnership itself aspired.

Establishing Performance Goals and Benchmarks

There was broad agreement that the partnership's vision needed to be supplemented by a definition of measurable outcomes and benefits of the partnership that could be used to establish benchmarks and to measure progress.[4]

Clear, achievable measures are needed to assess goal performance (e.g., results and return on investment) and these should include measures that speak to the quality of relationships in the partnership. The metrics should point to the desired end-state for the partnership, which some argued should provide the basis for an "exit strategy" that plans for the obsolescence of the current project and a path to the next one.[5]

Identifying Leaders

To realize the partnership's vision and to make it operational, a visionary and passionate leader is needed. This leader must either be brought in or cultivated from within the partnership.[6] In either case, because passionate leaders are rare, expensive, and in high demand, money must be available to pay whatever the market will bear for their services.[7] The frequency with which the topic of leadership arose suggested that many participants doubted whether a partner-

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[4]We will return to the question of performance measures in the next chapter.

[5]This could involve either a focus on a new area or incremental improvements (line extensions) to an existing line.

[6]According to some, the self-interest of all parties was important in both the short and long term, whereas champions (organizations and people) were needed for the long term.

[7]Many seemed to argue that the leader generally would precede and lead the development of a partnership, but the possibility of a leader emerging from within the partnership also was recognized.

ship could even survive without one or more vibrant leaders who could champion the partnership's cause.

A recurring theme in the discussions related to the broadening of discrete partnerships to larger networks and clusters was the need for strong local leaders from relevant professional communities (e.g., university, industry, venture capital, the law). These leaders had to be both influential and powerfully committed to the region, capable of knitting together all of the elements that were necessary to ensure a high probability of success: strategic and business plans, private capital, broader institutional and community support, and other elements. They also needed to be capable of building and managing the partnership and selling the partnership to the outside world (e.g., potential investors, the community, the state).

Recruiting Committed Partners

As suggested above, the core of a successful partnership was conceived of as comprising the minimal set of partners needed to provide all of the competencies and resources—an innovative idea, leadership, one or more technological approaches to its realization, entrepreneurial and marketing skills, administrative and financial support, and so on—to bring an innovation to market.

The overarching aim in finding partners was to identify other parties with common strategic interests and complementary strengths and weaknesses:

- For universities, this often meant looking for industry partners with equipment, infrastructure, or other needed resources—not necessarily financial ones[8]—who might be able to implement research.
- For industry, the aim was finding academic partners who had relevant know-how that could make a contribution to a joint venture.

[8]Indeed, some participants felt that academics who were going after money were going down the wrong path.

For purposes of building the partnership, this necessitates a three-step process for building shared commitment based upon mutual understanding and appreciation:

- *Mutual Understanding.* Successful partnerships were characterized by candor and mutual understanding of individual partners' principal reasons for involvement in the partnership, including their motives, goals, and needs; the compatibility (or potential incompatibility) of partners' interests; comparative strengths and weaknesses, resources, and constraints; and roles and responsibilities of each member of the partnership.[9]
- *Mutual Appreciation Based on Interdependency.* The mutual understanding found in genuine partnerships and the alignment of roles and responsibilities based upon an understanding of comparative strengths and weaknesses of the partners led to an interdependency that was viewed as healthy and essential for the partnership. If partners did not really need one another to accomplish the partnership's goals, some averred, then they should go elsewhere. A partnership meant that a partner really could not go anywhere else to accomplish his goals.
- *Shared Commitment.* In successful partnerships, it was critical that the interdependency and essential need for the capabilities of other partners just described be accompanied by shared commitment—all partners need to be highly motivated and deeply involved in the partnership.[10]

A network of committed customers and other stakeholders and supporters also must be developed, providing positive feedback and support for joint ventures. Customers and other stakeholders and supporters at all levels must be continually engaged and apprised of the status of progress.

University Strategies for Finding Partners. A number of elements of potential university strategies for finding partners were identified:

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[9]A prominent subject was ensuring a level of candor among partners to reveal their true motives rather than claiming purely altruistic ones.

[10]Words such as "driven" were used to describe the nature of the partners' commitment, and partnerships were said to require "a sense of urgency in the strategic sense—something needs to happen."

- "Partnership friendly" university policies were seen to make a big difference in attracting industry partners, with universities having such policies able to advertise these policies to attract industry partners;
- Multidisciplinary science, technology, and business centers and university-industry institutes were seen as excellent indicators of a "partnership friendly" environment that could provide a potentially effective and efficient liaison between the university and potential industry partners;[11]
- Technology transfer offices can evangelize the university's endowments in science and technology, including its skilled science and engineering workforce, and both senior researchers and graduate students;
- In light of the belief that universities need to understand an industry to target it, universities can conduct industry needs assessments and capacity assessments to ascertain what type of technologies are needed and commercially viable and where university researchers can add the most value;
- In relatively mature areas of technology, university researchers can identify firms with the most patents in an area;[12]
- Networks (such as alumni networks) were seen as a source of potential industry partners who would be sympathetic to joint ventures with university researchers; such networks should be encouraged and used by universities;
- Showcases and industrial research fairs were viewed as potentially powerful ways of drawing companies to university events and presenting opportunities for researchers to interact with firm representatives; such showcases could be coupled with projects that yielded models or pilot demonstrations that had potential for industry application.

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[11] On industry-university collaborations, see Industrial Research Institute (1996).

[12] This approach was believed unlikely to work as well in emerging technology areas and markets.

Industry Strategies for Finding Partners. Also described were a number of potential industry strategies for finding academic partners:

- Industry searches can focus on universities with technology transfer offices, multidisciplinary industry-oriented "centers of excellence," universities with "partnership friendly" policies, or those that have many patents or citations in an area of interest;
- Concentrating on identifying multidisciplinary centers of excellence or university-industry research centers that focus on the science, engineering, and technologies underlying a specific industry appeared to be a more profitable approach than focusing at the university level; similarly, focusing on schools with department-level reputation and expertise and those that educated particularly valuable employees were seen as potentially useful strategies;
- Individual professors doing work in relevant areas can be identified by reputation or by their publishing record; these academic researchers could be engaged on specific technological problems or challenges and invited to submit informal proposals;
- Industrial fairs were seen as a way of getting academics out of their departments and providing a basis for evaluating their performance and the prospects that they might contribute materially to solving an industry challenge;
- Some firms simply show up at a research institution and see what research has been done and what can be used;
- Firms can use a consultant to find the best universities for work in a specific area;
- Firms can use employees who are former graduate students as an interface between the business and universities;
- Representatives of firms can attend meetings of professional and technical societies;

- Finally, the internet can be used to conduct searches of universities and their expertise.[13]

Identifying Comparative and Competitive Advantages

Although there seemed to be agreement that the broader market environment narrows viable areas of research, participants felt that the partnerships should aim to shape that environment. To accomplish this, partnerships need to be guided by a systematic appraisal of their own strengths and weaknesses relative to other commercial efforts that goes well beyond the stock-taking of individual partners' strengths and weaknesses. The partnership needs to identify its comparative and competitive advantages over other technology development and industry efforts, whether in the larger context of an existing market, product, or process, or an entirely new one.

According to workshop participants, this appraisal should include a sort of market analysis that identifies customers, competitors, products, processes, and underlying technologies in the area in which the partnership hopes to compete and identifies the unique characteristics of the partnership's efforts that will make it competitive. A clear view of the market and potential competitors in that market also was seen as a characteristic of successful partnerships. If a partnership had some things that were unique and different from its competitors, then it could successfully compete and take advantage of individual partners' expertise.[14] The partnership also should identify any remaining elements (e.g., public relations, marketing) that will be needed to bring the innovation to market, particularly if it is an area outside the experience and expertise of existing partners.

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[13]For examples, see Yet2.com, which acts as a broker of technologies, and www.ninesigma.com, which has developed a way to find out who is doing research in what areas and can lead those interested in getting research done for them to proper scientists.

[14]Workshop participants appear to have taken a broad view of the market: A market could be a particular locality or industry niche, an entire industry, or a regional economy that was competing with other regional economies.

Resolving Intellectual Property Issues[15]

IP is the mechanism by which the benefits of an innovation are appropriated (owned) by one or more parties; in general, because industry is driven by the profit motive, historically it has sought to exploit intellectual property to a greater extent than have universities (see the box, below).

The disposition of intellectual property—for purposes of workshop participants, primarily patented inventions[16]—generally revolved around three key questions: Who owns and is the assignee on the IP? Who controls and has the right to commercialize, sell, or otherwise use the IP? Who benefits through a share in the profits made from the use of the IP? In short, it is the property rights associated with the intellectual property, and not the question of who invented it, that is crucial. In a standard university-industry collaboration, three other questions also typically arise: When can the academic partner publish? What level of confidentiality must be maintained in the academic environment? And what is the overhead rate?

There was broad agreement among workshop participants that the benefits to researchers of intellectual property were not exclusively—nor even necessarily primarily—in terms of financial sponsorship, opportunities for consulting, or the revenues that might result from licensing and patents. Indeed, a wide range of potential nonfinancial benefits of IP were cited, including internships for students and early recruitment of graduate students into industry, laboratory equipment and other "in-kind" benefits, and the potential treatment of patents as "publications" in performance reviews, promotion, and tenure decisions.[17]

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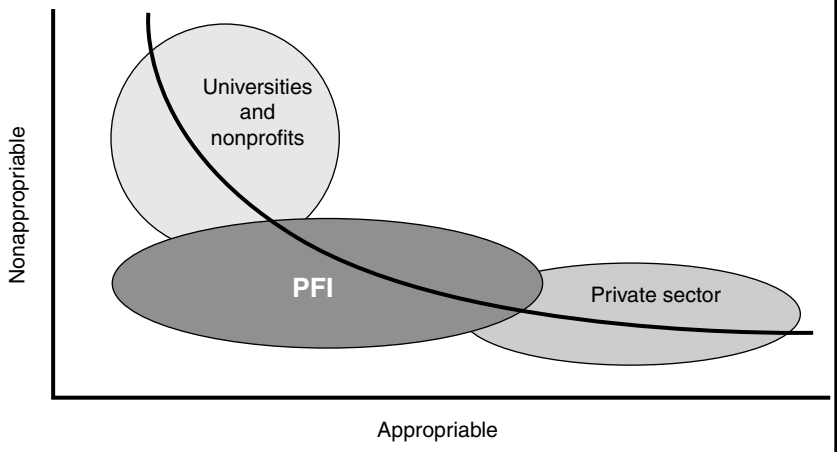
[15] One breakout session focused on the issue of intellectual property, and a number of others touched upon the subject in their discussions.

[16] Intellectual property also includes copyrights and trademarks, but these were seen as less important for purposes of the workshop.

[17] Many of these benefits occur from partnerships in general. However, participants discussed at length the benefits that were observed when IP was also involved.



SOURCE: Hurt (2001). Figure created by Jere Denton and used with permission.

NOTES: The academic and nonprofit sectors engage in activities the fruits of which generally are not appropriated back to them. They produce knowledge as a public good in the form of students, publications, and other outputs that can contribute to societal well-being, but they do not generally seek—and often are not able—to appropriate benefits from these activities for themselves. By contrast, the private sector engages in commercial activities, where the benefits from intellectual property (know-how, revenues, profits, etc.) generally are appropriable. PFI aims to fill a gap between university and industry that can arise as a result of the university's need for new funding sources and industry's need for innovative new ideas and willingness to pay for them. It provides an opportunity for academic, nonprofit, and private sector actors to appropriate enough of the benefits to make the effort worthwhile and sustainable. For the university, those benefits may be in the form of consulting, internships and on-the-job training, funding, or lab equipment and other infrastructure. For the private sector, new sources of knowledge can be harnessed, and skilled scientists, engineers, and other workers can be put to work laying the foundations for emerging commercial opportunities and challenges.

Although the numerous benefits seemed clear to participants, also clear were the numerous issues that needed to be resolved by each member of the partnership to ensure that IP did not become a source of friction. Participants noted that there often were a host of unstated expectations in IP agreements (e.g., regarding the ownership, control, and benefits from IP) that equally often went unmet and became a source of friction between partners. The importance of symmetry in the benefits also was mentioned as a critical issue, since all parties needed to have a sufficiently substantial stake in the outcome to devote effort to achieving success. A lack of awareness regarding what IP issues needed to be worked out also was deemed to be an important source of problems.

Some argued that the main challenge to resolving IP issues was related to the communication necessary to bridge gaps between partners. For example, cultural differences that arise from different (e.g., academic, industrial, legal) backgrounds and perspectives were seen as important; universities need to see themselves as partners rather than owners of IP.[18] There also is a lack of awareness of the very different capabilities and needs of small and large businesses; small businesses were seen as needing to own IP to be attractive to others, for their own strategic planning purposes, and to avoid licensing and other costs, whereas large firms typically have law departments that established IP guidelines and have established ways of doing business with universities. The best means for resolving disagreements was, not surprisingly, fostering communication and mutual understanding among all involved organizations and parties. Placing time limits on the ownership of the IP also was seen as a means for reducing long-term risks among the agreeing parties. By limiting the ownership, partners would have the ability to renegotiate, at a fixed point, the various equities for that IP (partners would not be forever signing away their rights).

Further, there frequently were tensions between the ownership of the IP and the benefits derived from the IP; IP generated at academic institutions typically remains the property of the institution, but the

[18] For example, proprietary information, confidentiality requirements, and reliability and validity of data can mean different things to different people.

tax code limits the ability of nonprofit institutions funded with tax-exempt bonds to share in the financial profits of IP.[19] Of course, such restrictions generally do not apply to industry, but the result is nevertheless that most IP is either not commercialized at all or is underutilized, with no one gaining benefits from it.[20]

The institutional, cultural, and legal roots of these differences suggested that changes might be needed. There was recognition, for example, that in many universities a cultural change would be required to change the reward system so that innovative activities were valued as highly as standard performance measures such as publications in peer-reviewed journals;[21] absent such a cultural change, workshop participants were somewhat pessimistic that innovative activity could be sufficiently encouraged and supported. In a similar vein, it was noted that a university's mission typically was to develop new knowledge and not to go about identifying new customers.

Developing Plans

Planning considerations play a number of prominent roles, including developing strategic implementation plans that relate goals to infrastructure and human resource issues; developing communications strategies; managing the time of key stakeholders to ensure that their time is not wasted; and planning for the ultimate institutionalization of the partnership or network so that its processes and benefits can be continued.

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[19] On the other hand, the Bayh-Dole Act of 1980 (amended in 1986) enabled nonprofit institutions to receive patents on the results of publicly funded research and has been credited with the resulting significant expansion in universities' efforts to support patenting, licensing, and transfer to industrial firms of university research results, as well as providing incentives for university-industry partnerships. See Mowery (1998).

[20] There is a growing trend for industry to take IP not being commercialized, donate it to a university (as a tax write-off), and in some cases to lend researchers to help the university develop the technology even further and possibly commercialize it.

[21] A yearly luncheon recognizing faculty who have patent inventions was proposed as an example.

There also seemed to be broad agreement that the partnership should be treated as a business, which meant that the partnership should have a business model and plan.[22] According to workshop participants, these should provide potential investors and others with an idea of the potential value of the innovative activity, judged on the basis of the estimated size and identity of the customer base in the relevant market, the nature of competition and demand in the market,[23] and analysis demonstrating that the expected rewards justified the expected risks. The plan also should lay out the steps—and costs—involved in bringing the innovative product or process to market, including how resources are to be allocated to accomplish the partnership's goals.

Competing, Communicating, and Resolving Conflicts

When a partnership has addressed the foregoing issues, it is ready to compete, but the continued integrity and viability of the partnership can be challenged as a result of unforeseen developments and the changing motives of the partners. This requires continued communication among all partners and conflict resolution procedures.

Competing. Competing consists of bringing the innovative product or process to market in competition with other products or processes.

Communicating. Effective communication within the partnership is necessary, as is promotion of success outside the partnership. Community/stakeholder buy-in that supports the enterprise, including frequent meetings with stakeholders and other means for overcoming fragmentation and isolation, is needed to mobilize organizations and resources. Moreover, the "selling of success"—celebrating success stories—was viewed as crucial from the outset, and identifying and developing key audiences for marketing and public relations

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[22] A typical conception of a business model is a one-page paper that describes how all of the elements of a business work together to build marketplace advantage and company value. The business model typically describes its intended customers and its marketing strategy for reaching them.

[23] The willingness of customers to pay for the innovation was specifically identified as being of interest.

was viewed as an instrumental means for drawing in additional resources. Since many principal investigators (PIs) lack expertise in effective public relations, some argued that a separate budgeting category needs to be created for public relations, and media contacts need to be included in the network.

Resolving Conflicts. As discussed above, participation in a partnership connoted an essential compatibility in the interests of universities and industry: The innovative capacity of universities could be harnessed to the proven technology of the private sector and made functional, manufacturable, and scaleable. However, as was described above, a number of potential areas of incompatibility were seen to offer the potential for university-industry friction, including differing time horizons and priorities, competing claims for royalties from intellectual property, and differences over the timing and scope for the dissemination of research results. In recognition of these—and other—potential flash points, workshop participants advocated a fairly sensible approach.

At the outset of a partnership, all partners should put their personal agendas on the table and ascertain the extent to which everyone's needs can be met. In some cases, areas of potential friction requiring tradeoffs may be creatively redirected into more productive arrangements. Rather than competing over shares of royalties, for example, universities might seek laboratory equipment or other in-kind investments, access to firm resources, consulting opportunities for faculty, or employment opportunities for students. Similarly, to the extent that universities are willing to modify performance and promotion criteria to weight patents and other evidence of innovative research as heavily as peer-reviewed publications are weighted, this can eliminate a source of potential friction that arises from the "publish or perish" reward system faced by most academic researchers and leads to a desire for speedy publication of results. Disputes that arise later in the partnership simply should be resolved with reference to what was described by one breakout session as a "hierarchy of values" that weighed the issue in contention against the benefits each party received from the partnership, the shared values of the partnership, and the interdependence of the partners.

CATALYZING ENABLING INFRASTRUCTURE TO FOSTER LONG-TERM INNOVATION

The PFI program also aims to catalyze the creation of the infrastructure that can sustain and nurture the spread of innovative activity over the long term. Workshop deliberations described infrastructure of three general kinds: that related to developing human capital, developing networks, and providing direct support for the innovation enterprise.

Developing Human Capital

To educate and train human capital for the research enterprise, workshop participants saw the requirement for an innovative educational process whose most important goal was serving the student. Such a program should be focused on creating an environment that rewards innovation and is characterized by passion and a commitment to success.

This process would identify talent as early as possible (from elementary school on), create good motivational teachers, and embrace versatility (e.g., affirmative action programs, recognition of cultural differences) to ensure that it was drawing upon the largest possible pool of new talent. As students progress, it is critical to make subjects real with hands-on education and training and to demonstrate the connections between popular programs and how they had progressed to that point. At the university level, the most important role of the university was seen as educating and training young scientists and engineers; good science and engineering students need to be recruited and then retained[24] and brought into partnerships with industry. And internships should work in both directions: faculty and student internships in industry and industry internships in universities.[25] Finally, young scientists and engineers need to serve as agents of change, i.e., by diffusing know-how and innovation.

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[24]For a recent report on the subject, see National Science Foundation (1999).

[25]The NSF's Research Experiences for Undergraduates (REU) program, which provides a framework for internships with industry, was mentioned as a good model in this regard, as was the PFI program.

To accomplish this, workshop participants viewed as critical early participation from all stakeholders and buy-in from the top for the principle that the most important goal was serving students. And buy-in could be quite literal: It could require investment in additional plant and teachers for traditionally underserved populations; buy-outs of faculty time for sabbaticals, mentoring, and other activities; or monetary rewards for excellence in teaching or research.

The education and workforce challenges that were identified ranged from simply keeping students in the state to paying for program coordinators, facility space, equipment, etc., and reaching all stakeholders, especially minority-owned businesses. At a macro-level, there also are longer-term workforce challenges related to ensuring that the nation can develop (or attract and retain) needed science and technology (S&T) workers in key areas (see the box, below).[26]

Concern also was expressed about the challenges arising from adverse demographic trends, including an increasing ratio of pensioners to workers and chronic problems with the K–12 educational system.[27]

Creating Networks that Embed Social Capital

The intellectual capital and know-how embodied in young scientists and engineers, honed through advanced education and training, must be embedded in social networks characterized by shared commitment and trust. Such networks can be built only through extended interactions and problem-solving and represent a form of

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[26]Future workforce challenges already have been recognized and are the subject of high-level attention. See National Science and Technology Council (2000). Additionally, the National Science Board currently has a task force that is examining national workforce policies for science and engineering. See National Science Foundation (2000), available at http://www.nsf.gov/nsb/documents/2000/nwp004/nwp004.htm. In considering the issue, however, one needs to consider the capacity of labor markets themselves to correct for increased demand by raising wages. See David and Hall (2000).

[27]See Good (2001). For an industry perspective on the challenges faced by the K–12 system and some suggested remedies, see Popper, Wagner, and Larson (1998), pp. 108–109. For a perspective on workforce issues, see National Research Council (1998), especially pp. 17–24, 46–47.

Ensuring an S&T Workforce for Future Areas of Innovation

According to a presentation from Mary Good[a], U.S. policymakers need to look at the implications of a U.S. S&T workforce that is both aging and changing in its composition. To illustrate why the United States should be concerned, she used the following example.

Many believe that the next generation of computing will be based on quantum computing, and Hewlett-Packard (HP), IBM, Lucent, and many universities accordingly have invested heavily in quantum computing research. Looking at members of the Quantum Science Research at HP's laboratories, however, two striking observations can be made. First, all of the U.S. members are over the age of 45; and second, all of the younger ones are non-U.S. citizens. This pattern also has been observed in the universities that are doing this type of research.

As Good pointed out, this is just one anecdote, in only one area of S&T, but it does raise several important policy-relevant questions. How can the United States reverse adverse trends that may be occurring in core areas of S&T and better ensure that the nation will have a future workforce with enough qualified workers in these areas? How can the nation draw enough U.S. students into the science and engineering workforce to ensure a robust indigenous capability in what appear to be emerging core areas of S&T? Failing that, how can the United States ensure the availability of H-1 visas and immigration-friendly policies for foreign students who are doing research in core S&T areas in U.S. universities and who might remain in the United States thereafter? If there are too few American students, and industry cannot hire foreign students, where will industry and universities find the expertise they need?

Although there are no simple answers to these questions, they are among those that the United States must consider and take action on to ensure the necessary intellectual capital to keep the United States competitive in the global market.

[a]Good (2001).

social capital that, in some workshop participants' minds, seemed to be the most important type of infrastructure of all.

As suggested by the earlier discussion of what is required to catalyze innovative partnerships, to create such networks requires a substantial investment of time and resources over an extended period of time. Although they may begin with a specific project in mind, such networks may grow and expand beyond the terms of the original partnership and yield additional relationships, projects, and partnerships.

The development of this sort of infrastructure is enhanced by leaders and organizations that undertake the full range of activities that can improve the prospects that researchers and business people with compatible interests simply can meet one another, and by a track record of successful partnerships that yield desired benefits to all participants and impel them to expand the network into other types of partnerships relevant to the engineering piece of the enterprise. It also is enhanced by successful marketing and public relations efforts that celebrate successes, thereby drawing other parties into the network, and in the dissemination of innovative practices that reflect learning curve phenomena.

Providing Physical Facilities and Support

A base of operational support is essential, and sustainability cannot exist without such operational support. The network therefore needs to provide this. Ultimately this was viewed as a resource issue—a diversified base of private investment providing support for all needed components. Among the components identified were:

- *An Incubator.* At the most basic level, innovation was seen to require a place that can facilitate routine exchanges between the business community and the university, where partners can meet and work.[28] This can be accomplished through a host of

[28]One study found R&D geographic spillover effects in France and concluded that "[t]his trend towards a proximate localisation can be explained by the complexity of the R&D process, which reflects the need to co-ordinate a set of heterogeneous competencies (combinatory complexity) and the intensity of technological changes (technological complexity)." See Carrincazeaux, Lung, and Rallet (2001). On the other

means, ranging from informal open door policies that stem from good university-industrial relations to formalized university-industry research centers. Whether formal or informal, such a location also can provide a venue for meetings, whether for partners or extension efforts to educate and build community.

- *Technical Support.* Beyond the faculty researchers and students who are doing the research and their industry partners, a range of issues requiring subject matter expertise are likely to be beyond the capabilities of the immediate partnership. Supporting infrastructure accordingly may include an office that provides in-house legal (e.g., patent assistance and IP policies), financial, marketing, and public relations expertise that can generate support from newspapers and business publications.
- *Management and Administrative Support.* Beyond the specialized expertise just described, a range of basic management and administrative functions—from managing personnel, payroll, and budgets to providing clerical, reception, and other services—need to be performed by competent, well-trained staff to enable the partners to focus on research and commercialization.
- *Laboratory Capacity and Other Physical Plants.* Needed infrastructure also can include various sorts of physical plants, including computers, lab equipment, machine tools, and laboratory or other working space.
- *Communications.* Infrastructure also needs to include support for a variety of alternative means of communication—LISTSERVs, websites, email aliases, moderated email discussions, mailings, and other means—both among the partners and between partners and other stakeholders.[29] This may include capabilities to make videos and CD-ROMs to assist marketing efforts.

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hand, Love and Roper provide a skeptical view of the importance of location and network effects on the success of innovation for manufacturing plants in three other European countries. See Love and Roper (2001).

[29]For example, participants mentioned a website, mainscience.org, which includes proposals and abstracts on research from researchers and reaches 3,000 people a week.

- *Reliable Sources of Capital.* Finally, needed infrastructure includes venture capital firms, angel investors, commercial banks, government, foundations, and other sources (e.g., Small Business Innovative Research (SBIR) grants) that can provide start-up, bridge, or other funding.

Beyond the fundamental elements of needed infrastructure just described, some argued that the PFI also needs to attend to a core constituency—members of Congress. Given that the federal government's role in promoting innovation is a politically controversial topic on Capitol Hill, it is necessary to ensure that elected leaders understand and support the PFI program's aims, that the program address elected leaders' potential concerns, and that there are no disconnects between project and program metrics and the political view of the program's goals. According to some, a tight linkage between project and program goals and metrics and a broader communication strategy were needed for the PFI. This strategy should include conversations with congressional representatives regarding what they expect out of this program and what metrics are appropriate (or inappropriate) for evaluating the program.

Challenges and Barriers to Sustainability

Workshop participants identified a number of key challenges or barriers to the emergence of these characteristics. These include turf battles among stakeholders; burn out; clashes with university culture reflected in institutional reward systems and rigid policies regarding intellectual property, startups, private sector engagement, and other matters; maintaining an ability to learn from other participants; having the right people in the right place at the right time; and the vagaries of politics.

Measurement Issues

Outcome Measures: Capacity. Another difficult-to-measure outcome was the marginal increase in aggregate capacity that had resulted from the PFI program. At the project level, this was discussed in three different forms. First, increased capacity was discussed in terms of the actual infrastructure (laboratory equipment, facilities, etc.) that had been added as a result of the partnership. Second, it

was discussed in terms of the value added to individual partners' infrastructure that arose from exploiting the partnership's synergies. Third was training and workforce development, discussed largely in terms of providing research professors with opportunities to apply know-how to commercial problems and opportunities for graduate students to develop know-how regarding technology application and entrepreneurship.

Capacity that had been built as a result of the PFI program—whether in terms of infrastructure or of training and workforce development—was seen as a summative outcome at the program level; to the extent that the measurement problems could be resolved at the project level, however, it generally appeared to be a simple matter of aggregation for the program as a whole.

Outcome Measures: Sustainability. Although their measurement was not discussed in much detail, a number of suggested outcomes were identified as being of interest for assessing the sustainability of the partnerships. These included outcomes related to the survival and self-perpetuation of the partnership; project staff in the community; success at fund-raising activities; cross-membership on boards and other organizations; the growth of the partnership (i.e., its ability to attract new people and organizations to join the partnership); partnering for other grants and continuation even after a lack of success in receiving these grants; and the emergence of new innovation-oriented partnerships.

For a host of reasons, assessing the sustainability of each partnership was seen as a challenging enterprise. First, there was some concern that the short (two to three year) time horizon for PFI grants probably was too short a window for assessing sustainability; the sustainability of a partnership might not be known until five or even 10 years after its creation. Accordingly, workshop participants wanted to know how those involved in the partnership turned out five years later—whether they stayed in the game and pursued this sort of activity well after the grant ended.

Another reason for the difficulty was that a focus on the sustainability of the partnership might obscure the importance of the larger goal of catalyzing innovation; in this view, it was the quality of the innovation that mattered, not whether a partnership survived at some

nominal level.[30] This point recognized the transitivity and "creative destruction" that are inherent in the innovation enterprise: A partnership that makes sense for today's innovative project may not make sense for tomorrow's. But it also pointed to the potential importance of partnerships evolving into broader networks that might link compatible partners who can choose to combine and recombine in different ways.[31] This latter view of partnerships—as seeds that have the potential for evolving and growing into a broader network that could itself catalyze additional partnerships and innovative activity—was one that seemed to be widely, if only tacitly, embraced by workshop participants, and one that was not explored in much detail in the workshop.[32]

Sustainability of the partnerships across the entire PFI program also was a summative outcome measure: To the extent that the difficulties in measuring the sustainability of individual projects could be resolved at the project level, it was a simple matter of indicating the number or proportion of projects that were judged as sustainable.

Signposts. Also suggested were measures that addressed a number of issues related to the partnerships themselves, including:

- *Organizational Issues.* How was the partnership formed? Is the leadership team in place? Is the leadership structure of the partnership settled? Can it be easily described to others so that they understand how the partnership is organized and how it works? Are the necessary administrative arrangements in place (e.g., budget, IP, support staff)? Are information infrastructure, personnel, other resources "integrated" in the operation of the partnership (integration needs to be measured)? Are policies and rules sufficiently flexible?

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[30] One breakout session asked how one compared a partnership that survived but did not succeed at generating an innovation with one that was successful in innovating but where the partnership dissolved.

[31] On innovation networks, see Freeman (1991).

[32] The evaluation of sustainability would need to take into account the intended life of the partnership, whether it is a short-term project, which, when its objective is achieved, is dissolved or whether it a longer-term relationship that is being established. Evaluating sustainability should be based on when the goals are to be achieved.

- *Agreements.* Have the necessary agreements on benefits, burden-sharing, and other issues (e.g., regarding intellectual property) been negotiated? What have members of the partnership agreed to share? Dollars? Risk? Resources? Graduate students? Professors? Measures are needed to look at the quality of relationship. How long did it take to come to an agreement?
- *Finances.* Have start-up funding needs been identified? Have sources of support been identified, including internal resources (including, e.g., "skunk works"), grant funding (federal, state, local), philanthropy, private sector (angels, venture capital, corporate)? Have sales and other revenue sources been identified? Are budgets and finances transparent and able to be tracked? Is there flexibility in moving funds? Have processes been established for managing in-kind and matching funding and for linking in-kind support to hard cash?
- *Plans.* Is there a project plan? Is there a business plan that assesses the market and the demand for the innovation? Have potential testing/beta sites been identified in the business plan? Is there a financial plan? Is there agreement regarding the processes for modification of these plans? Do the plans reflect reasonable expectations? Is there a risk analysis scheme?
- *Communications.* Are the partners actively engaged? Does the partnership hold regular meetings? Is there a process for communication? Are partners communicating well? Are there provisions for talking to top management to resolve problems? Have measures for outreach activities been established? Does the partnership produce products for dissemination?
- *Diversity.* What level of participation is there from traditionally underserved populations and institutions?

Workshop participants seemed somewhat divided on these measures, however. On the one hand, there was an interest in understanding the partnerships themselves in ways that could generate the information that can help participants in their activities and help the NSF in further refining the PFI program. On the other hand, there also was a clear recognition that successfully encouraging participants to keep good records cannot only be difficult but it can divert their focus from innovative activities to administrative and docu-

mentary ones. The solution for some was to be found not in large and complex survey instruments but in identifying a few "nuggets" that needed to be reported to track the progress of the partnerships, for identifying best practices, etc.

BROADENING PARTICIPATION IN THE NATIONAL INNOVATION ENTERPRISE

A final aim of the PFI program is to broaden the participation of underrepresented, disadvantaged, or underserved individuals and institutions. Workshop participants discussed this issue almost entirely in terms of specific means for measuring project- and program-level success at promoting this aim. Accordingly, we turn directly to the issue of measurement.

Measurement Issues

Outcome Measures. At the level of the individual, the PFI program aims to expand opportunities for students and professors who are women, minorities, and members of other demographic groups; at the level of the community and region, it aims to encourage new bases for economic and workforce development in less well-endowed locales; and at the institutional level, the PFI program aims to catalyze innovation in smaller institutions and in those that do not have extensive experience performing government-supported research.

At the project level, participants suggested that individual partnerships should report what types of people were involved in the partnership and provide basic demographic information related to gender, race and ethnicity, and other factors.

At the program level, achievement of diversity goals can be aggregated up from project-level data, e.g., indicating the number of minority, female, or other individuals who participated in all of the PFI programs.

Signposts. The signposts were essentially identical to the outcome measures.

CONCLUSIONS

There was broad support in the workshop for a number of propositions regarding partnerships and networks. First, most seemed to believe that the NSF should foster technology and economic development through local networks and support alternative models of partnerships, clusters, and networks for encouraging innovation. There also seemed to be a shared view that the PFI's (and NSF's) support for innovation should not amount to an entitlement. The aim, consistent with the PFI's program goals, should be to catalyze innovation by bootstrapping innovative partnerships and networks and providing the necessary resources and technical assistance to improve the chances that they could become self-sustaining. It was recognized, however, that some partnerships would achieve sustainability and others would not.[33]

Although universities were seen to have a major role to play in innovative partnerships, there was broad support for the proposition that cultural changes are needed to secure that role and to ensure balance between educational, research, and innovation goals. A recurring complaint was that university policies and promotion and other reward systems too often fail to encourage—or even actively discourage—efforts to apply and commercialize research. Many workshop participants argued that this needed to change, even as they recognized the risks to educational and academic research missions of becoming overly focused on commercialization of new knowledge.

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[33]One reviewer of this report suggested that sustainability is not and does not always have to be a goal in partnerships. Indeed, the world is full of fluid organizational arrangements to drive the innovation process. However, in the case of PFI, sustainability is an important factor.