REVIEW OF R&D MANAGEMENT LITERATURE CONCERNED WITH TECHNOLOGY TRANSFER BETWEEN GOVERNMENT LABORATORIES AND INDUSTRY

August, 1996

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"Competitiveness as a mission is a loser"

- Al Narath, Director, Sandia National Laboratories

ROLE OF TECHNOLOGY/INFORMATION TRANSFER

IMPORTANCE TO CANADA

Government laboratories around the world are increasingly viewed as important players in their countries' technological innovation systems. As a result, they are under pressure to play a more significant role in increasing the technological competitiveness of their nations' industries. Serious questions arise, however, about the role they can or should be playing.

In the U.S.A. in 1986, for example, only 5% of 30,000 government patents were licensed for commercial use. By 1990, revenue from licenses had only reached $9.7 million on expenditures of $20 billion in over 700 laboratories. This in spite of government legislation, such as the Stevenson-Wydler Technology Innovation Act of 1980, the Patent and Trademark Amendments Act (known as the Bayh-Dole Act) of 1980, the Federal Technology Transfer Act of 1986, and the National Competitiveness Technology Transfer Act of 1989, to support and encourage transfer of technology from government labs to industry

Papadakis (1995), in a major review of the U.S. federal laboratory system, observed that, "the vast majority of the [U.S. federal laboratory] system (about 80% of the labs) has no meaningful role in American competitiveness, while the remaining labs are characterized by powerfully entrenched agency missions with circumscribed economic roles". She notes that much of the R&D of the federal laboratories flows directly to the government or to regulated organizations for achieving government-imposed performance standards in health, safety, environmental quality, etc. She concludes that, "there is no reason to believe that the federal laboratory system can directly enhance U.S. international competitiveness". She further concludes that, "in order for federal laboratories to contribute to competitiveness, they must have explicit missions to do so". She states that "spinoff transfers" are the best that can be hoped for from those laboratories that have some commercial orientation.

Canadian government laboratories are also under pressure to enhance Canadian industrial competitiveness. A major driver of this pressure is the efforts of government to show taxpayers that they are getting good value for their investment in government science and technology. In 1994, the estimated expenditure on intramural R&D in federal government laboratories was approximately $1.7 billion.

Thus Canadian government laboratories are being directed to increase their interactions or collaborations with the private sector to enhance the job- and wealth-creating capabilities of Canadian industry. This has put new pressures on government R&D managers. They must, in a sense, put the management of their laboratories on a more business-like footing, while still meeting the mandates of their departments and while still under the yoke of bureaucratic rules and regulations.

This contradiction in goals and means was noted in an OECD study in 1989 entitled, "The Changing Role of Government Research Laboratories". "The congenital problem of government research establishments [is] the incompatibility between, on the one hand, the public sector's administrative and financial rules etc. and on the other hand, the very nature of research activities". The report also states that, "this incompatibility becomes even more detrimental when it is no longer merely a matter of conducting research but also of promoting its use within the economy and society".

The authors of the OECD report argue that, "it is essential for government research establishments to be allowed greater autonomy in order for them to be genuinely integrated within the country's research system ..."

The authors warn that, "the legitimate importance of the function of transferring knowledge and know-how should not, however, be over-emphasized to the detriment of the research function proper. Knowledge and know-how have to be produced before they can be transferred, so the potential for high calibre research must be developed and maintained". Government laboratories should be careful not to sacrifice a "minimum level of independent research needed to maintain their scientific potential and their capacity for renewal over the medium to long terms" on the altar of political and/or commercial expediency. This warning was echoed by Bozeman and Coker (1992) who stated, "the whole idea of increasing the commercial consciousness of the government laboratories must be treated with some caution, as there is a potential that the new enterprising entrepreneurial laboratories may lose their edge in basic research, or pre-commercial applied research".

Canadian government laboratories have an important role to play in strengthening the economy. If fact, the mandates of some departments and agencies (e.g. National Research Council of Canada, Atomic Energy of Canada Limited) have always been to provide scientific and technological support to Canadian industry, while in other departments, such as Environment Canada and Health Canada, the opportunity to support Canadian industry is secondary to their policy or regulatory mandates.

A major way in which government laboratories are contributing to strengthening the

Canadian economy is by providing advice and information to Canadian companies. Another is providing industry with access to unique facilities that are too expensive for any one firm to own, e.g., NRC's wind tunnels, AECL's nuclear reactors. Less frequent is the transfer of a developed technology to industry via licensing or by assignment of ownership.

FIT WITH DEPARTMENTAL MANDATE

Government technology transfer programs can be divided into two categories depending on the mission of the laboratory: "Technology Spin-off Programs", and Technology Utilization Programs" (see Table 1 from Mock, et al., 1993)

TECHNOLOGY UTILIZATION PROGRAM	TECHNOLOGY SPIN-OFF PROGRAM
A FEDERAL PROGRAM CREATES TECHNOLOGY TO MEET A NEED IN THE PRIVATE SECTOR	A FEDERAL PROGRAM CREATES TECHNOLOGY TO FULFILL A FEDERAL MISSION
MOST OF THE DEVELOPED TECHNOLOGY MUST BE INTEGRATED INTO THE PRIVATE SECTOR	SOME OF THE DEVELOPED TECHNOLOGY MAY BE SPUN-OFF TO THE PRIVATE SECTOR

Table. 1 Types of Technology Transfer Programs

Technology Utilization Program

In a technology utilization technology transfer program, the mission of the government laboratory is to improve or create technology specifically for use in the private or non-government sector. The principal mission of the laboratory can only be achieved if successful technology transfer takes place.

Government laboratories primarily involved in technology utilization transfer are those conducting R&D in agriculture, mining, energy conservation, manufacturing and fisheries.

Technology Spin-Off Program

A technology spin-off technology transfer program tends to be associated with government laboratories involved in environmental, health or defence research where the primary results of the research are targeted at meeting the department or agency's policy or regulatory mandate, or the needs of an internal client, as in the case of DND where the primary client is the Canadian Armed Forces. Only some of the technology developed in the laboratory is appropriate for transfer to the private sector and the technology may be used for purposes other than that for which it was originally created. In this case, the primary mission of the department or agency can be fulfilled even if technology transfer efforts to the private sector are ineffective.

The strategy used by the department or agency to transfer technology to the private or non-government sectors is dependent on the mandate or mission of the laboratory. In technology utilization programs, the non-government end-user's needs should be pre-eminent in planning the research program and, therefore, should involve considerable consultation with the end-user. In spin-off programs, the main thrust is to identify "dual use" technology or research results that will benefit industry as well as the internal departmental client.

BENEFITS TO THE GOVERNMENT LABORATORY

While many of the technology transfer interactions between government laboratories and the private sector do not involve money changing hands, those that involve "contracting in", whereby the government laboratory undertakes some specific R&D work for an external non-government client, usually do.

Depending on the conditions in the IMAA agreement between the department and Treasury Board, the department is able to retain a fixed percentage of the earnings from the contract research. This money can be used to augment declining research budgets and enable the laboratory management to retain existing staff, hire new staff or purchase much needed equipment.

Under the 1993 Treasury Board policy of retention of royalties from Crown-owned intellectual property, government laboratories can retain any fees or royalties resulting from technology developed or owned by the department.

An equally important benefit to the government laboratory is new knowledge acquired through mechanisms such as collaborative research projects with private sector partners. Chapman (1994) has defined the term "spinback" to describe the flow back to the government laboratory of valuable technology (or knowledge) as a result of the laboratory's scientists and engineers participation in technology transfer activities. He documented the "spinback" phenomena in a study of technology transfer activities at NASA.

INFORMATION AND TECHNOLOGY TRANSFER OUT OF AN R&D BASED ORGANIZATION

Information is the life-blood of any R&D based organization. Establishing effective mechanisms to ensure the efficient and timely transfer of information both into and out of an R&D based organization is therefore essential.

The United Nations Advisory Committee on the Application of Science and Technology to Development defines technology transfer as "Application of know-how through the medium of people who have knowledge of the user's needs, problems, and limitations, and can communicate to the user what is needed and can be applied".

Souder (1990) defines technology transfer as, "the managed process of conveying a technology from one party to its adoption by another party, e.g., from a developer to a user, etc.".

In both these definitions the "managed" aspect of technology transfer is emphasized. Efficient technology transfer must be managed; it cannot be left to the whim of chance.

There are several categories of technology transfer:

- between countries when, for example, technology developed in an industrially advanced country is transferred to firms or institutions in a developing third world country;

- within the firm, as illustrated by moving technology from the laboratory to prototype production and then to full production to end-user; and
- between organizations in different economic sectors as when technology is transferred from a government laboratory to industry or from a university or provincial research organization laboratory to industry.

In all categories, the most efficient mechanism of technology transfer is to transfer the person/team who developed the technology to the organization that needs the technology.

This review will emphasize how organizations can improve the flow of technical information out of their R&D units, and how government R&D managers can be more effective in moving both technical information and technology out of their laboratories and into the hands of private sector technological innovators.

TECHNOLOGY TRANSFER PROCESS

Spann, Adams and Souder (1993) believe that successful technology transfer results from management of a multistage process designed to move technology/information from developer to user. Figure 1 shows the interplay between the various stages and the transfer roles.

Figure 1: Technology Transfer Process

The stages of the technology transfer process are:

- Prospecting consists of activities such as preliminary analysis, searching and screening alternative technologies and selecting the ones that fit the user's needs.

- Developing consists of necessary R&D activities designed to enhance and tailor the selected technology to meet the user's requirements, including field trial and final development.

- Adoption consists of technology modification, and user implementation activities.

Souder et al. also describes three roles that are needed to influence the flow of activities through the stages of technology transfer:

- Sponsor role covers political and financial support for moving technology along the various stages, including dissemination of information about the government technologies. Example of a sponsoring role would be government programs to support pilot projects.

- Developer role involves the conduct of laboratory, scale-up and field-trial R&D.

- Adopter role deals with the users or potential users of the government technology or information.

Spann et al. state that these roles may be found in adopting organizations as well as in federal agencies and government contractors.

TECHNOLOGY TRANSFER FROM GOVERNMENT TO INDUSTRY

As noted earlier, there is considerable pressure on government laboratories to transfer technology to the private sector in order to increase the competitiveness of their nation's industries. Government departments are using various mechanisms to accomplish this transfer or to facilitate partnerships with the private sector.

TYPES OF TECHNOLOGY TRANSFER MECHANISMS

Technology transfer can take place in a number of ways with organizations using several at the same time. Roessner and Bean (1994) identify the following mechanisms:

- Publications produced by the government laboratory (e.g technology awareness reports, media announcements) and other publications containing articles reporting on laboratory results (e.g. trade and learned journals, conference proceedings);

- Workshops/seminars conducted by federal laboratory scientists or engineers to disseminate information on new or emerging technologies with possible applications to industry;

- <u>Laboratory visits</u> by industrial technical personnel to share information and discuss technical problems with government personnel;

- <u>Technical consultation</u> with industry by technical and scientific laboratory personnel with unique expertise;

- <u>Industrial use of government facilities</u> where unique government facilities exist (e.g., wind tunnels, particle accelerators);

- <u>Personnel transfers</u> where government personnel involved in the technology development temporarily go to the receiving organization, or industrial personnel who will be involved in the adoption of the new technology work in the government laboratory before the transfer;

- <u>Cooperative R&D</u> where government and industry researchers work together to develop the technology;

- <u>Sponsored R&D</u> where industry contracts with the government laboratory for work on a specific project (i.e., contracting-in);

- <u>Contract R&D</u> where the government laboratory contracts with a private sector firm or consortia for the performance of research (i.e., contracting-out); and

- <u>Licensing</u> where the government department or agency licenses the technology to a firm on either a exclusive or non-exclusive basis.

To this list can be added the following transfer mechanisms:

- <u>Pilot testing</u> of government developed technology by the private sector to demonstrate the technology;

- <u>Data banks</u> containing information about federal government research (e.g., U.S. Federal Government Research In Progress (FEDRIP) data bank);

- <u>Information dissemination centers</u> designed to answer requests from industry about research or to put requesters in contact with expert personnel within the organization;

- <u>Industrial shows, exhibits and trade fairs</u> to provide a broad spectrum of potential industrial adopters with information about the technology;

- <u>Industrial visits</u> by government scientists and engineers to learn of industrial technical problems and of opportunities for the application of government developed technologies or technical information;

- Third party organizations, such as the U.S. Federal Laboratory Consortium, the U.S. National Technology Transfer Center, and Canada's National Technology Index, that are set up or given the mandate to facilitate the transfer of government technology to the private sector; and
- Internet Web-Sites that are established and maintained by the individual government laboratories which list technologies, expertise and facilities available to the private sector.

FACTORS AND PRACTICES PROMOTING SUCCESSFUL TECHNOLOGY TRANSFER

Many R&D management researchers have attempted to identify the common factors and/or practices associated with successful technology transfer from government laboratories to industry. These factors or practices will depend, of course, on whether product or process technology is being transferred and the characteristics of the adopter firms and industry.

Jervis (1975) found the following factors associated with the successful transfer of technology from government or university laboratories to the instrument industry:

- involvement of the technical innovator with the development group in the company;

- the ability of the recipient company to develop and modify the technology to meet market needs;

- enthusiastic support by someone in the receiving organization who could make sure the transfer project would receive the support and resources it needed; and

- recruitment of staff from the originating laboratory to aid in the transfer of information and know-how and ensure good communications between the two organizations.

A study of technology transfer from the Irish Government's National Dairy Research Centre to the Irish dairy industry identified two factors that distinguished between success and failure of the technology transfer process.

In product technology transfers, the probability of successful transfer was higher when the R&D for the product was suggested or recommended by the industry and industry was involved in some capacity in the R&D effort. With process technology transfer, the R&D project could be initiated by the government researchers and be successful if industry involvement was secured at an early stage of the R&D (Higgins, 1977).

When examining the technology transfer process, the type of technology being transferred, either product or process information, must be identified. Chakrabarti and Rubenstein (1976), in a study of technology transfer from NASA to private industry, found that the adoption of process innovations seems to be related to a firm's immediate problem-solving needs. The firm's technical personnel are the "users" and exert the predominant influence in the adoption decision process of the firm. The adoption of product innovations was found to be a more complex process requiring both the commitment of a greater amount of resources, and a higher level of top management participation than in process innovations.

A study by Dembo (1979) of the technology planning process used by the British Government's Building Research Establishment found the following to be among the important elements in the transfer process:

- the introduction of technology transfer management should be initiated at, and supported by the highest level in the organization;

- cases should be handled as projects using project management techniques (i.e., clear objectives, time- scales and cost estimates);

- planning the transfer should start before the research is complete, and in consultation with the research staff, otherwise researchers have moved onto new projects and have lost interest;

- the target audience or prospective firms that can use the technology (hardware or information) should be precisely defined; and

- follow-up activities should be available to ensure the effective transfer of know-how along with the technology, either by training or by the originating research worker working with the recipients.

Dembo also noted that the success of one of the projects was because of a competent development group in the receiving firm that was capable of developing the laboratory prototype into a production version.

Kohli and Virdi (1980) believe that a government laboratory's willingness to develop technology as far along the innovation process as possible is a key factor in the transfer process. In particular they consider that the probability of successful technology transfer is increased if the government laboratory develops a product to, at least, the prototype stage or, for a process, tests the process in a pilot plant. The work at the pilot plant level enables premature or exaggerated claims of government scientists to be identified earlier. It also enables government scientists to overcome industry skepticism about the technology's capabilities in a real life situation rather than an artificial laboratory environment.

In his review of strategies for marketing government technology to industry, Weijo (1987) recommends that government "technology transfer strategies should emulate the approach being used by private sector organizations to identify and develop new product ideas".

Marketing strategies available to government laboratories involved in "technology spin-off" transfer include:

Passive Role

- make information available to all interested organizations;
- industry must take the initiative to seek out the information; and
- publish in journals/conferences proceedings selected by scientific staff.

This approach is more applicable for the dissemination of information on basic research that may be of interest to a wide range of industries.

Active Role - General

- seek out organizational gatekeepers and target information to the media that they monitor; and
- government personnel should be more active in trying to publish research results in key journals or conference proceedings known to be monitored by the gatekeepers (i.e., rewrite a "learned journal" paper and put the results into terminology understandable to the target audience).

This approach is more appropriate for S&T information of interest to a specific industrial area.

Active Role - Targeted

- seek out specific firms as potential technology adopters; and
- use personal contacts with specific firms.

This approach is more appropriate for well developed technology.

Several authors warn that, in making direct contact with a specific firm, government technology transfer agents should ensure that they talk to people in the firm who are authorized to examine and make decisions on technology acquisition. If care is not taken, government officials can waste a lot of time dealing with people who have no stake in acquiring new technology for their organization and are unable to "sell" their organization on the merits of the government technology.

Dorf and Worthington's (1990) review of government-to-industry technology transfer in the U.S. suggests that the following incentives should be made available to government laboratory personnel:

- returns on royalties;
- travel funds for consultation with industry; and
- sabbatical leaves to work in industry.

There are many factors that technology transfer managers must take into account when determining the best approach or approaches to use in attempting to transfer technology. As noted earlier, if the program is of the technology utilization type, close and early involvement of the end-users in the development of the technology or technical information is essential.

In a detailed study of government-industry technology transfer, Brown et al (1991) examined the following six technology transfer approaches:

- contracting R&D to industrial partners;
- working with industrial consortia;
- licensing to industry;
- identifying and influencing key technology adoption decision makers;
- working with broker organizations such as trade or professional organizations to give the technology third party support; and
- generating end-user demand through information dissemination programs aimed at favourably influencing the end-user, or encouraging procurement through incentives or reduction in regulatory obstacles.

Note that interpersonal communication between government and industry personnel is the most effective method for achieving success when adopting any one of the above strategies.

Brown et al. believe that there are many factors that have to be taken into account when deciding upon a particular technology transfer strategy. They group these factors into three categories:

<u>Technological Criteria</u>

NATURE OF THE TECHNOLOGY
- Process
- Product

NATURE OF THE R&D
- Exploratory
- Applied

COMPLEXITY OF USE
- Simple
- Difficult

NATURE OF INFORMATION
- Proprietary
- Non-proprietary

TECHNOLOGICAL UNCERTAINTY
- Low
- High

Market Criteria

BREADTH OF APPLICATIONS
- Unified
- Diverse

NATURE OF INDUSTRY
- Concentrated
- Competitive

Government Policy Criteria

GOVERNMENT SUPPORT LEVEL
- Limited
- Abundant

DESIRED TIME LAPSE
- Normal

BETWEEN R&D AND
MARKET PENETRATION — Accelerated

Figure 2 outlines the relationship among the technological, market and policy criteria and the various technology transfer strategies.

According to Brown et al., government would need to influence key decision makers through demonstration projects of new processes that provide the decision makers with performance data.

In applying this approach to determining the most appropriate strategy to adopt, the user counts the number of times a strategy is show to be highly appropriate for a particular technology. For example, if a technology is classified as a process, applied, complex, proprietary, with low uncertainty and unified applications in a concentrated industry, the most appropriate strategy would be to contract the R&D to industrial partners. This model does not assume that only one strategy would be used at a time, thus the second strategy to use in the above example would be to generate end-user demand.

Figure 2: Relationship Among Criteria and Strategies

Souder et al. (1990) found that many organizations use a decision checklist to confirm that all the important segments of the transfer process have been considered carefully. Among the questions in a transfer-decision checklist are:

Considerations relevant to the nature of the technology

- Does the technology perform reliably?

- Will it perform reliably in the recipient's application?

- Is it a low risk venture for the recipient?
- Is it a low cost venture for the recipient?

- Is this technology important to the world?

- Will this technology have a major positive impact?

Considerations relevant to the recipient

- Is the recipient familiar with the technology?

- Is the technology appropriate for the recipient?

- Does the recipient have a plan to receive the technology?

- Does the recipient have adequate resources to receive it?

- Is there a high level transfer champion for this technology in the recipient's organization (e.g. an angel)?

- Does the recipient have adequate business acumen?

- Will the recipient be able to maintain the technology, or is there a third party vendor who can?

Considerations relevant to the transferring laboratory

- Are we fully committed to the technology?

- Do we have a long term partnership with the recipient?

- Do we have the technical ability to transfer the technology?

- Do we have the appropriate staff for this transfer?

- Can we adequately train the recipient?

Considerations relevant to the transfer process

- Has complete information been exchanged?

- Has useful information been exchanged?

- Is there a proper hand-off point for this technology?

- Does a sense of joint commitment exist on the parts of both the recipient and us?

In a major study of best technology transfer practices, Souder, Nashar and Padmanabhan (1990) describe 37 practices grouped into seven classes of best practice which they believe are important to technology transfer. The article is included in this review in Appendix One.

Among the factors or best practices considered essential for effective technology transfer were:

- use of a decision check list to select technologies for transfer;

- matching transfer strategies to the nature of the technology;

- use of joint evaluations and demonstrations of the technology;

- use of the government lab facilities to try out the technology;

- use of outreach programs by the government laboratories to make prospective adopters aware of what they had to offer;

- open and widespread interactions between personnel in both the transfer and adopter organizations, at all levels;

- use of joint transfer teams made up of member of transfer and adopter organizations;

- the existence and activities of technology transfer champions in overcoming obstacles to transfer;

- the involvement of neutral outside parties who could endorse the technology;

- the technology being adopted had tangible value, and could be adopted incrementally;

- the use of interdisciplinary groups that stay with the project throughout the research to transfer life cycle; and

- early involvement of the users.

Roessner and Bean (1991, 1994) found the following factors to be most frequently identified as influencing successful transfer (items marked with an asterisk were considered to be critical to the success of the technology transfer interaction):

- person-to-person contact*;

- flexibility of approach;

- existence of a transfer champion;

- support of company middle management*;

- support of federal laboratory middle management*; and

- clarification of proprietary rights*.

When the industrial respondents were asked about future promise of different types of interaction, cooperative research was ranked at the top.

Bozeman and Coker (1992), in a study of the degree of success government laboratories have had in transferring technology, found that multi-mission laboratories were more likely to be successful in technology transfer, especially if they had relatively low levels of bureaucracy and either ties to industry or a commercial orientation in the selection of research projects.

From their study of technology transfer from the Sandia National Laboratory to a small technology based transducer firm, Wood and EerNisse (1992) considered the following factors to be important in the successful transfer of the technology:

- the technology for transfer must fit the adopters strategic plans;

- the adopter gains exclusive proprietary rights to the intellectual property, either ownership or exclusive license;

- there is potential for additional proprietary coverage which will strengthen the adopter's competitive edge;

- the technology was a result in a scientific/engineering breakthrough;

- the technology had the potential for diverse market applications;

- suitable incentives were in place to encourage the cooperation of the inventor;

- the government inventor transferred over to the firm; and

- the adopter firm had the required marketing and technical resources needed to develop and market the technology.

Carr (1992) offers the following menu of best practices, derived from interviews with technology transfer managers at federal laboratories and universities:

Organizing the Technology Transfer Function

- Organize the technology transfer function so that policy and operations, including licensing, cooperative research, and patenting are combined within the same organizational unit, preferably at least at the division level.

Involving the Science and Technology Staff

- There must be strong support for the technology transfer activity not only from the top, but also from middle and lower level managers;

- There should be changes to job-descriptions and personnel evaluation systems to formally recognize technology transfer activities; and

- Technology transfer networks should be set up to link the central technology transfer office with the research groups. The networks would be made up of individual scientists or engineers (volunteers or formally selected) in the research groups who are interested and knowledgeable in the field of technology transfer who would, in addition to their regular scientific work, assist their colleagues in technology transfer activities, and alert their central office of commercial opportunities.

Capturing Intellectual Property

- In order to recognize potential intellectual property, training should be provided to technology transfer officers, network members and the bench scientists or engineers;

- To encourage disclosure, the disclosure and patenting system must be made as inventor-friendly as possible, with assistance being provided when requested;

- To compensate for the time taken away from their scientific work, incentives should be in place in addition to the promise of future royalty payments. e.g. Monetary or honourary awards on patent filing etc.

- To reinforce disclosure behaviour, the technology transfer office should respond quickly to enquiries from prospective inventors, and should provide timely evaluations of disclosures; and

- Allow technology experts representing industrial groups or associations free access to the laboratories so that they can identify technologies or capabilities that might be of interest to their members [called Technology Ferrets, these individuals are familiar with the technology needs of their industry; a technique first pioneered in U.K. government laboratories].

Evaluating and Patenting Intellectual Property

- Not all disclosures can or should result in patent filing. The decision to patent depends to a large degree on the operating budget of the technology transfer office; large budgets usually implies earlier patenting before a potential recipient has been identified, while limited budgets demand considerable market identification before patenting. In either case, the decision to patent should involve the inventor who may know of interested companies, the technology transfer office, which should house marketing intelligence, and possibly potential adopters. The author suggests that where further marketing studies are warranted, use of business school students should be investigated.

Marketing Laboratory Techniques

- A highly targeted approach to particular prospective adopter firms with a license being issued to the first firm demonstrating sufficient interest and capability; and

- A focussed marketing approach with information about the technology going to a limited number of prospective adopters at the same time. It may also involve information distributed in a specific trade publication.

Carr concludes his article with a collection of "conventional wisdom" about technology transfer:

- barriers to technology transfer are mostly man-made (e.g. organizational resistance, laws and regulations, etc.);

- technology champions are required on both sides of the process;

- people are the key to technology transfer (e.g. good technical, entrepreneurial and marketing skills); and

- limit the role of lawyers as technology transfer is not a legal process but a business process.

As a result of a study of best practices in technology transfer, Gurney and Anderson (1993) state that public sector sources of technology have to understand the private sector mindset of, "I need a technology that is manufacturable in the appropriate quantities, a market that can be successfully exploited and a healthy profit margin". The authors noted "significant cynicism, especially among small business, with the 'trade fair approach' to marketing university or federal technology". Respondents to their study felt that Federal Laboratory Consortium meetings "were a waste of time" if a small firm was looking for a specific technology or to meet with people from a specific laboratory.

Gurney and Anderson suggest that the R&D producing organization apply the following practices to enhance technology transfer:

- it should have a strategic plan for technology transfer that clearly identifies its products/services and the market segments to be addressed (i.e., who its customers are);

- its policy on ownership of intellectual property should be clearly stated;

- it should actively maintain and keep up-to-date an inventory of its facilities, capabilities and strengths, and technologies for transfer;

- it should employ cross-functional teams (technical and non-technical) to facilitate technology transfer;

- it should have in place some mechanism for assessing a technology's market potential;

- an adequate level of resources (money, people, and time) should be made available to increase the probability of successful transfer; and

- it should have a well thought-out reward system that supports the technology transfer process, and rewards all members of the team.

The authors point out that the existence of a "champion" in both the sending and receiving organization is a valuable asset, and may be essential to ensure transfer.

In their study, they noted a lack of a consistent approach to technology transfer, even among laboratories in the same agency. They therefore recommend that, "The federal government should establish a consistent set of operating practices for technology transfer that make it easier for private sector companies to partner with different laboratories".

Respondents to their study conveyed a "strong undercurrent that researchers should, by and large, stick to their research" and organizations should not require them to dedicate a large proportion of their time to technology transfer activities.

Radosevich and Lombana (1993) argue that the government should aggressively enforce patent positions when licensing to small firms to scare off predator companies who would otherwise challenge the patent through a long, drawn-out court case that the small firm could not afford. In addition, when the government laboratory continues work on a technology previously licensed to a small firm, it should give the firm preferential consideration in acquiring any improvements or alternate technologies. This provides the firm with the confidence to invest its own limited resources in the development of the technology. The authors also believe that continued technical assistance by the government laboratory to the small firm is especially important in ensuring successful technology transfer, as is allowing access to the laboratory's unique equipment or facilities.

Other government practices that Radosevich and Lombana believe can enhance technology transfer to small firms are:

- interaction with potential investors to assure the technical feasibility of the project;

- deferring up-front fees or royalty payments for a time; and

- taking an equity position rather than royalties.

Roessner (1993) recommends that, to maximize idea transfer, federal laboratories and public policies should encourage close personal interaction among government scientists and engineers and their counterparts in industry. The most effective mechanisms for this are professional meetings and conferences, lab visits, seminars, workshops, and cooperative research. Roessner states that public funds should be spent to support travel to conferences by federal laboratory and industrial researchers, industry visits to federal laboratories, and sabbaticals or temporary assignments of federal laboratory scientists to industry and vice versa.

Spann et al (1993) make the following recommendations for improving the technology transfer process:

- improved communication to educate potential adopters of the availability of technologies and expertise in government laboratories;

- use of targeted marketing techniques to identify specific potential adopters or cluster of adopters such as the identification of relevant industry-wide problems through the use of focus groups or workshops, i.e., a marketing approach rather than just a 'selling what we have' approach;

- increase the understanding of the government personnel to the key business drivers that determine whether a firm will or will not adopt a technology or make use of government expertise. Knowing the need to keeping the transfer time short, so that firms can move quickly with their new knowledge or technology will enhance the process;
- clearly define the goals, objectives, and related measures of performance for each specific transfer project at the project's inception. This requires assessing the adopter's present system, setting reasonable expectations for the new technology or information, and establishing criteria by which the transfer process will be judged.

In their study of the factors that affect the success of technology transfer and commercialization (TT/C) from federal U.S. laboratories to industrial companies, Geisler and Clements (1995) found that successful transfer was more likely when, "senior management [in the federal laboratories] actively supports cooperation with industry with a positive attitude and actual incentives, and the scientific personnel exhibit intrapreneurial attributes and have a positive attitude towards commercialization".

They also found that success in the commercialization depended upon similar perceptions in the receiving company. There was more likely to be a successful working relationship with the company when there was support for commercialization (through managerial support and resources), where the private sector technical personnel perceived their government counterparts to be willing to take risks and deal with ambiguity, and when the company had a positive attitude towards working with federal laboratories.

Geisler and Clements did not find technical capabilities of the federal lab personnel or the attractiveness of their skills to be good predictors of successful commercialization. They did find that intrapreneurship attitudes, as perceived by both the federal laboratory and the company, were strong predictors of success.

Prosser (1995) reinforces the call for incentives to encourage technology transfer, especially royalty-based incentives, to motivate federally funded personnel and research divisions. He also notes the need for significant licensing-based protection to motivate firms to make the investments necessary to develop the technology for the market.

Several authors argue for more industrial involvement in setting the research agendas of government laboratories. Gover (1995) suggests that, "additional industry influence on the research agendas of federal laboratories will make them more useful industrial partners". He adds that if federal programs are intended to benefit industry sectors, they must be compatible with the strategic direction of the industry. Mansfield and Switzer (1984) found that the probability of a government contract resulting in commercial spin-off R&D projects was higher if the contractor had input in the project definition stage and that success was related to the extent of the input - greater input, higher probability of success. Roessner (1993) also suggests putting industry leaders on government boards to help in setting priorities.

Winebrake (1992) found that the use of advisory groups (e.g., end-user review groups and technical review groups), and collaboration with cost-sharing (e.g., industrial consortia, cooperative R&D, demonstration projects) were more effective than other technology transfer mechanisms. Both these mechanisms involve considerable industrial input in establishing and carrying out the research agenda.

Examples of Practices Reported by U.S. Government Laboratories

As part of their services to their clients, the Federal Laboratory Consortium maintains a list of "best practices" that members have reported to be of value in their technology transfer activities. The following items are drawn from this list.

Marshall Space Flight Center

The Technology Utilization Office of the Marshall Space Flight Center in Huntsville, Alabama is engaged in transferring technology from NASA to the private sector. They have developed a model that guides their technology transfer efforts to show how available technology can address the needs of industry.

Briefly, the model involves:

- signing Memoranda of Understanding with the Governors of the surrounding states that call for cooperative efforts to introduce local industry to the technology available from NASA in general, and the Marshall Center in particular;

- county-wide canvassing, by volunteers, of all industry in the region to identify technical problems and highlighting ways in which NASA know-how might help;

- the Chamber of Commerce sponsoring an aggressive outreach effort to ask industry, large and small, to identify where improved technology could increase their productivity;

- encouraging the involvement of their most knowledgeable scientists or engineers, by amending (in 1991) the job descriptions and the performance requirements of all engineers and scientists at Marshall to require positive participation in the technology transfer process; and

- advertising identified technical problems and requesting solutions to them in their organization's weekly newspaper, The Marshall Star, which is distributed to employees, retirees, and contractors.

The Marshall Space Flight Center feels that the application of this model has improved their technology transfer activity in terms of a dramatic increase in the number of requests for information. This has forced them to adopt new procedures for handling requests so that each enquiry receives prompt, efficient, and thorough attention.

Pacific National Laboratory

The technology transfer activity of this DOE installation in Richland, Washington, is managed by a Director who reports to the Director of PNL. The laboratory uses a series of committees in its technology transfer activities; a "TNT Committee" (Transferring New Technology) screens new inventions, and selects those with commercial potential. A committee for intellectual property protection (IP2) assists by reviewing inventions and selecting inventions for patenting and technology transfer.

The laboratory has an "Intellectual Property Management System" that can track technologies from evaluation to commercialization. It can also track the costs and income associated with the total life cycle development of each piece of intellectual property.

Technology portfolio managers, drawn from both the technology transfer office and the research centres, participate in the screening, evaluation, and identification of PNL intellectual property that has potential commercial value. They also prepare deployment plans or strategies, marketing information, and brochures etc.

In addition, in 1989, PNL adopted a "Recognition and Reward Program for Commercialization of Intellectual Property" which applies to all active full-time and hourly PNL employees and to retirees. This program, which involves cash awards, increased visibility, and well-deserved praise for staff achievements, is in addition to the standard government royalty payment system (15% to inventors) that applies to all US government laboratories.

Cash awards of $300 are given to each person named on a patent and to the creators of validated software and non-software copyrighted material. Recipients of national technology awards, such as the R&D 100 Awards and the FLC Awards for Excellence in Technology Transfer, are given $500 cash awards. Other recognition activities include a gala dinner for inventors, key contributors and their guests, where presentations are made of special mementos, such as Waterford Crystal.

"Key contributors" are defined as staff members whose innovative efforts in the commercialization process have resulted in income to the laboratory through licenses or other agreements. Key contributors are rewarded in direct proportion to their contributions over the period of commercialization; they share in a pool of 10 percent of the royalties received by the laboratory. In addition to royalty sharing, transactions cash awards may be given to key contributors upon the signing of a license or other contractual intellectual property transaction. This one-time award ranges from $100 to $1000, based on the revenue potential of the agreement and the timing of expected revenue to the laboratory.

FACTORS OR PRACTICES THAT INHIBIT SUCCESSFUL TECHNOLOGY TRANSFER

Researchers into technology transfer have identified many factors and practices that either inhibit or do not promote successful technology transfer.

Kohli and Virdi (1981) noted the following barriers to successful transfer which, although based on studies in India, have some relevance to the Canadian scene for government to industry transfer:

- lack of confidence in the minds of entrepreneurs in indigenously developed technology; and

- lack of adequate infra-structure and expertise in industry to adopt or digest the technology offered to it.

In their review of technology transfer from U.S. government laboratories to industry, Dorf and Worthington (1990) found that major barriers to the commercialization of government technology were:

- lack of awareness and communication between the government laboratory and industry;

- lack of incentives for the laboratory and the laboratory personnel to engage in technology transfer; and

- lack of exclusive rights to the technology by industry.

In a major survey of members of the Technology Transfer Society in the U.S.A., conducted in 1990, Lee (1991) found that the members considered the following to be major impediments to technology transfer from U.S. government laboratories to industry:

<u>Impediments Related to Policy Issues</u>

- industry's unwillingness to take risks in technology development unless there is a competitive advantage or the technology fits into a firm's strategic plans;

- the Administration's attitude that government should not be involved with technology transfer because it is industry's responsibility to develop it's own technology;

- government-developed technologies might be useful but often are not immediately compatible with industry needs;

- government laboratories do not focus on commercial R&D because they have different missions; and

- funds designated for technology transfer are inadequate to carry out the government's objective of increasing the flow of technology to industry.

Impediments Related to Information Marketing Issues

- ineffective government-industry communications have impeded efforts to inform industry about federal technologies; and

- government has not been effective in informing industry about its technologies that have potential commercial value.

Impediments Related to People Management Issues

- government lacks technology management expertise for technology transfer;

- government bureaucracy is too cumbersome and difficult to deal with;

- cultural differences between government and industry have hurt their working relationships;

- industry needs to overcome the "not-invented-here" mentality;

- industry lacks technology management expertise for technology transfer; and

- industry management has a lack of interest in federal technology.

Lee believes that the U.S. government should be more aggressive in marketing its technology to U.S. industry.

In his review of technology transfer in U.S. federal laboratories, Carr (1992) identified two groups of factors that limit technology transfer:

Cultural Differences Between Business and Government

- misunderstanding of the needs and motives of the technology transfer partners;

- businesses lack of tolerance for bureaucratic procedures;

- government's lack of appreciation for businesses to move quickly to capture market opportunities;

- conflicting priorities between a laboratory's primary mission and technology transfer activities;

- industry's lack of knowledge about the range of capabilities and technologies available from federal laboratories;

- government laboratories' lack of a clear idea of what industry wants and needs; and

- industry's general suspicion of government.

<u>Structural Limits to Technology Transfer</u>

- national security issues related to defence technology;

- mandated preferences to dealing with U.S. firms;

- uncertainties regarding what constitutes "fairness of access" to government information or technology which inhibits targeted marketing efforts; and

- conflict of interest issues that inhibit the government inventor from extensive involvement with the adopting firm.

The last two barriers cited can only be totally avoided by abandoning what is accepted as good technology transfer practice, namely targeted marketing and personal involvement of the originator of the technology or knowledge with the recipient.

Spann, Adams and Souder (1993), in a field study of technology transfer activities of government laboratories and companies in the Huntsville, Alabama area, identified four fundamental types of barriers to successful technology transfer:

<u>Adopter Resistance</u>

- This included the potential users' overall resistance to change and the unwillingness to adopt outside technology and was derived from lack of interest, risk aversion, and refusal to admit technical problems or shortcomings.

Unknowledgeable Adopters

- Potential adopters lacked knowledge about available government technologies or expertise and transfer programs, were technologically unsophisticated, and were difficult to locate without entry through established networks.

Government Shortcomings

- These included erratic and insufficient government funding for technology development and transfer activities; bureaucratic red tape; and lack of transfer expertise in government sponsors and developers.

Distrust

- A general distrust of the transfer process by adopters which took the form of wariness about proprietary ownership of government technology and consequently an unwillingness to make financial commitments to its development. Developers were very distrustful of rivalries between agencies and were concerned about conflicts of interest.

As noted earlier, Spann, et al (1993) proposed the concept of three roles that are involved in the technology transfer process; sponsor, developer and adopter. They found that sponsors believed that the lack of knowledge about federal technologies and transfer programs by adopters was a major barrier; developers thought that long development times, long payback times and government shortcomings were the most frequently encountered barriers; and adopters believed that their own lack of transfer expertise and long payback times were the most frequently encountered barriers.

Not unexpectedly, "red-tape" (i.e., bureaucratic controls) has been found to be negative factor in promoting successful technology transfer (Bozeman and Crow, 1991). In many cases, firms need to move quickly to capture commercial benefits and slow decision making by the government can severely hinder the firm.

Some authors believe that transfer of technology to small firms poses special challenges for technology transfer officials. Radosevich and Lombana (1993) cite the following as barriers specific to the transfer of technology to small firms:

- lack of awareness about government technologies or expertise;

- considerable differences in the working cultures - need for small firms to act quickly vs. time delays associated with bureaucracies;

- small businesses may lack the technical capacity to understand, adapt and utilize the new technology without assistance; and

- small firms unable to afford the charge-out rates demanded by government laboratories for assistance needed to develop the product.

Gover (1995) describes several negative practices that he believes severely limit the value of federal R&D institutions to private corporations:

- lengthy serial work processes;
- intense conformance to rules;
- focus on program inputs rather than on outputs and impact;
- hierarchical decision-making; and
- preference for control rather than empowerment.

MEASURING THE IMPACT OF THE TECHNOLOGY TRANSFER PROCESS

How can the success of a technology transfer activity be measured? Is success measured by the benefits gained by the firm in terms of new products or processes developed, technical problems overcome, increased sales in domestic and foreign markets, new jobs created, etc., or by the revenues acquired by the transferring government laboratory, the increased technical capability of the lab, or the renewed viability of the government lab. Another set of criteria might be the impact of the government laboratories' work on the health and welfare of its public in terms of a reliable food supply, clean air and water, and a sustainable health system.

No articles that cited revenues returned to the lab as a criterion for successful transfer were found, perhaps because revenue generation was not a major objective of U.S. government laboratories about which most US authors write.

Based on a review of the literature, Spann et al. (1993) provide the following measures of success of technology transfer:

<u>Input Measures</u>

- transfer expenditures;
- transfer budgets;
- time spent in transferring the technology;

- requests for assistance from industry; and
- number of site visits.

Intermediate Measures

- technical briefs/papers published;
- technical briefs/papers requested;
- technical presentations;
- technical problems solved;
- licenses granted; and
- success stories published.

Long-Term Impacts/Outcomes

- 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; and
- jobs created or Saved.

Absent from the list of measures are factors such as increased laboratory capability (industry and government labs) and benefits to the government labs from new or increased revenue streams.

The authors state that one of the most surprising findings was the overall infrequent measurement of technology transfer performance.

Several authors who have studied government-to-industry technology transfer in the U.S. warn of the danger of only looking for factors indicating commercialization of a government technology as the sole indicator of the way government laboratories can contribute to industrial vitality.

Carr (1992) states that while measuring market impact through measures such as royalty income is an attractive approach, he believes that "it is not a very useful tool for technology transfer managers in the short term" as revenues usually lag licensing by many years and vary dramatically from license to license. He points out that half of Stanford University's royalty stream comes from just one "home-run" license. He suggests surveying the industrial recipients of government technical knowledge, technologies, etc. to learn about the total impact of a laboratory on the commercial competitiveness of a firm.

Roessner (1993) states that measuring only the effectiveness of industry-government lab interaction in terms of technology transfer (e.g., licenses and royalties) is too limiting and will substantially underestimate the full value of the government laboratories to industry. He further states that more appropriate measures of interaction are the intermediate ones of:

- number of technical papers authored jointly with industry;
- company patents and invention disclosures directly attributable to collaborative work;
- new development projects undertaken by companies as a result of interaction with a federal laboratory; and
- technical problems solved, or dead-ends avoided as a result of information obtained from the government laboratories.

Bozeman and Papadakis (1995) argue that "much of the activities of laboratories involve processes that are quite fluid and informal, and the entity transferred is not a finished technology, but a prototype, a process, or practical knowledge or know-how, for example, technical assistance.

Payoff to the Adopting Firm from Collaborative Interactions

Why do companies initiate commercially relevant interactions with government laboratories? U.S. studies show that they are not looking for immediate economic payoff. However, these studies are of relatively large firms, and studies of much smaller firms in other countries may find more expectations of immediate economic benefit from government to industry interactions.

In their study of collaborative interactions between federal government laboratories and industrial partners, Bozeman and Papadakis (1995) found that the major commercial reasons for, or objectives in companies' interactions with the federal laboratories were: (in order of priority)

- engaging in strategic pre-commercial research;
- interest in accessing unique resources of the lab;
- desire to develop new products and services;
- improving products; and
- solving a technical problem.

The authors noted that "obtaining technology" was mentioned in only 24% of the cases of technology transfer examined, leading them to suggest that, "a narrow focus on licensing and tangible technology transfer can underestimate the commercial role of the federal laboratories".

Bozeman and Papadakis found that, in deciding whether to work with the federal labs on a specific project, companies' valued:

- gaining access to the skills and knowledge of the federal laboratory scientists and engineers;
- gaining access to the unique expertise of the laboratory;
- previous personal contacts with the lab personnel; and
- equipment and facilities.

Having been contacted by the federal laboratory was ranked at the bottom of the list.

The types of commercially relevant interactions employed by their industrial sample were: (in order of frequency)

- cooperative R&D agreements (26%);
- technical assistance (23%);

- cooperative R&D not covered by a CRADA (15%);
- use government lab equipment (10%)
- company scientists at government lab (9%)
- lab consortium (8%)
- licenses federal government technology (5%) and
- lab scientists at industrial labs (4%)

The low ranking of licenses makes the number of licenses issued by a laboratory to industry a poor indicator of the laboratory's interactions with the private sector.

The authors also noted that the most common initiators of cooperative projects were, in order:

- company R&D managers (53%);
- company bench level scientists (44%);
- federal laboratory R&D managers (41%); and
- government bench level scientists (36%)

Federal laboratory technology transfer staff accounted for only 16% of the interactions studied.

Bozeman and Papadikis concluded that most government laboratory-industry linkages are forged through personal contacts, not through official organizational overtures. They suggest that contacts occur because of the scientists' connections in scientific and professional associations. Conference attendance would also play an important role in forging personal links.

LESSONS FROM NON-GOVERNMENT TO INDUSTRY TRANSFER

The following findings are from literature on the transfer of technology from either industrial laboratories to internal customers, or from university to industry.

Internal Corporate Technology Transfer
<u>from Internal R&D Labs to Manufacturing</u>

While the focus of this literature review is on transfer of technology from government labs to industry, some important insights can be gained from articles that deal with the transfer of technology from a company's internal R&D laboratory to its manufacturing facility. Many of these would be useful for government laboratories when approaching a firm.

Cohen, Keller and Streeter (1979) listed the following factors as important in enhancing the transfer of technology from R&D to production:

- researchers should fully understand the technology to be transferred;
- the technology's feasibility should first be demonstrated;
- the R&D division should maintain a support capability even after transfer to production;
- new technology should have a greater growth potential than the present technology;
- the existence of a technology transfer "champion" is important;
- the existence of an advanced development group to act as a transfer agent and to provide criticism in terms the R&D staff will understand;
- actions of competitors with similar technology;
- establishment of joint programs; and
- the recognition of a need.

Souder and Padmanabhan (1989), in a survey of technology transfer from the laboratory to manufacturing, found that the following factors inhibited transfer:

- manufacturing unit with insufficient technical skills and knowledge to adopt the new technology;
- manufacturing personnel perceived that the new technology was too fragile for their dusty and dirty plant environments;
- poor liaison between R&D and manufacturing personnel leading to the perception that the new technology was too complex;
- manufacturing management's fears about disruption to their production schedules and their reluctance to accept the risks of downtime; and

- lack of time to try out new technologies because of the demands of day-to-day problems.

Souder et al. found that, even in the face of these barriers, successful technology transfer could take place if certain promoting activities took place. The more of the following "promoters" present, the greater was the probability of transfer success:

- upper level managements of both R&D and manufacturing jointly advocate the adoption of the new technology (bilateral technology transfer champions);

- involvement of manufacturing personnel in the design of the new technology thus fostering strong partnerships between R&D and manufacturing;

- R&D and manufacturing jointly select the supplier or vendor of the new technology (e.g., parts and service);

- vendor provided with the training necessary to operate the new technology;

- vendor involved early in the development process (e.g., either involved during the development stage or during prototype trials);

- creation of an R&D/manufacturing team to demonstrate the new technology; and

- assignment of an experienced manufacturing engineer to monitor the transfer and provide information to manufacturing personnel.

University to Industry Technology Transfer

Dalziel, in a review of university to industry technology outlines the following technology transfer mechanisms and suggestions to increase effective technology transfer:

Most Effective TT Mechanisms

- collaborative research;

- university sabbaticals in industry;

- contract research;

- industry visits to the university labs;

- consulting assignments to industry; and

- student projects and work terms in industry.

Least Effective TT Mechanisms

- industry sponsored university research chairs;

- licensing;
- seminars and workshops;

- "member" company programs; and

- newsletters.

Steps to Increase Effective Technology Transfer

The following are considered to be important actions that can improve the transfer of technology from universities to industry:

- involve industry in applied research e.g. setting research goals, evaluating the work, as a source of industrial problems;

- increase industrial R&D investment;

- promote university-industry communications;

- increase funding for the most effective TT mechanisms; and

- change the academic environment to promote industry interactions, e.g., tenure and promotion dependent on technology transfer.

CANADIAN GOVERNMENT EXPERIENCE WITH TECHNOLOGY TRANSFER

While most of the literature or studies available are based on U.S. experience with technology transfer, there have been a few Canadian studies.

There are many examples of successful technology transfer from Canadian government laboratories to industry. One is the successful transfer of laser technology from the Department of National Defence laboratory in Valcartier, Quebec to a newly created company in Ottawa. This company, Lumonics Research, is now one of the major suppliers of industrial lasers in the world.

In 1978, a study was carried out to determine Canadian experience in transferring technology from government laboratories to small and newly established firms in Canada. Martin et al. (1978) found the following impediments to technology transfer:

- underestimation by receiving company of the amount of development work still to be performed before manufacturing could begin;

- difficulties with the actual transfer of detailed specifications, know-how and de-bugging experiences at all technical levels (scientist/engineer, technician, design/draftsman);

- lack of cooperation by originating scientist;

- inadequate understanding by government R&D personnel of the interactions and tradeoffs among technology design, production requirements, performance, and cost considerations when developing a new product for the marketplace;

- naive and sometimes hostile attitudes of government personnel to industry, commerce and the profit motive;
- lack of sense of urgency by government employees in providing timely technical assistance when problems arose during product development; and

- orientation of government research personnel towards publication rather than towards new product development.

Martin et al. (1978) noted that one of the key factors in the successful transfer of government technology via license was a continuing close working relationship between the originating laboratory and the recipient company. Interpersonal contact between government and company scientists was very important.

Bhaneja et al (1982) examined eight cases of technology transfer from the Department of Communications laboratory to Canadian industry and found the following to be among the critical factors determining the success of the transfer process:

- the need for the new technology was recognized and identified;

- the presence of high calibre engineers and scientists on both sides;

- being able to have government scientists follow the technology into industry for a period, and for industrial scientists to work in the government laboratory before transfer;

- the government research team having technical personnel with an engineering orientation;

- continuity of S&T personnel throughout the duration of the project encouraged cross-fertilization of ideas and contributed to developing team spirit;

- the support of senior government management at the Director General and Assistant Deputy Minister level;

- making technology transfer activities part of the S&T personnel's performance evaluation; and

- the existence of companies with the resources and interest to commercialize government technology.

In his review of commercialization resulting from Canadian government contracts, Supapol (1990) refers to an earlier 1968 study which found that commercial utilization of inventions that arise from research performed under government contract was greater when the contractor had the rights to the invention. His own study found the same result. He stated that, "Contractor retention of property rights is therefore stimulative to private commercial exploitation".

Like most activities, technology transfer must be well planned and people must be motivated to ensure it is done properly. Resources must be made available for the transfer process itself; it will rarely happen of its own accord.

Natural Resources Canada adopted the use of a "Business Opportunity Document" to facilitate technology transfer to the private sector (Innovation, 1991).

The Business Opportunity Document is divided into six sections:

<u>The Business Opportunity</u>: a simple statement of how an investor will make money from a product, service or process generated by the technology;

<u>The Technology</u>: a brief description of the technology so that potential investors can determine quickly if it fits with their own missions;

<u>The Products/Services and Processes</u>: a brief description of each, along with possible next generation products, etc.;

<u>The Markets</u>: identifies who will purchase the products, services and processes and the approximate quantities over the next five years;

<u>The Investment and Payback</u>: an indication of how capital-intensive the exploitation process is likely to be, along with the timing and magnitude of the payback; and

<u>Technology Transfer Possibilities</u>: how investors might work with the owner of the technology (e.g. licensing, consulting arrangements, etc.).

The completed Business Opportunities Document is then sent out to specific firms to elicit their interest.

Large and Belinko (1995) suggest that technology transfer from government laboratories to industry is enhanced if a multi-organizational team is involved in the transfer. They further suggest that the order in which the various team members should be involved is:

- the public laboratory (technology source);
- a credible and committed test customer/user organization;
- a credible and committed transfer agent (public or private);
- a credible and committed public funding agency (to provide funding for further development);
- a credible and committed manufacturer; and
- a credible and committed private funding agency.

In a review of the Canadian laboratory system in 1990, Niosi and Manseau (1994) reported that their government respondents found the following technology transfer strategies to be "very successful" (% of labs that found strategy very successful):

- person-to-person contact (87%);
- cooperative R&D (67%);
- contractual relations for direct R&D funding (46%);
- memberships in R&D consortia (41%);
- encouraging informal visits (36%);
- permitting outsiders to access labs (36%);
- on-site seminars and conferences (33%); and
- sales of patents, licenses, etc. (33%).

Strategies such as presentations at scientific meetings, fliers, newsletters, personnel exchanges, and a centralized technology transfer office were considered successful strategies by less than 28% of the government respondents. Person-to-person contact was ranked first, as a successful strategy, by both the industrial and academic respondents.

In a review of the history of technology transfer from Atomic Energy of Canada Limited to the private sector, Smith (1995) summarizes what he considers to be the more important and obvious success factors in licensing technology to existing or newly spun-out companies:

- the key technical staff must be committed to the success of the technology transfer, and be directly involved;

- ideally, the tranfer should involve the key technical people moving out with the technology to the licensee;

- the licensee must have people in place who can understand and implement the technology effectively, and should also have strong managers;

- on-going collaboration between the licensor and the licensee during the product development activities to maintain the interest of the original inventors; and

- the existence of a clearly defined and understood agreement on the expectations of both parties is essential.

Smith also considers that the geographical proximity of the licensee and licensor is an important success factor that should not be underestimated. Studies of communication patterns in R&D organizations confirms that the closer two scientists are to each other geographically, the greater the probability that they will communicate on a daily basis, especially if they share a common scientific interest.

SUGGESTIONS FOR IMPROVING TECHNOLOGY TRANSFER

Some of the tools suggested by Canadian government technology transfer officials to improve the transfer of government technology to industry are:

- presentation of regional seminars and conferences describing government technology available;

- identification of company's specific technology acquisition interests; and

- establishment of business development officers in each laboratory who go out and talk to their industries.

One official suggested that Canada requires a Technology Transfer Act to administer intellectual property. At the moment government intellectual property is treated like a piece of furniture under the Financial Administration Act.

IMPEDIMENTS TO TECHNOLOGY TRANSFER REPORTED BY CANADIAN GOVERNMENT OFFICIALS AND SCIENTISTS/ENGINEERS

The following information was gathered by the author as a result of previous unpublished studies and during development of an R&D management course dealing with the commercialization and utilization of government developed technology or information.

Resistance to Working with Industry

It is not unusual to find researchers in government laboratories who view the pressures to work with industry as a unwarranted challenge to their "right" to select the research problems of interest to themselves. These are usually older scientists who were hired at a time when they were allowed, and even encouraged, to work on scientific problems of their own choosing. The mandates of their departments were not particularly attuned to the needs of potential industrial clients. As noted above, mandates have changed and become more oriented to industrial needs. Thus pressure to work on industrially oriented "relevant" problems of a near-term nature breaks the "psychological contract" these older scientists made with their employer when they joined the government.

This resistance is not as prevalent with younger, recently hired scientific personnel as they are aware of the new orientation of government laboratories. Staffing officers should make sure that prospective recruits are clear about the new direction of government laboratories, otherwise resistance to working on near-term industrial projects will continue.

Resistance to working with industry can also be more prevalent in government laboratories with a primary mandate to serve internal policy or regulatory clients. It may not be part of the past culture of these laboratories to work with industry.

A potential solution to overcome this resistance is to make sure that government personnel are in face-to-face contact with their research or engineering counterparts in industry so that they can learn about interesting and challenging industrial problems that can be highly motivating.

Reward Structure Does Not Support Working with Industry

A major impediment to government scientific personnel working with industry may be that the existing reward structure does not recognize and reward the scientists for being involved with industrial projects.

Industrial R&D projects may result in reports which, for proprietary reasons, the company may wish to keep secret for some time. The project may involve solving a technical problem about which there is no wide-spread interest. In either case, the government researcher may not produce the usual scientific paper for publication in a refereed journal. If the promotion or performance evaluation system judges the scientists solely on the basis of published work in scientific journals, then the researchers will be reluctant to "waste" time and publication opportunities on industrial work.

Some departments, e.g., Natural Resources Canada, are modifying their evaluation/promotion procedures to take technology transfer into account when evaluating the performance of their scientific staff.

Another disincentive to working on industrial projects is perceived to be the risk of loss of government funding associated with working on industry funded projects. The fear is that if a researcher is successful in obtaining a multi-year commitment from an external client to fund research, the department may reallocate the funding support that the research would normally have received to another person or internal project. If the external funding ceases, the researcher may find that the department may no longer have the funds to keep them on staff or to support their research.

Where technology has been licensed to industry, the researcher (named in the patent) may receive royalties from the work. Under the 1993 changes to Treasury Board policy on royalties from Crown-owned intellectual property and the Public Servants Inventions Act, departmental management may provide an inventor with between 15 to 35% of the royalties resulting from Crown-owned intellectual property. One time cash payments can also be made to government inventors for the internal use of their inventions. Many departments are interpreting the Act and 1993 Treasury Board policy more broadly to include payments to people other than the named inventor, e.g., technical support personnel. This interpretation may have no legal foundation.

While it is government policy to provide royalty payments, or cash awards, some departments are not completely following this policy.

While most science-based government departments allow for some of the revenue from royalty or license fees to go back to the originating laboratory, this is not the practice in the Department of National Defence or Fisheries and Oceans Canada.

Barriers to Technology Transfer

In a survey of Canadian government technology transfer officials, the following were identified as barriers to transfer:

- Canadian industry, especially small and medium sized industry, is not sophisticated enough to appreciate the value of government technology (i.e., many do not recognize that technology can play an important role in their operations);

- industry, even if they recognize the value of government technology, don't know how to access it;

- government internal promotional criteria still doesn't fully reflect technology transfer activities by government employees;

- some Canadian industry personnel still think that government R&D is second-rate or not useful;

- government R&D culture is still emphasizing publication;
- lack of money for demonstration projects;

- inadequate number of multi-day visits by government researchers to identify technological needs of industry;

- lack of significant financial rewards for innovators, not just inventors, to transfer know-how; and

- disagreements with industry over ownership of the intellectual property; government won't assign ownership but will only give a sole license.

The following barriers to the transfer of government technology to Canadian industry were reported by bench level scientists and engineers attending an R&D management course presented in 1993 by this author in Ottawa:

- stifling government bureaucracy (red tape);

- lack of human and financial resources for technology transfer;

- lack of a proper technology transfer mechanism;

- difficulty in finding a technology transfer champion;

- lack of training and skills on both sides, e.g. government's lack of marketing skills and industry's lack of technical skills;

- lack of commitment to technology transfer;

- contacting the wrong person in the firm;

- no real political will to promote technology transfer;

- government scientists being unaware of industry standards, regulations, codes and accepted practices;

- difficulty in identifying a receiving firm with adequate capabilities and resources; and

- industry mistrust of the value and merit of government technology.

The attendees considered that the following were potential solutions to the above mentioned barriers:

- provision of adequate resources to conduct marketing activities;

- reduction in the paper burden associated with transfer;

- hiring specialists in technology transfer;

- seminars with industry;

- personnel exchanges with industry to learn about production and development;
- training for government scientists and engineers in technology transfer;

- educate government personnel about industry standards;

- identify potential industrial recipients of government technology at the beginning of the R&D project; and

- make use of colleagues, related laboratories, DIT&C, etc. to assist in identifying prospective recipients.

ANALYSIS - FACTORS AND PRACTICES ASSOCIATED WITH SUCCESSFUL TECHNOLOGY TRANSFER

The literature reviewed shows some common threads or themes associated with successful technology transfer. Some of these are organizational factors, and others are practices or actions taken by the government laboratories to enhance transfer.

This section pulls these threads together in some coherent fashion. As noted in the Souder, Nashar and Padmanabhan (1990) article (see Appendix One), the different factors or practices may be more critical at different stages of the technology transfer process.

Factors Associated with Successful Technology Transfer

The following factors have been associated with the more successful technology transfer activities:

- high level of support for technology transfer activities in both the originating and adopting organization;

- middle management support in both organizations;

- the government laboratory is multi-missioned;

- strong intrapreneurial attitudes among the federal government personnel;

- existence of technology transfer champions in both organizations;

- technology to be transferred could be adopted/utilized incrementally, did not cause great disruption to the adopting firm;

- technology had the potential for diverse market applications;

- low level of government "red-tape" and bureaucratic rules; and

- existence of a royalty-based incentive system within the government department or agency.

Practices or Actions Associated with Successful Technology Transfer

The following practices have been categorized in terms of general organizational practices, prospecting/marketing practices, and developing/adopting practices.

Organizational Practices

- organization of the technology transfer activity is contained within a senior level organizational unit;

- adequate level of resources have been assigned to support the technology transfer activity (people, money and time);

- each technology transfer activity is managed as a discrete project with objectives, deadlines, cost-estimates and evaluation of success being laid out;

- inventor-friendly disclosure and patent systems are established;

- technology transfer within the government department is recognized as a legitimate, valued activity;

- networks of bench level scientists/engineers are set up to assist their colleagues in the technology transfer activity and to advise the central technology transfer unit of commercial opportunities as they arise;

- a suitable reward and incentive system is in place to motivate the technical staff;

- technology transfer operating practices are consistent across all government departments; and

- bench level scientists and engineers in the government laboratories have received training so that they understand the concerns and actions of business in developing a new product/process.

Prospecting/Marketing Practices

- a strategic plan for technology transfer is prepared that clearly identifies the products/services to transfer and the potential markets;

- only firms with the technical capability to further develop the technology for the market are considered for transfer;

- technology transfer champions in both the originating and adopter organizations are identified and supported;

- industrial personnel are involved in shaping the government laboratory's research agenda (especially important in departments whose mandate is to transfer technology to the private sector);

- targeted or highly focussed marketing procedures are used to identify and approach prospective adopters;
- market studies are conducted to identify technical problems in, or technological needs of, potential client industries, or individual firms;

- the key decision makers in the prospective adopting firm are identified and marketing efforts are focussed on them;

- adequate funding is made available to support government personnel traveling to industrial sites and conferences, and for sabbatical leaves in industry;

- checklists are used to ensure that all the important issues concerning the technology and the transfer process have been considered;

- general communications mechanisms are used to make prospective customers of the government laboratories technologies, expertise, etc. aware of their existence and willingness to work with companies, e.g. trade journal articles, newsletters, internet web-sites, etc.

- potential adopters are advised clearly of the government's intentions regarding ownership/licensing of intellectual property rights;

- adopters are assigned exclusive proprietary rights to the intellectual property in order to encourage additional investment in the technology development;

- bench level scientists and engineers are trained so that they can identify potentially valuable intellectual property;

- industrial experts are invited to the laboratory to identify possible areas of technology/knowledge transfer;

- major stakeholders are involved in the patenting decision, it is not left to lawyers to decide; and

- up-front fees or royalties are deferred, especially for small adopting firms.

<u>Developing/Adopting the Technology</u>

- the technology/knowledge originator is directly involved with the technical staff of the adopting organization;

- the industrial adopter of the technology is involved very early in the development of the technology, ideally in a collaborative arrangement;

- multi-functional teams made up of members of the originating laboratory and the adopting company are established to facilitate the technology transfer;

- technical staff are permitted to move on a temporary or permanent basis to the adopting organization;

- on-going technical assistance is provided to the adopting firm after the transfer, as necessary;

- the originating government laboratory is willing to develop the technology to the prototype stage, or in the case of a process, to demonstrate its merits in a field trial; and

- private sector firms are allowed access to government facilities and equipment.

ANALYSIS - FACTORS AND PRACTICES THAT IMPEDE OR PREVENT THE SUCCESSFUL TRANSFER OF TECHNOLOGY

As noted in this review there are many factors and practices that either prevent or impede the successful transfer of technology or technical knowledge from government laboratories to industry. Some of these factors or practices are associated with industry, and some with government. Factors mentioned by Canadian respondents as especially relevant to the Canadian scene are marked with an asterisk.

<u>Government Factors</u>

The following factors in the government environment inhibit the transfer process:

- lack of orientation of government R&D to meet industry needs, e.g.,clash between internal mandate and industry requirements;

- cumbersome, difficult government bureaucracy (red-tape) which among other things results in slow decision-making;*

- cultural differences between government and industry;

- lack of knowledge by government personnel of businesses' need to reduce risk (IP ownership/control question) and to move quickly to capture market opportunities;

- orientation of government scientists towards publication rather than to new product/process development;*

- resistance by government researchers to working with industry, or on industrially relevant problems;*

- government reward and promotion system that penalizes government researchers for working with industry, or being involved in technology transfer activities;*

- fear of loss of government financial support if research funding becomes solely dependent on industrial sponsors;

- lack of technology transfer expertise in government laboratories;*

- lack of cooperation of the government inventor in providing timely advice or assistance to the adopting firm;* and

- lack of a serious commitment to technology transfer; no real political will to transfer technology.*

Government Practices

- lack of appropriate incentives for the laboratory and laboratory staff to engage in technology transfer;*

- lack of assigning exclusive or sole rights to the technology to the adopting firm;*

- inadequate funding of the technology transfer activity;*

- lack of significant financial rewards for the innovation team;*

- inadequate number of visits to industry to identify technological needs; no clear understanding of what industry wants and needs;*

- difficulties in dealing with "fairness of access" issues which inhibit targeted marketing efforts;

- conflict of interest issues that inhibit extensive involvement of the inventor with the adopting firm;

- stifling government bureaucracy (red-tape);*

- difficulty in identifying the technology transfer champion;*

- difficulty in identifying an adopting firm with adequate capabilities and resources;* and

- lack of a proper technology transfer mechanism*.

Industry Factors

- lack of awareness of what government has to offer;

- inability to appreciate the value of government technology in improving their commercial capability*;

- industrial resistance to adopting government technology or technical advice (not-invented-here syndrome);

- technical inability of industry to adopt the technology;

- lack of technology transfer expertise in the adopting firm;*

- industry's general suspicion and distrust of anything coming out of government - belief that government R&D is second-rate;*

- smaller firms unable to afford the charge-out rates of government laboratories;

- adopting firm underestimating the amount of development still to be done to commercialize a technology;* and

- businesses lack of tolerance for bureaucratic procedures.

COMMERCIAL IMPACT OF GOVERNMENT LABORATORIES

As many of the authors noted, it is inaccurate to measure the impact of the government laboratories on the commercial capability of the private sector only through such metrics as royalty or license fees. Much of the value of the output of the laboratories is via informal channels and is not captured by measures of returns to the laboratory.

Several authors point out that knowing about government scientists and their work results from personal contacts, mainly through professional activities such as conference attendance. Firms are more likely to approach a government laboratory if their own scientists or engineers have had previous contact with personnel in the laboratory.

To assess the full impact of the value of the government laboratory on the commercial capability of a firm requires obtaining the views of the key people in the firm who can provide information on new products/processes developed, problems solved, dead-ends avoided, new leads identified etc. These valuable outcomes could all occur without the formal transfer of intellectual property in the form of licenses. Thus evaluating licensing activities only could result in grossly underestimating the contribution of a government laboratory to industry.

CONCLUSION

"Technology Transfer is a Body Contact Sport"

Changes in government mandates are resulting in laboratories looking for ways to increase their interaction with the private sector. Complementing this are budget pressures on private sector laboratories that force them to look for ways to obtain commercializable technology, or technical assistance and advice from external sources.

While this increased interaction should be encouraged and applauded, it should not occur at the expense of the government laboratory conducting sufficient longer-term research to retain its value to industry in the future. Relevance is not a substitute for scientific excellence. They must go hand-in-hand if the government laboratory is to have anything to transfer in the future.

The strategies and management practices used by government departments to transfer technology or information will depend on the degree to which their mandates are directed towards supporting industrial growth and wealth creation.

Many studies have been conducted to determine the factors or actions that contribute to successful technology transfer from government laboratories to industry. These studies have also identified the many impediments to technology transfer.

Effective technology transfer is a managed process that requires support at all levels in both the developer and recipient organizations, and a dedicated budget to cover the additional costs associated with the technology transfer process. Many practices that promote technology transfer have been identified. These include early involvement of industry in the planning and development of projects, use of multi-functional, collaborative transfer teams, continued involvement of the originating researcher during the transfer process, the existence of an adequate reward and incentive system for the government technical and marketing personnel, and pro-active targeted marketing of the technology or technical information by the government laboratory.

One key element in efficient and effective technology transfer is personal contact. Donors and recipients of information or technology should be familiar with each other's work and capabilities. For this to occur, flexible management that permits cross transfers of personnel, and adequate travel budgets to enable scientists and engineers to establish and maintain new contacts outside the organization are required.

Conference attendance is an important facilitator of personal contact. It gives government researchers an opportunity to meet with their industrial counterparts and learn about technical problems and of opportunities to apply their newly developed technologies in support of industrial initiatives. However, if conference attendance continues to be regarded as a luxury or a reward by those in charge of allocating travel budgets, then the R&D organization must be prepared to accept a lower level of technical information or technology transfer.

Budgets must also be available to establish web-sites on the Internet that describe the technologies, expertise and facilities available to industrial customers or collaborators.

Government laboratories can clearly play a limited, but valuable role in supporting the international competitiveness of Canadian industry, if they are given the resources and the freedom to operate in an effective and efficient manner. The measure of their impact must not be confined to examining royalty and licensing fees flowing to the laboratory, but must also include industries' perception of the value of a government laboratory to their bottom line.

Exhortations to transfer more technology to the private sector will fall on deaf ears if the technical and marketing personnel are not provided with the necessary tools to enable them to be aware of the needs of industry, and to act on that information.

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