RESEARCH

IMPROVING FEDERAL TECHNOLOGY COMMERCIALIZATION: SOME RECOMMENDATIONS FROM A FIELD STUDY

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This study identified three distinct roles of the federal technology-transfer process in the Huntsville, Alabama region: sponsors, developers, and adopters. The basic structure of transfer barriers and measures during the prospecting and developing of the federal technology-transfer process is also discussed. Sponsors attributed transfer problems to adopters' lack of awareness, while developers cited long development and payback times. Adopters admitted their lack of transfer expertise and their resistance to technologies with long paybacks. None of the role-players were measuring technology transfer very well. While sponsors agreed with adopters that long-term outcome measures were important, sponsors relied on measures of input effort and intermediate results. Developers with the most transfer experience reported the lowest use of measures. Recommendations are made for each role to help improve federal technology transfer.

Federal mandates, such as the Federal Technology Transfer Act of 1986 and the National Competitiveness Technology Transfer Act of 1989, were passed with the intent of helping US industries become more competitive by making the technology developed in federal laboratories, agencies, and programs more accessible. Although the Chapman Report (1) suggested potential benefits from such technology transfers could be enormous, success of government-to-private-sector transfers has generally been less than satisfactory.(2,3) For example, by the mid-1980s, only about 5% of more than 30,000 federal patents had been licensed for commercial use.(4) By 1988, revenues from technology patent licenses from the 700 US federal laboratories totaled less than $4 million.(5)

This low rate of transfer may be the result of inabilities to reach consensus on how to define, track, or measure transfer progress and success. Organizational, financial, behavioral, and other barriers in federal-to-private technology-transfer processes may also effectively limit if not nullify the spirit behind the above federal technology-transfer mandates. This paper reports the results of a field study that identified the fundamental structure of transfer barriers and measures. Recommendations are made to technology-transfer sponsors, technology developers, and technology adopters for actions they can take to overcome these barriers. Recommendations are also made on the use of some important measures of transfer progress and outcomes.

BACKGROUND

Technology transfer has been defined as the managed process of conveying a technology from one party to its adoption by another.(6)

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Figure 1. Model of the Technology Transfer Process

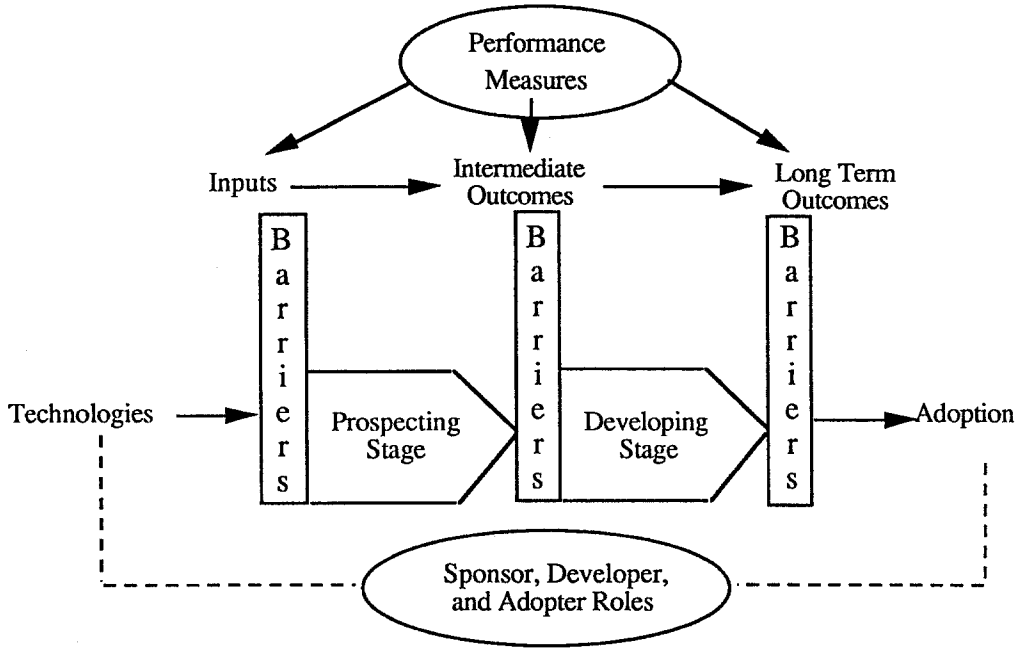


Figure 1 presents the guiding model for this study, which was based on four streams of research on technology transfer. One stream deals with technology transfer as a staged process. A second addresses the roles of various players within this process. A third emphasizes barriers that inhibit the process. The last stream focuses on ways of measuring technology-transfer performance. Following is a brief summary of these four streams of thought and an explanation of how each contributes to the model in Figure 1.

Transfer Stages and Roles

Technology transfer can be viewed as a multi-stage process.(7) In this study, two aggregate stages were examined: prospecting and developing (see Figure 1), which differ in scope and purpose. Prospecting refers to activities aimed at screening alternative technologies and selecting those that fit user requirements. It describes both the efforts of sponsors and developers to find potential adopters in searching for technologies. Developing activities include R&D, field trial, and final development activities for specific technologies. Developing activities are technology- or project-specific activities intended to solve a specific problem for a given organization, but prospecting usually involves many technologies, problems, and organizations.

Several roles influence activities within the transfer process.(8,9,10,11) We studied three roles: sponsors, developers, and adopters. Sponsors fund technology development, disseminate information about government technologies, and/or facilitate their transfer.(12) Developers develop and apply technology under government or private funding and sponsorship.(13) Adopters include users and potential users of government technology. These roles may be found in adopting organizations, as well as in federal agencies and government contractors. We investigated the degree to which barriers to technology transfer and measures of technology transfer differed among the roles played by various parties, at each stage of the transfer process.

Barriers to Technology Transfer

Barriers to technology transfer are factors

inhibiting the flow of technology from one organization to another, from one application to another, or from one stage to the next in the transfer process.(14) Barriers essentially prevent individuals from playing their proper roles in transferring technologies.(15) Researchers have identified at least five types of barriers: perceived deficiencies in transferable technologies; motivational disincentives to transfer; low adopter awareness of federal technologies and programs; legal, political, and cultural constraints; and financial constraints.(16,17,18, 19,20,21,22,23) This study identified the basic structure of key barriers at two stages of the process.

Measuring Technology-Transfer Progress and Success

Some of the many different measures of transfer that have been used by sponsors, developers, adopters, and researchers follow:

- The attainment of transfer objectives.(24)
- Changes in users' revenues and costs.(25)
- The number of user requests and jobs created.(26)
- The number of products launched.(27)
- The degree of technology adoption or rejection.(28)
- The degree to which a significant emotional and financial commitment is made to the routine use of the technology.(29)

Since federal technology-transfer mandates are aimed at improving firm and industry competitiveness, firm-level measures are also relevant measures of transfer performance. Such firm-level measures include:

- Achievement of milestones.(30)
- Accounting-based measures such as return on investment. Competition-based measures such as market share.(31,32)
- Number of new products developed.(33,34)
- Number of patents filed.(35)

As shown in Figure 1, input and intermediate outcome measures of transfer apply to stages within the process, while long-term measures assess final outcomes at the project or firm level. This study identified the basic structure of the key measures for each role in the transfer process.

STUDY DESIGN

To collect data on 27 transfer barriers, 23 measures of transfer progress and success, two transfer process stages, and the three roles played by transfer agents, a questionnaire was developed from the research of literature cited in this study. The questionnaire was pretested with a set of transfer agents and revised in response to their comments.

The membership list of the Huntsville, Alabama, chapter of the Technology Transfer Society and a technology-user list maintained by the local Technology Utilization Office at NASA's Marshall Space Flight Center (MSFC) provided the names and addresses of 95 potential respondents. The Huntsville area is home to numerous other government facilities including the US Army Missile Command, Redstone Arsenal, the Strategic Defense Command, and the Huntsville Division of the Army Corps of Engineers. Since about 1970, MSFC has had one of NASA's model technology-transfer programs. The Huntsville area is also home to a large number of government contractors that develop federal technology, adopt this technology for use in their own operation, and include plans for federal technology transfer in their government-contract bids and proposals. A snowball technique appropriate to field research was used to expand the sample.(36) Specifically, initial contacts were requested to provide names and addresses of other potential respondents, who then provided more names. The initial mailing list of 95 was thereby expanded to 145. Of the 98 respondents, each indicated that he/she was actively involved in technology transfer during the last year.

Data-Analysis Methods

Factor analysis was used to reduce the 27 individual barriers to four factors and to reduce

the 23 individual performance measures to three factors. In both applications, the final factors represented the common underlying dimensions across all observations. Analysis of variance was used to determine the differences between transfer roles, stages, and barriers. Analysis of variance was also used to determine the relationship between transfer roles and performance measures.

Each respondent estimated the percent of work times spent on various technology-transfer activities (37), and each respondent used definitions provided in the questionnaire to specify his or her own role. Transfer roles were then determined from those data using discriminant analysis, which classified respondents into 30 developers, 49 sponsors, and 19 adopters.

SAMPLE DEMOGRAPHICS

Analysis of the results showed that the developers averaged 11 years' experience in transfer activities, significantly more than the 7 years reported by sponsors and the 8 years by adopters. Sponsors averaged 23 hours per week on technology-transfer activities. This was significantly more than the developers and adopters, who averaged 13 and 9 hours per week, respectively. These results suggest that technology transfer is an important job duty in all three roles. But it is, perhaps, the most important job duty only for sponsors.

Developers allocated their technology-transfer time to developing government-funded technologies (68%), applying government-funded technologies to problems in their own organization (12%), applying government-funded technologies to the problems of adopters (17%), and providing support to transfer efforts (4%). Sponsors spent their time making potential users aware of government technologies and helping them define their technology needs (49%), helping users apply government-funded technologies to their needs (21%), providing political and financial support for transfer efforts (20%), and administering and managing technology-transfer activities (5%). Adopters spent most of their time using government technologies to solve problems in their own firms (70%), providing political and financial support for transfer efforts (8%), and developing government-funded technologies (6%). Thus, each role has a dominant activity with secondary activities overlapping other roles. Such overlap may give each role-player some understanding of the problems encountered in other roles.

Respondents also reported the amount of time they spent in each stage of the technology-transfer process. All spent at least 20% of their time in the prospecting stage. Sponsors spent 63% of their time in the prospecting stage and the rest of their time in the developing stage. Developers spent 23% of their time prospecting and 77% developing. By contrast, adopters spent 32% of their time prospecting and 68% in developing activities. Thus, each role operates primarily, but not exclusively, in one stage. Together with the differences in activities, these results confirm the existence of the three distinct roles in the federal technology-transfer process.

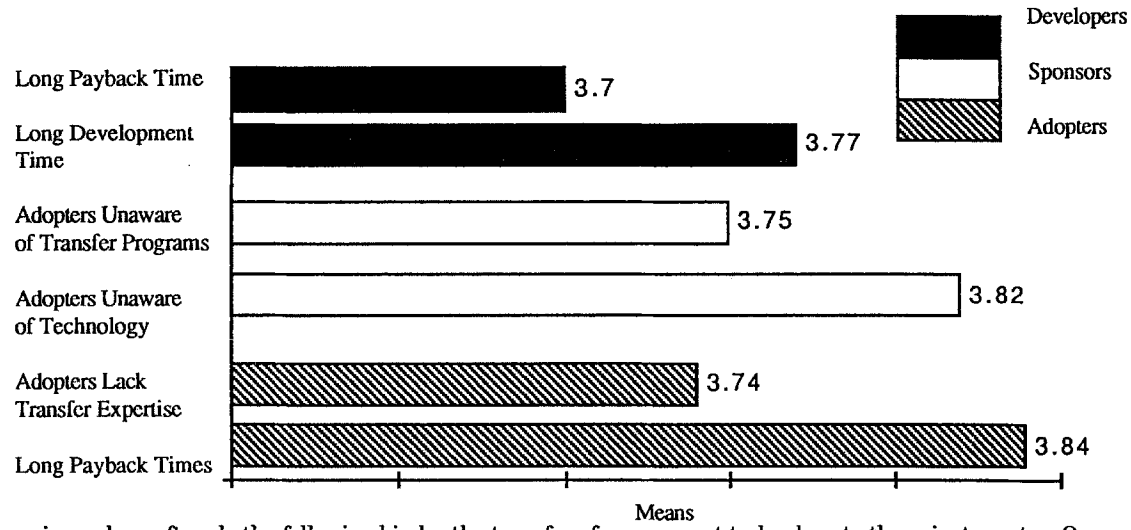
KEY RESULTS ON BARRIERS AND THEIR IMPLICATIONS

Developers, sponsors, and adopters agree that they frequently encounter nu-

Table 1. Technology Transfer Barriers

Adopters unaware of technology
Long payback time
Adopters unaware of programs
Proprietary concerns
Adopters lack funding
Long development time
No network to adopters
Adopters lack transfer expertise
Too much bureaucratic red tape
Erratic government funding
Adopter concerns over ownership
Insufficient government funding
Adopters are risk averse
Projecting costs
Adopters' resistance to change
Government efforts lack focus
Government lacks transfer expertise
Adopters lack interest
Not-invented-here syndrome
Technology not verified
Immature technology
Transfer not important job duty
Concerns over conflicts of interest
Adopters deny problems
Technically unsophisticated adopter
Rivalries among government agencies
Distrust of government

Figure 2. Transfer Barriers Encountered Most Frequently by Developers, Sponsors and Adopters*



*In your experience, how often do the following hinder the transfer of government technology to the private sector, On a scale of 0 (Never) to 5 (Always)?

merous, but different barriers. Overall, respondents reported that they frequently encountered many barriers to technology transfer, as shown in Table 1. The mean for each barrier was above the midpoint of 2.5 on the scale. Thus, all of the items listed in the table were rated as barriers that were encountered on a regular basis. This may reflect extensive frustration with the transfer process.

Table 2. Underlying Dimensions of Technology Transfer Barriers

1. **Adopter Resistance.** Adopter resistance to transfer included the potential users' overall resistance to change and the unwillingness to adopt outside technology. Such resistance was derived from lack of interest, risk aversion, and refusal to admit technical problems.

2. **Unknowledgeable Adopters.** Potential adopters lack knowledge about available technologies and transfer programs, were technically unsophisticated, and difficult to locate without entry through established networks.

3. **Government Shortcomings.** The shortcomings included erratic and insufficient government funding for technology development and transfer efforts, and lack of transfer expertise in government sponsors and developers.

4. **Distrust.** A general distrust of the transfer process took several forms. Adopters were wary about proprietary ownership of government technology and consequently displayed an unwillingness to make financial commitments to its development. Developers were very distrustful of rivalries between agencies and concerned about conflicts of interest.

The factor analysis revealed four fundamental types of barriers from the individual barriers listed in Table 1: adopter resistance, unknowledgeable adopters, government shortcomings, and distrust. Table 2 explains each of these underlying dimensions. Some important differences existed among developers, sponsors, and adopters on the fundamental barriers. Adopters reported their own resistance to transfer efforts as a significant barrier. Sponsors found unknowledgeable adopters a more significant barrier than either developers or adopters. But developers reported that their own distrust, the potential adopters' distrust, and government shortcomings were the barriers they encountered most frequently.

To explore the sources of these barriers, we looked at the specific barriers contributing to each factor. Figure 2 displays the two individual barriers that each role reported encountering most frequently. Developers most often encountered barriers related to technology: long technology-development times and long payback times on investments in technology. Sponsors frequently found that potential adopters were unaware of the availability of federal technologies and transfer programs. In fact, the sponsors perceived that the lack of adopter knowledge about technology transfer was their major

hurdle. Interestingly, adopters rated their own lack of transfer expertise and the long payback times on investments in technology as the barriers they encountered most frequently!

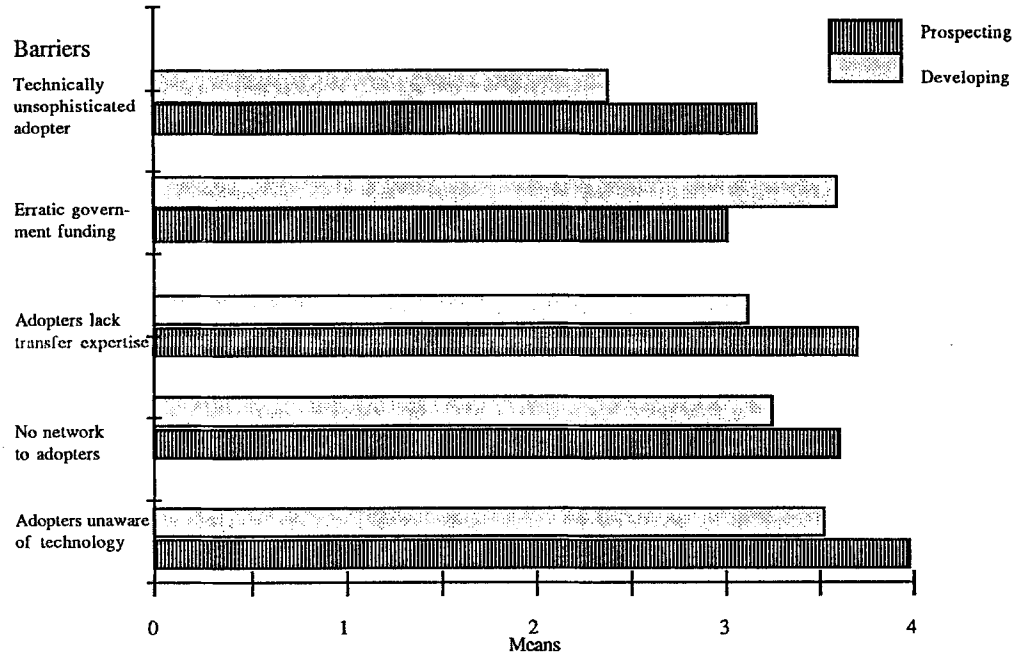
Barriers are encountered more frequently during the prospecting stage. For the key individual barriers, statistically significant differences between the two stages are shown in Figure 3. At the prospecting stage, the most frequent barriers were related to the potential users' lack of awareness of available technologies, the lack of established networks for reaching some potential adopters, and the adopters' lack of transfer expertise and technical sophistication. Since it was found that prospecting activities occupied almost half of the reported 45 hours of technology-transfer activities per week, these results may indicate that the transfer process has stalled at the first step, prospecting, primarily due to a lack of knowledge by potential adopters.

KEY RESULTS ON PERFORMANCE MEASURES AND THEIR IMPLICATIONS

Developers, sponsors, and adopters do not agree on how to measure transfer performance. Figure 4 shows the two measures of technology-transfer performance that were used most frequently by developers, sponsors, and adopters. Developers usually measured transfer performance by the number of technical briefs or papers published and by their level of new commercial sales resulting from the transferred technology. Sponsors usually used technical problems solved and number of new products as measures of their transfer efforts. By contrast, adopters usually measured transfer performance with three long-term outcomes: productivity gains, competitive advantage gains, and number of new products. In addition to these most-used measures, many others were used to varying degrees by developers, sponsors, and adopters. Statistically significant differences existed among the three roles in more than half of the 23 measures of technology transfer listed in Table 3.

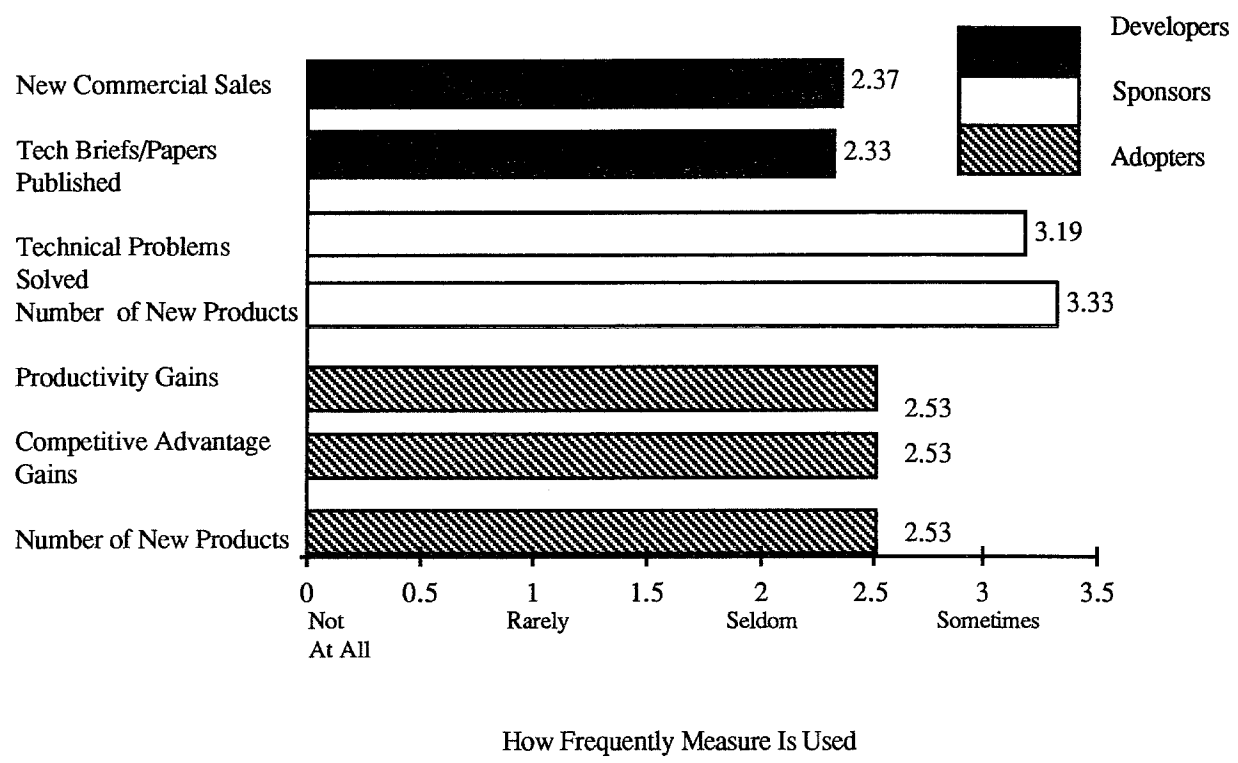
The results of a factor analysis of the 23 measures revealed three underlying measures: benefits to the adopting firm, outreach efforts, and commercial success. Each of these underly-

Figure 3. Significant Differences in Perceived Barriers Between the Prospecting and Developing Stages*



*In your experience, how often do the following hinder the transfer of government technology to the private sector, on a scale of 0 (Never) to 5 (Always)?

Figure 4. Measures Used Most Frequently by Developers, Sponsors and Adopters



ing measures and its explanation are presented in Table 4. Sponsors tended to use measures of outreach efforts more frequently than developers or adopters. Sponsors also measured transfer by ultimate success in the commercial market (commercial success). Adopters were most concerned with bottom-line results (benefits to the adopting firms). Thus, the adopters in this sample appeared to be much more concerned with improving their existing lines of business than developing new lines of business. Developers tended not to use any of these aggregate performance measures.

Some technology-transfer role-players (mostly developers) do not measure transfer performance at all. Perhaps the most surprising finding is the overall infrequent measurement of transfer performance. The developers' and adopters' predominant response to questions about their frequency of use of all the measures was "rarely to seldom." To explore this issue further, the five measures used most frequently by the entire sample, regardless of their role, were examined in more detail. These measures are technical problems solved, number of new products, cost savings, competitive advantage, and user satisfaction. Figure 5 shows the percentages of respondents indicating that they *never* used these items to measure transfer performance. One can postulate that all of these measures should be relevant to all the roles. Yet about 25% of developers responded that they never used these measures to transfer. About 20% of adopters never measured transfer as cost savings or competitive advantage gains and about 15% never measured transfer as technical problems solved or as user satisfaction. Though sponsors as a group used a wide variety of measures, about 10% never used the five most popular measures.

We anticipated that these developers, as federal contractors, would use measures similar to sponsors, since both groups are often tasked with transferring federal technologies. However, we found that many of the developers

Table 3. Performance Measures of Technology Transfer

INPUT MEASURES
Transfer Expenditures
Transfer Budgets
Time Spent
Requests for Help
Number of Site Visits

INTERMEDIATE OUTCOME
Technical Briefs/Papers Published
Technical Briefs/Papers Requested
Technical Presentations
Technical Problems Solved
Licenses Granted
Success Stories Published

LONG-TERM OUTCOME
Return on Investment
Cost Savings
Productivity Gains
Royalties
Competitive Advantage Gains
Market Share Gains
New Commercial Sales
Number of New Products
New Commercial Customers
User Satisfaction
New Businesses Started
Jobs Created

never measured technology transfer at all. Yet, as discussed above, developers reported spending time in transfer efforts that went beyond technology development. Moreover, developers reported more years of experience in technology

Table 4. Dimensions for Measuring Technology Transfer Progress and Outcomes

1. **Benefits to the Adopting Firm.** The benefits to a firm adopting government-funded technology included gains in competitive advantage and productivity, cost savings, and return on investment.

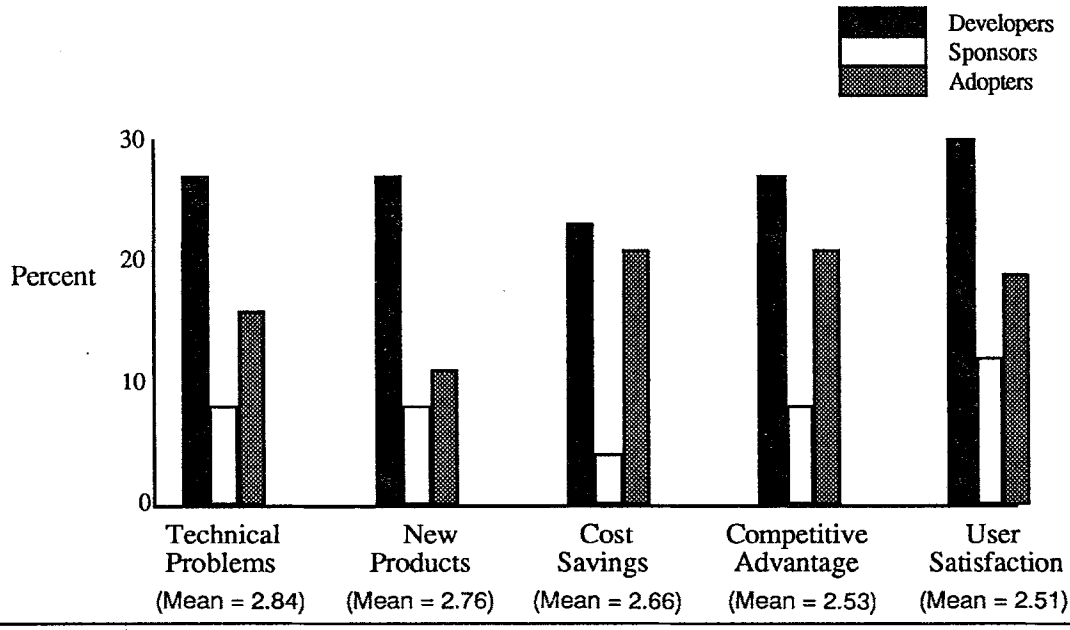
2. **Outreach Efforts.** Outreach efforts included the number of technical briefs published and requested, technical presentations made, success stories published, site visits, requests for help, and amount of time devoted to transfer efforts.

3. **Commercial Success.** Success in the commercial sector might include the number of commercial customers and the volume of commercial sales as well as royalties and licenses granted.

transfer. Additionally, 67% of the developers reported that their own organizations were presently attempting to develop products or services for commercial markets by utilizing technologies developed under government funding. Given this level of individual and organizational technology transfer effort and interest, it was surprising to find that developers were remiss in measuring the performance of their transfer efforts.

Sponsors take a much broader view of transfer performance measurement than

Figure 5. Percent of Developers, Sponsors, and Adopters Who *Never* Use the Most Popular Transfer Measures



either adopters or developers. Sponsors were concerned with a much wider variety of measures of both efforts expended and outcomes created. Fewer sponsors reported that they never used a given measure. These results indicate that sponsors have made considerable efforts to define technology-transfer success and to measure it multi-dimensionally. However, while sponsors appear to be more aware of the need for measurement, their apparent willingness to substitute input and intermediate outcome measures for adopter-favored long-term outcome measures means the measurement approaches of the two roles may be in conflict.

RECOMMENDATIONS FOR IMPROVING THE TRANSFER PROCESS

Education of potential adopters about technology transfer is critical. The results of this study indicate that the major barrier to technology transfer is an educational one that can be solved by improved communication initiatives. Sponsors and developers need to use local, state, and regional networks, such as extension agents and chambers of commerce, to communicate the availability of government technology to a targeted audience. Focus groups, seminars, and exchange fairs provide effective mechanisms for reaching targeted adopters. Adopters need to be more open to the idea that government technology may be able to solve technical problems in their own firms and that programs are available to facilitate transfers. Until attitudes change, major efforts will continue to be wasted looking for users and very little transfer will actually occur.

Sponsors must take the lead in improving the transfer process through target marketing. Sponsors need to adopt the principles of target marketing to improve the transfer of government technologies. They should identify a list of relevant industry-wide problems on which adopters and developers can focus. They could begin by assembling appropriate industry groups and conducting focus sessions or problem-brainstorming sessions. Even if fragmented, each industry will have some firms that lead in performance. This superior performance is usually derived from technological leadership and proactive management of product and process innovations. Sponsors should identify and target these industry leaders with an open invitation to all other members of the industry to attend workshops aimed at identifying industry-wide problems. The resulting consensus on critical problems could reduce the amount of effort currently spent on mass prospecting activity. It could also enhance selected adopters' awareness through targeted information campaigns. Such an approach could also generate political support for more stable federal and state funding for technology transfer by broadening potential benefits to all members of the targeted industry.

Sponsors must understand the key business motives of the adopters. Sponsors need to raise their level of understanding of the key business drivers for adopters and developers, especially development times and payback periods. Attributing the cause of a low transfer rate to adopter resistance does little to solve this problem. Anything federal agencies can do to shorten the transfer cycle, e.g., by reducing the time in each stage of the process and by lowering investment costs, will greatly lower adopter resistance, enhance the rate of transfer and improve national competitiveness. New, much more cost-effective mechanisms for industry-government collaboration like licensing and gain-sharing can be used to tap into the entrepreneurial drive of developers and potential adopters. The new mandates enable the originators to retain intellectual-property rights, the sponsors to set incentives for inventors and to negotiate royalty agreements with adopters and inventors, and the adopters to negotiate agreements to protect the technology and their competitive market position.

Technology transfer should be viewed as a multi-stage process and approached with a two-stage strategy. Future transfer programs might improve their overall effectiveness by using a stage model, identifying the potential and probable barriers in each stage,

and managing the transfer effort to overcome the barriers at each stage. The National Aerospace Plan program has taken this approach (38) and shows evidence of dramatic results.(39) However, stage models should not be used sequentially to focus only on the barriers in the intermediate stage. Rather, they must be viewed in their entirety. For example, understanding the sources of adopter resistance and lack of awareness in the first stage are keys to understanding later-stage problems. If adopters resist in the first stage because they anticipate low benefits to the firm in the final stage, sponsors would need to shape their prospecting efforts accordingly.

Sponsors may improve the acceptance and rate of transfer with an integrated two-stage transfer strategy. In the first stage, they could provide technologies that increase adopter benefits, perhaps by transferring cost-saving process technologies. Working from this established relationship, sponsors could then follow up by helping adopters commercialize new products that would generate royalties through licensing. In this way, each party could meet its multiple goals.

Technology-transfer agents should set objectives for transfer projects, then measure performance against these objectives. The results of this study evidence a strong need for technology-transfer agents to clearly define the goals, objectives, and related measures of performance for each specific transfer project at the project's inception. This requires managers in all three roles to baseline the performance of the adopter's existing system, set reasonable expectations for the new technology, and define appropriate success metrics from the outset. Managers should recognize and understand the differing perspectives of the various role-players.

The performance measures used by adopters must be used by all role-players: The adopters' use of performance measures based on benefits to their current lines of business effectively forces these measures on both sponsors and developers. The measures adopters use are consistent with the national goal of improving private-sector competitiveness through the transfer of government-funded technologies. Still, adopters could help enhance overall transfer effectiveness by showing greater interest in new-product development for commercial growth, especially since new products are a key driver of firm performance.(40) To increase their effectiveness, sponsors should focus more on the bottom-line benefits to adopters at the firm level, and less on input and intermediate measures of transfer effort. This would help focus efforts on the whole process and its purpose, technology commercialization, and away from the outreach efforts of the first phase, prospecting.

Developers must learn how to measure the performance of their transfer efforts and routinely use these measures. Developers could improve their rate of technology transfer and adoption by using more measures of performance, particularly those oriented to commercial success and adopter benefits. These measures would help refocus scientists and technologists away from pure research toward market applications that meet end-users' needs. For developers, this means more market research to identify opportunities to increase adopter benefits, as well as closer working relations with the adopter to assure success. Government funding agencies could probably speed this refocusing of developers by also measuring the effectiveness of developers, both at the organizational and individual level, in terms of benefits to adopters rather than effort expended.

SUMMARY AND CONCLUSIONS

This study confirmed the existence of three distinct roles—sponsors, developers, and adopters—played by various actors within two stages of the technology-transfer process—e.g., product improvement and new-product commercialization. The research also enumerated some key barriers to transfer, and developed important measures of transfer progress and outcomes. Players of the three roles generally agreed that many barriers to transfer were often encountered, but each role reported expe-

riencing somewhat different barriers. Sponsors attributed transfer problems to adopters, while developers cited long development and payback times. Adopters admitted their lack of transfer expertise and their resistance to technologies with long paybacks. Surprisingly, none of the three roles were much concerned with measuring transfer progress or outcomes. While sponsors agreed with adopters that long-term outcome measures were important, sponsors also relied on input measures of effort and intermediate outcome measures. Developers, who had the most transfer experience, reported the lowest use of measures. A significant percentage of developers, sponsors, and adopters reported never using key measures.

The results of this study suggested several recommendations for managers in each of the three roles. Federal and state-government funders and sponsors of technology-transfer programs could lower barriers by focusing their communication efforts on clearly defined problems in target industries, rather than pursuing the current practices of mass prospecting. Sponsors should also be more concerned with bottom-line benefits to adopters, and they should manage the technology-transfer process across all stages rather than sequentially by stage. Developers should learn to measure the progress toward transfer as well as the final outcomes. Adopters should try to become more receptive to federal technologies and proactive in learning about federal transfer programs.

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