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TECHNOLOGY TRANSFER BY
DEPARTMENT OF COMMUNICATIONS:
A Study of Eight Innovations

1980



Ministry of State
Science and Technology
Canada

Department of
Communications

Ministère d'État
Sciences et Technologie
Canada

Ministère des
Communications



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TECHNOLOGY TRANSFER BY DEPARTMENT OF COMMUNICATIONS: A Study of Eight Innovations

1980

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This study is a joint project of the Department of
Communications (DOC) and the Ministry of State for
Science and Technology (MOSST).

The views expressed are those of the authors and do not necessarily reflect the policy of the Ministry of State for Science and Technology or the Department of Communications or any other department of the Government of Canada.

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Preamble

Successful innovation is a complex process. It involves a multitude of factors usually coming together over relatively long periods of time. Neither governments nor industry can realistically aspire to manage all aspects of it. Although each case of technology development and its subsequent exploitation has its own unique set of variables, shaped by the nature of technology being developed, the mandates of the research organization and the technical and commercial competence of the recipient, there are common factors which can be identified as having important bearing on the level of innovation.

The study of eight innovations which were developed with the active support of scientific and technical expertise and skills within the Department of Communications' Communication Research Centre (CRC) illustrates the role government laboratories can play in influencing the "innovation process" to foster the industrial development of the communications sector in Canada. The study shows clearly that, under the right conditions, opportunities exist for government and industrial laboratories to work together, and that work in government laboratories can supplement the development work being done in the private sector.

The case histories of the eight innovations were prepared in close consultation with the CRC's scientists and research managers. The MOSST-DOC study team would like to thank these colleagues as well as those outside the CRC for their cooperation.

SUMMARY

The government decision on the subject of enhancing technology transfer from government laboratories to industry outlined a series of initiatives which should be undertaken by federal departments and agencies. Among other initiatives, the Ministry of State for Science and Technology (MOSST), in conjunction with the Department of Communications (DOC), was asked to carry out a review of the effect of such policies for transfer of technology as are used in DOC, to identify further means by which government programs can help promote innovative industrial developments.

In November, 1979, both MOSST and DOC agreed to jointly conduct the study with the following terms of reference:

- (a) to identify the factors, processes and mechanisms that have contributed to the successful transfer of technology from DOC to industry; and
- (b) to prepare a report on DOC's relevant activities that would be useful to other departments in their efforts to increase technology transfer.

Eight innovations from DOC's Space and Research sectors were chosen for detailed examination as case studies. These are: Scanning Electron Microscope (SEM), Low Cost Earth Terminals (LCET), Field Effect Transistor Amplifier (FETA), and Delta Codec from the Space sector; and Telidon, Fibre Optics coupler, Mobile Radio Data System (MRDS) and Syncomplex from the Research sector.

A series of interviews were carried out with the DOC scientists and research managers who had worked closely on the development of the above eight technological innovations. The meetings sought to identify scientific and technical events which were critical to the development of these innovations as well as to examine the environment which had contributed to the transfer of these technologies to the private sector.

FINDINGS

Historically, technology transfer from federal laboratories to industry and others has been narrowly perceived. It has been limited to publications of reports, papers in journals, attendance at learned societies and patenting of inventions. Very little

attention has been paid to post-invention phase aspects. The resources, particularly financial ones, required for prototype design, prototype construction, product design and pilot plant are sizeable, and a lack of direction and an integrated strategy in obtaining and making use of the resources can result in delays and poor transfer of technology.

The primary conclusion drawn from DOC's experience is that successful transfer is dependent on a host of variables, ranging from need identification, morale and calibre of the research team and adequate financial and management support to the existence of a supporting infrastructure which encourages the development and transfer of federal technology to aid industrial development.

A detailed examination of the DOC technology transfer case studies pointed to the following factors as important in the successful transfer of technology from DOC laboratories to industry.

- (a) Perceived Need for Technology: The technology transfer process begins with a perceived need which may be identified in terms of departmental mandate and its S&T requirements through mechanisms such as task forces, research advisory committees and marketing studies.
- (b) The two most effective mechanisms for transferring federal technology to industry are through:
 - (a) use of research and development contracts and
 - (b) interchange of S&T personnel with industry.Both mechanisms have proven to be effective in developing personal contacts and professional relationships among the generators and the recipients of the technology. In most cases, as the work progressed, because of the joint nature of the effort of the federal and industry S&T personnel on the development of the technology, the originator-recipient distinctions became blurred.
- (c) Small to medium sized high technology companies are often most receptive to adopt federal technologies. These companies, though having smaller operations, are seen to be eager and enterprising in establishing a unique product line. The large firms have their own source technology and are constrained by their existing expertise and specialized market.

- (d) S&T personnel with engineering orientation are vital to a research team seeking technology transfer. Experience of interaction with industry or the user by either the professionals or the engineering support staff helps to expedite the workability of the innovation.
- (e) Continuity of S&T personnel throughout the duration of the project encourages cross-fertilization of ideas and contributes to developing team spirit.
- (f) The support of senior management (particularly at the Director General and the Assistant Deputy Minister levels) is critical to a project for it indicates the relative status of the project in terms of the departmental priorities and influences the allocation of capital and human resources to the project.
- (g) S&T personnel must be satisfied that their technology development activities are taken into consideration in their performance appraisal.
- (h) Canadian Patents and Development Ltd. (CPDL) has an effective role to play in technology transfer by making patentable federal technologies available to industry. Opportunities exist for CPDL to adopt a more aggressive marketing role in improving industry interface with government laboratories.
- (i) Because the R&D costs rise dramatically as the technical development gets closer to the pre-production phase, the availability of funds to support the development phases of industrial R&D becomes vital for successful technology transfer to industry. The funding of R&D-related activities such as product engineering, marketing, prototype development, field trials and demonstrations et cetera is far more expensive than initial R&D. The activities are critical for the advancement of the development as well as to allow better identification of the eventual product/process technique and for the commercial exploitation.
- (j) The transfer in a majority of cases studied, was related primarily to the fulfillment of departmental requirements. However, there appears to be a gap between the responsibility of line departments and the programs of the departments

explicitly concerned with industrial development. One possibility is to extend the mandates of line departments to cover R&D-related activities that are closer to the production phase.

- (k) Government purchase of equipment developed by industry on the basis of technology transferred from federal laboratories has considerable impact in fostering the industrial capability in that S&T field in the country. The departments through the Department of Supply and Services (DSS) can actively solicit industry proposals with a high degree of innovative content and be ready to provide special support for such innovations. The initial purchase of such technology by the government ensures the development of a new product line and builds confidence in the marketability of the product.
- (l) Closer consultation between DSS and federal laboratories as well as streamlining of procedures related to R&D contract management can play an important role in reducing the time span of innovation developments.

TECHNOLOGY TRANSFER

BY

DEPARTMENT OF COMMUNICATIONS:

A STUDY OF EIGHT INNOVATIONS

INTRODUCTION

Background

The government decision on the subject of enhancing technology transfer from government laboratories to industry outlined a series of initiatives which should be undertaken by federal departments and agencies. Among other initiatives, the Ministry of State for Science and Technology (MOSST), in conjunction with the Department of Communications (DOC), was asked to carry out a review of the effect of such policies for transfer of technology as are used in DOC, to identify further means by which government programs can help promote innovative industrial developments.

It was anticipated that a study of selected DOC innovations and their transfer to industry would help other federal departments and their laboratories to identify means by which innovation-based industrial development can be promoted in Canada.

Terms of Reference

In November, 1979, both MOSST and DOC agreed to conduct a joint study with the following terms of reference:

- (a) to identify the factors, processes and mechanisms that have contributed to the successful transfer of technology from DOC to industry; and
- (b) to prepare a report on DOC's relevant experience that would be useful to other departments in their efforts to increase technology transfer.

The case histories of eight DOC innovations from the Space and Research sectors were selected for detailed examination.

These innovations are: Scanning Electron Microscope (SEM), Low Cost Earth Terminal (LCET), Field Effect Transistor Amplifier (FETA), and Delta Codec from the Space sector; and Telidon, Fibre Optics Coupler, Mobile Radio Data System (MRDS) and Syncomplex from the Research sector.

DOC's Mandate

The 1979-80 Main Estimates describes the DOC raison d'être as fostering "orderly development and operation of communications for Canada" in the domestic and international sphere.¹ This all-encompassing responsibility for the development of the communication sector is made explicit under the 'Program Description' and the 'sub-objectives' headings, underlining departmental commitments in the following two areas:

Space Application - Planning, development, coordination and implementation of policies and programs to meet Canada's needs in the field of space telecommunications; development and coordination of plans and procedures to provide for optimum participation by Canadian industry in the design, development and construction of Canadian satellite systems.

Telecommunications Research - Technological forecasting; planning and conduct of exploratory and applied research and development directed towards the solution of problems and the advancement of technology in support of Canadian communications requirements.

A great deal of discussion has taken place within DOC recently concerning its industrial development and technology transfer roles.² One of the main objectives of special programs, such as the Industrial Contract Fund (ICF) and Cooperative Projects with Industry (COPI) programs, adopted by DOC in recent years, has been to facilitate the transfer of technology. Foci for liaison with industry, have been achieved through the creation of industry development directorates, in both Space and Research sectors, and establishing an industry exchange program for S&T personnel within the department.

¹ 1979-80 Main Estimates, pp 3-6, 3-7, and 3-8

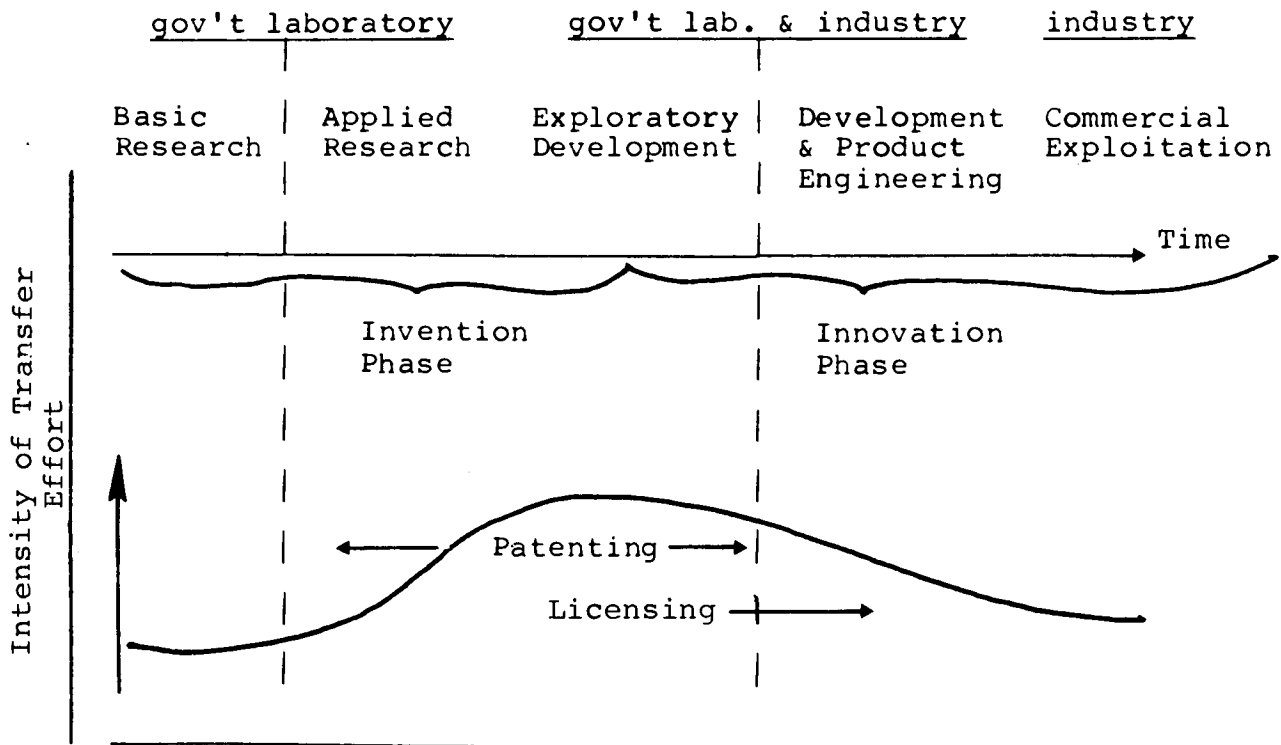
² See Department of Communications, 1978 Report of the Communications Research Advisory Board.

TECHNOLOGY TRANSFER: A PROCESS

In the context of enhancing the transfer of technology from federal laboratories to industry³, technology transfer is considered to have taken place whenever technical knowledge, a particular technique or a device developed in federal laboratories, is adopted and used by industry. Thus technology transfer refers to both hard technology (material devices and designs of such devices) and soft technology (inventive ideas and the know-how needed for implementation of such ideas). The process of technology transfer involves various aspects of the research, development and demonstration spectrum, ranging from basic and applied research to product engineering, seeking to promote a new product or process, or improving an existing one. For a conceptual view of interrelationships between the development cycle and the timing of technology transfer, see figure 1 below.

Figure 1

Idealized Development Cycle and Timing of Technology Transfer



³ For further discussion on the subject, see: Science Council of Canada, Technology Transfer: Government Laboratories to Manufacturing Industry, Report No. 24, December 1975, and Science Council of Canada, The Role and Function of Government Laboratories and the Transfer of Technology to the Manufacturing Sector, Background Study No. 35, April 1976.

For the purpose of this report, the technology transfer process has been classified into two phases: invention and innovation. The invention phase often culminates in the patenting of ideas and discoveries, publications in journals or presentations at international technical meetings. The innovation phase, on the other hand, involves the development of the invention for its practical application, and preferably, the licensing of the invention to a company for its possible commercial exploitation. The innovation phase, as such, often entails the undertaking of product engineering, prototype development, field trials, and pilot testing.

There are significant overlaps and links between the two phases of technology transfer. The direction given to R&D in the early stages may have been triggered by a specified need identified by the industry or a departmental user. Transfer may have been made easier because of the early user involvement in both the research and the development phases. It has been noted elsewhere that in terms of deployment of financial resources, the rate of spending increases gradually as the area of R&D activity moves from the invention to the innovation phase.⁴

STUDY METHODOLOGY

For the study, two rounds of interviews were carried out with the DOC scientists, engineers and research managers, who had worked on the development of the technological innovations selected for examination.⁵ The first round covered the identification of scientific and technical events which were critical to the technology transfer (e.g. origins of a particular scientific/technical development, role of CRC technology base, and recognition of need and its definition). The second round examined the characteristics of the research team as well as the environment in which the invention had been developed and exploited. Case studies, based on these meetings and the discussions with the

⁴ Mansfield, E., Industrial Research and Technological Innovation, New York: W.W. Norton, 1968.

⁵ See Appendix for further details on the questionnaire format used for discussions with DOC scientists and research managers.

industrial recipients of DOC technology, were prepared. These studies were then examined for common patterns and common factors which had encouraged the transfer of these technologies to the private sector. The results of the analysis of the case histories have been organized for the purpose of this report as follows.

First, the nature of the technology transfer itself is considered. This is followed by a look at both the industrial recipients of the technology and the government originators. The latter, because of the focus of the study on government laboratories, are examined in more detail, with considerations of the origins of the technologies, the make up of the research teams and the environment in which the innovation transfers take place. This is followed by examination of government policies and procedures that effect the transfer processes. Factors which are considered important are pointed out in the conclusion.

THE NATURE OF TECHNOLOGY TRANSFER

(a) Two Types of Technology Transfers

The examination of the eight DOC innovations indicated two major types of transfer: the transfer of know how and the transfer of hardware. The transfer of knowledge was predominant in all of the cases. This was accomplished through the exchange of reports and personal contacts with the companies concerned mainly during the execution of R&D contracts, which often spread over a period of three to five years.

In two cases, the transfer of knowledge was accompanied by the movement of DOC S&T personnel to the private sector. In the case of the Scanning Electron Microscope (SEM) technology, as a part of the licensing arrangement, two CRC scientists moved from DOC on secondment through CPDL, to join the newly formed high technology company, SEMCO. It was agreed that these persons could return to CRC after technology transfer had taken place. Later on, the company recruited eight personnel from CRC; some of these were permanent employees, others were contract employees and graduate students who had worked on the SEM

project at CRC. These were among the first employees of the company, essentially responsible for founding the company's technical expertise.***

In another case, a DOC engineer closely associated with the Telidon project left the department to join the company, which was the recipient of DOC technology.

Temporary personnel transfer from industry to DOC was also used as a mechanism for diffusion of know-how. The department invited an RCA (now SPAR) employee to work together with the DOC team on the development of Field Effect Transistor Amplifier technology.

The transfer of hardware primarily took place in the Space sector side, especially in the Low Cost Earth Terminal, and Delta Codec. In the Research sector, such a transfer, although on a smaller scale, was noted in the development of Syncomplex and Telidon technologies.

(b) Mechanisms of Transfer

The use of research and developmental contracts was the predominant mechanism for technology transfer in all of the eight cases studied. Personal contacts and exchange visits between government laboratories and industry were found to be interwoven around these R&D contracts and these relationships were gradually enhanced with the increased contract activity.

In the majority of cases, the initial contract with the industry was the result of a successful competitive bid by the company to carry out specified R&D work. The unsolicited proposals

*** Two aspects of significant importance in SEM transfer must be pointed out here. First, NRC, under its Industrial Research Assistance Program (IRAP), agreed to provide additional assistance in terms of salaries and facilities to SEMCO, for the further development of the project. Second, the reciprocal agreement between the government and SEMCO regarding the portability of superannuation contributed to the movement of CRC personnel to the company on a permanent basis.

program was used in two cases, possibly because the program did not exist when the other technology transfers took place.

In general, once a company was chosen through a competitive bid contract and the company had successfully executed the contract, demonstrating its capability and desire to further the development of technology, the company was successful in obtaining further "directed" developmental contracts. It must be emphasized here that the primary purpose of these contracts was not to foster an industry in a certain sector, but to meet primarily a departmental or governmental S&T requirement. Transfer to industry was, in a sense, often a 'spinoff' arising from the contracting-out work.

In all the eight cases studied, the importance of publications or academic meetings during the innovation phase, as a transfer mechanism was rated "low" or "minor" by the members of the research teams. Attendance at scientific conferences was, however, considered essential by the R&D staff in order to maintain their technical abilities.

THE INDUSTRIAL RECIPIENTS

A profile of the recipients of DOC technologies showed that the companies which benefitted most from DOC innovations were often small to medium sized high technology. Most employed less than 100 scientific and technical personnel. The companies' receptiveness to DOC technology arose in part as a result of their senior management's technical background, their in-house R&D capability in terms of manpower and equipment, and their eagerness to diversify their product lines.

THE GOVERNMENT LABORATORIES

(a) Origins of DOC Technologies

In all of the case studies examined, a recognized need for the further development of an invention had been identified. The identification of the need for technology by its users (demand pull) along with the departmental concern to maintain awareness of the potential of emerging technologies (technology push) played a significant role in the development of related innovations. In

the case of Mobile Radio Data System (MRDS), the project evolved as a result of the recommendations of DOC's Computer Communications Task Force (1971) which had stated the need for the department's involvement in the development of new computer/communications systems and applications. Fibre optics coupler, Telidon, Low Cost Earth Terminal (LCET), and the Scanning Electron Microscope (SEM), could be cited as some examples of 'technology push'.

(b) Training and Experience of CRC Teams

In all the cases examined, it was found that DOC research teams were comprised predominantly of those with graduate or post-graduate training. The presence of high calibre engineers/scientists was noted in each case. However, because of the group effort on the majority of the DOC research projects, it was difficult to discern the importance of personal contributions by an individual engineer or scientist. The assistance of skilled support personnel in the laboratory or the model shop, was essential to success in many cases.

An important feature contributing to the success of the research teams was identified as the continuity of the personnel on these R&D projects. Such continuity, through the encouragement of cross fertilization of ideas over time, was stated to have contributed greatly to enhancing the productivity of a team.

(c) Management Policies

The support of the senior management (at the Director General, Assistant Deputy Minister and the Deputy Minister levels) was perceived as critical to a speedy and smooth completion of the R&D project in all of the cases examined. The extent of support of the senior management on projects such as the Low Cost Earth Terminals, Telidon, the Mobile Radio Data System and the Fibre Optics Coupler, while reflecting the relative status of a project in terms of the departmental priorities, also helped the research team in obtaining financial resources more easily, and acquiring relative flexibility in both allocation and control of the resources. This, combined with the provision for a capitalized funding for a project (e.g. Telidon and Communications Technology Satellite (CTS)) played a significant role in

expediting the development of these technologies to enable both their early practical application and timely exploitation by industry.

The emphasis on technology transfer within the Communication Research Centre's laboratories began approximately ten years ago with the Centre's (then, Defence Research Telecommunication Establishment - DRTE) transfer from the Department of National Defence to the newly created Department of Communications. The orientation in terms of realizing the goals of the government's contracting-out policy and the DOC mandate was gradual. As the department goals became better defined, the scientific staff accepted willingly the industrial aspects of their work. As a result, in recent years, the mention of transfer of technology in the performance appraisal of S&T personnel, particularly as related to the scientific authority and contract management functions of the R&D personnel, have become more explicit. Due recognition of technology transfer activities in the merit assessment and career progression of engineers on the research teams was found in all of the cases studied.

The DOC policy, of undertaking work on behalf of other departments when its expertise is not easily available elsewhere, has proven very beneficial for the application of DOC technical know-how and expertise. A traditional user of DOC technical expertise has continued to be the Department of National Defence (DND). In many of the cases examined, the DND funding support and other 'contracting' work proved to be critical to the development of these projects (e.g. Syncompex and Telidon inventions).

GOVERNMENT POLICIES & PROCEDURES

(a) Role of CPDL

The role played by the Canadian Patents & Development Ltd. in the exploitation of the eight inventions examined was described from "minor" to "very helpful" and "really needed". In general, CPDL, a Crown company, was regarded as responsible for patenting and marketing the federal S&T inventions on behalf of government departments. CPDL's activities included: (i) registering of the invention prior to the issue of patents;

(ii) protecting the rights to the invention and (iii) licensing inventions to entrepreneurs for commercial exploitation. The first preference for the licensing of a patent was usually given to the contractor who had worked with DOC research teams on the innovation phase of the development. Opportunities, however, exist for CPDL to adopt a more aggressive marketing role in improving industry interface with government laboratories.

CPDL played an important role in the case of the Scanning Electron Microscope by bringing SEMCO closer to CRC expertise, as well as arranging the secondment of CRC staff to SEMCO.

(b) DSS Contracting Procedures

As R&D contracts were the predominant mechanisms for transferring technologies in the cases studied, it was considered vital that adequate support in terms of appropriate administrative procedures and personnel were available to alleviate problems encountered in the management of R&D contracts, e.g. the speculative nature of R&D activity, evaluation of technical capabilities of a company, time lags in the approval of a contract, the ownership of intellectual property, et cetera. A closer liaison between the CRC team and DSS personnel seemed to expedite matters, reducing the time span on innovation development. In the case of the Field Effect Transistor Amplifier (FETA), the fact that a DSS contract manager was seconded to DOC to support the development of the Communication Technology Satellites expedited the operations substantially, cutting the contract procedural time by almost half.

(c) Role of Special Industrial Research Development Funding

From our case studies it was noted that in the technology transfer process the closer that the R&D activity got to the product engineering phase of the R&D spectrum, the more the costs of technology development increased. In some of the cases studied, there was a 5 to 6-fold difference between the cost of the initial phase development and the final phases.

Special industrial research development funding as the Industrial Contract Fund (ICF) in the case of DOC's Space sector helped to cover a part of such development costs, playing a vital role in encouraging the development of a Canadian capability in space systems development. Since 1978, DOC has also made use of the Cooperative Projects with Industry (COPI) program. However, such programs for technology development, available to the Department, have been few and far between. In general, DOC has benefitted from its contacts with the Department of National Defence and the RCMP, testing the practical applications of its innovations while undertaking contract work on a cost-recovery basis for these agencies.

(d) Government Procurement

The initial purchase by the government of DOC technology-based innovations was described as having considerable impact on the commercial exploitation of the technology and the establishment of industrial capability in that field. The initial purchase of equipment based on DOC technology ensured the development of a new product line and helped to build confidence in the marketability of the new product.

In the case of the Scanning Electron Microscope (SEM) the first two instruments of the company were bought by CRC and NRC. DOC was the first buyer of 100 low cost earth terminals from the SED and Electrohome companies. In the case of Telidon technology, NORPAK, the company exploiting CRC work in the area under a non-exclusive license, has already sold more than a million dollars worth of equipment to government departments.

CONCLUSIONS

The primary conclusion to be drawn from the foregoing study of the DOC's experience is that technology transfer comprises complex processes and that the successful transfer is dependent on a host of variables ranging from need identification, the calibre of the research team, and adequate financial and management support to the existence of a supporting infrastructure which encourages the development and transfer of federal technology to aid industry development. Until recently, technology transfer from the federal

laboratories to industry and others has been narrowly perceived. It has been limited to publications of reports, papers in journals, attendance at learned societies and patenting of inventions. Very little attention has been paid to post-invention phase aspects. The resources, particularly financial ones, required for prototype design, prototype construction, product design and pilot plant are sizeable, and a lack of direction and an integrated strategy in obtaining and making use of the resources can result in delays and poor transfers of technology.

An examination of the considered case studies points to the following factors as important in the successful transfer of technology from DOC laboratories to industry:

- (a) Perceived Need for Technology: The technology transfer process begins with a perceived need which may be identified in terms of departmental mandate and S&T requirements through mechanisms such as task forces, research advisory committees and marketing studies.
- (b) Effective mechanisms for transferring federal technology to industry: (a) use of research and development contracts and (b) interchange of S&T personnel with industry. Both mechanisms have proven to be effective in developing personal contacts and professional relationships among the generators and the recipients of the technology. In most cases, as the work progressed, because of the joint nature of the effort of the federal and industry S&T personnel on the development of the technology, the originator-recipient distinctions became blurred.
- (c) Small to medium sized high technology companies are often most receptive to federal technologies. These companies, though having smaller operations, are seen to be eager and enterprising in establishing a unique product line. The large firms have their own source technology and are constrained by their existing expertise and specialized market.
- (d) S&T personnel with engineering orientation are vital to a research team seeking technology transfer. Experience of interaction with industry or the user by either the professionals or the engineering support staff helps to expedite the workability of the innovation.

- (e) Continuity of S&T personnel throughout the duration of the project encourages cross-fertilization of ideas and contributes to developing team spirit.
- (f) The support of senior management (particularly at the Director General and the Assistant Deputy Minister levels) is critical to a project for it indicates the relative status of the project in terms of the departmental priorities and influences the allocation of capital and human resources to the project.
- (g) S&T personnel must be satisfied that their technology development activities are taken into consideration in their performance appraisal.
- (h) Canadian Patents and Development Ltd. (CPDL) has an effective role to play in technology transfer by making available to industry patentable and potentially patentable federal technologies. Opportunities exist for CPDL to adopt a much more aggressive marketing role in improving industry interface with government laboratories.
- (i) Because R&D costs rise dramatically as the technical development gets closer to the preproduction phase, the availability of funds to support the development phases of industrial R&D becomes vital for successful technology transfer to industry. The funding of R&D-related activities such as product engineering, marketing, prototype development, field trials and demonstrations et cetera is far more expensive than initial R&D. These activities are critical for the advancement of the development as well as allowing better identification of the eventual product/process technique and for the commercial exploitation.
- (j) The transfer in a majority of the cases studied, was related primarily to the fulfillment of departmental requirements. However, there appears to be a gap between the responsibility of line departments and the programs of the departments explicitly concerned with industrial development. One possibility is to extend departmental mandates to cover R&D-related activities that are closer to the production phase.

- (k) Government purchase of equipment developed by industry on the basis of technology transferred by federal laboratories has considerable impact in fostering the industrial capability in that S&T field in the country. Through DSS the departments can actively solicit industry proposals with a high degree of innovative content and be ready to provide special support for such innovations. The initial purchase of such technology by the government ensures the development of a new product line and builds confidence in the marketability of the product.

- (l) Closer consultation between DSS and federal laboratories as well as streamlining of procedures related to R&D contract management can play an important role in reducing the time span of innovation developments.

PART II

CASE HISTORIES OF

EIGHT DOC INNOVATIONS

SPACE SECTOR

CASE HISTORIES



SCANNING ELECTRON MICROSCOPE

Introduction

Electron microscopes, which typically have magnifications of the order of 100,000, can be of the transmission or reflection type. If of the transmission type, the target specimen has to be very thin - in the order of 100A^o. Electron microscopes, of the reflection type, are more common and are easier to use. In the middle 1960's the development of the scanning electron microscope began and promised an ability to examine a larger area specimen and its changes on a real-time basis, much along the lines of a TV picture.

Not only is a scanning electron microscope complex equipment but, at the time the technology transfer was undertaken, there existed no Canadian company to which the technology could be transferred. Therefore, this case history involves the transfer of technology and the establishment of a new company - SEMCO Instrument Company Limited. The problems encountered in the early years of SEMCO (although a study of the resolution of them might provide a valuable insight into the difficulties of establishing a new high technology company) are mentioned only to explain the major role played by the National Research Council (NRC) in sustaining the company after the initial transfer of technology from the Communications Research Centre (CRC). Not only is this case history unusual in the involvement of four government departments and agencies (CRC, NRC, Canadian Patents and Development Ltd (CPDL) and the Department of Industry, Trade and Commerce (DITC)) but it involved also the movement of staff from CRC to industry.

History

In 1967 it became clear to those managing the space program at the Communications Research Centre (CRC) of the Department of Communications (DOC) that increased emphasis should be placed on reliability analysis. One of the most promising tools in the pursuit of reliability was the Scanning Electron Microscope (SEM) and CRC had no experience in SEM technology. Consequently Dr. P. Thornton, who was a SEM expert at the University of Wales, and two of his students joined the staff of the Defence Research Telecommunications Establishment (later CRC) and set up an analysis facility using the SEM bought from the University of

Wales. In accordance with the original plan the work changed gradually from an analysis of failed devices to an analysis of the failure modes of devices and the manufacturing techniques which led to these failure modes.

In parallel with this reliability analysis work, Dr. Thornton and his team, now augmented by physicists and engineers on staff at CRC, continued the development of SEMs. After Dr. Thornton left CRC the group was directed by Dr. C.D. Cox. One of the successes was the mini-SEM and the group tried, unsuccessfully, to interest manufacturers in Canada. About this time the group was visited by individuals from U.S. companies, which later introduced SEM's to the market incorporating CRC ideas, before the SEMCO product was available. After the unsuccessful search in Canada CPDL was asked to handle the mini-SEM, and a licence was sought by a U.S. company - Ultrascan. CPDL agreed to license Ultrascan provided that the mechanical components were manufactured in Canada. Ultrascan declined the license. Some months later, CPDL agreed that a license would be granted to a new company to be formed by Dr. R.F. Webb in Canada. Dr. Webb had considerable entrepreneurial experience in the U.S.A. and had previously worked with Ultrascan. In the fall of 1971, Dr. Webb, with the encouragement of DOC and DITC, which made PAIT funds available, established the SEMCO Instrument Company Limited. Carl Zeiss Ltd., which manufactured transmission electron microscopes but did not market a SEM, assessed the CRC concepts, offered to buy 49% of the SEMCO stock, and agreed to provide world-wide marketing. SEMCO was committed to deliver an instrument, meeting agreed specifications, to Zeiss after eighteen months. The company was originally established in the premises of Computing Devices of Canada but moved within a few months to its own premises in Ottawa.

It was recognized that, in order to transfer the technology effectively to SEMCO, some CRC staff members should be made available to the company. As it was difficult to place government employees in industry, there being no Interchange Canada program at that time

it was agreed, at the suggestion of CPDL, that Dr. D. Shaw and another CRC staff member would be seconded to CPDL and that, as part of the arrangement under which SEMCO obtained the mini-SEM licence, these two CRC staff members would go under contract to SEMCO. SEMCO paid their salaries, but it was agreed that they could return to CRC after the technology transfer had taken place.

After about a year it was determined that the design of the electronics of the mini-SEM NOVASCAN 30, although containing novel features, was not suitable for production. Additional capital was required and, as only part of this was made available by Zeiss. Nevertheless SEMCO continued development and delivered, two years after its start, its first instrument to Zeiss. But because of the improved performance of instruments manufactured by at least one of the companies which had earlier examined the CRC mini-SEM development work, Zeiss declared that the SEMCO instrument was not marketable and SEMCO was forced to upgrade the instrument and to commence the design of a range of "accessories" to make the instrument more marketable. At this time (1973) it was decided to increase the R&D effort at SEMCO and it was arranged that, under the IRAP program, the National Research Council (NRC) would pay the salaries of eight engineers and scientists and that NRC would retain the rights to inventions, with SEMCO having the first rights to exploit them. This enabled SEMCO to recruit Dr. Shaw, Dr. Cox and other members of his group who were involved in the design of the mini-SEM. (The addition of SEMCO to the list of companies who had agreements with the government concerning the transfer of superannuation rights made it easier for these public service employees to join a private company.) Because SEMCO did not have adequate facilities, NRC provided essential laboratory space, support facilities and consultants, in a program which was, in effect, a precursor of the Incubator program. In addition, to the provision by CRC of capital equipment for use by the group at NRC, SEMCO received contracts for the completion of the development of the mini-SEM borrowed from CRC and a wide-angle display for use by CRC in its reliability analysis work.

It is likely that any company, and especially a new one, placing on the market the first models of a new development, in an area of such high technology, will require its best technical expertise "standing by" to deal with the almost inevitable imperfections. In 1976 SEMCO had the necessary expertise in the group at NRC but it had been set up under the Industrial Research Assistance Program to meet the longer term research requirements of future generations of SEM's and not to deal with problems arising from imperfections in production models. Nevertheless SEMCO gradually overcame the problems of the NOVASCAN 30 and developed, at NRC, the prototype of the second-generation instrument - the NANOLAB 7 - which was displayed in Los Angeles in April 1978. It was at this time that the first fiveyear SEMCO-NRC Incubator period ended and the time when SEMCO took over its own marketing in North America. The second Incubator period was shorter and with fewer SEMCO staff at NRC. The main subject of development was the high brightness electron source, now used in SEMCO production. The development of the third generation of SEM (NANOLAB 9) was transferred to the company's premises under a PILP contract signed in 1978 and is now nearly complete. SEMCO now builds a SEM of high quality and a line of attachments which have earned a reputation throughout the world for quality and technical support.

Conclusions

In examining this case history several events and attitudes which facilitated or hindered this successful transfer of technology can be identified:

- (a) the concept provided by Dr. Thornton
- (b) the premature disclosure of the techniques
- (c) the encouragement of CRC management
- (d) the entrepreneurial activity of Dr. Webb in the establishment of a new company
- (e) the initiatives and support provided by CPDL
- (f) the support provided by DITC
- (g) the willingness of CRC staff to take positions in industry and the agreement on the transferability of superannuation rights
- (h) the underestimation, by all concerned, of the difficulty of converting the laboratory technology to industrial production, especially when the recipient company was being formed at the same time
- (i) the continuous support of NRC through the Incubator and PILP programs.

LOW COST EARTH TERMINALS

Introduction

A space communication system includes not only the satellite in space but the transmitting and receiving earth terminals. A standard earth terminal in the INTELSAT system for international communications includes an antenna with a diameter of 30 m. The high cost of such a terminal is acceptable because of the limited number required and the high level of traffic handled by each. However, domestic systems including a large number of earth terminals, each with little traffic, require low cost earth terminals to minimize the overall system cost. The same considerations are even more important in satellite broadcasting systems where the number of earth terminals may be several hundred thousand, if not millions.

History

Very early in the 1970's agreement was reached between the Department of Communications and the National Aeronautics and Space Administration to develop and launch the Communications Technology Satellite (later known as HERMES). Central to this proposal was the development of a 200 watt transponder whose output was to be radiated by high gain, narrow beamwidth (2.5°) antennas to provide experimental broadcast services. Clearly if such a service was to become operational, the size and price of earth terminals should be reduced as far as possible. The earth stations procured to permit the carrying out of communications experiments using HERMES were too large and too expensive for large scale acceptance by the general public for use as broadcast receivers and it is interesting to note that none of the proposals originally made for the use of HERMES was for broadcasting alone. What was required was a truly low cost earth terminal (LCET).

In the early 1970's Logan and Associates of Montreal carried out a study for CRC and concluded that the promised reduction in prices of SHF components was not justified and that component prices would not fall sufficiently to allow the development of a LCET in the \$500 to \$1000 price range. By the middle of the 1970's, field effect transistor amplifiers and low cost low conversion loss mixers became available. Because it was realized that problems of multipath transmission were less serious than had been considered in the past, it was believed at the Communications

Research Centre, and indeed around the world, that earth terminals of sufficiently low cost could be produced.

Although work on the LCET was planned to begin in 1974, the start was delayed by the requirements of the HERMES FET amplifier development. The early work was done in-house, with a team of eight or nine at its peak, to obtain a full understanding of the problems involved, and at the University of Manitoba where work was carried out, under an eight thousand dollar contract, on the design of a 90° prime focus scalar feed. Because of this parallel work at the University of Manitoba it was decided to build a Cassegrain antenna (4 ft. dia.) at CRC. This design employed double-conversion and a tuneable high IF - a new concept for LCET's, later adopted by SED Systems Ltd. (SED) and many other designers. The design of the indoor unit (IDU) used conventional communications circuit technology. A \$4000 contract was awarded to Electrohome Ltd. for a paper study of the design of an LCET IDU using Electrohome's production technology. To this task Electrohome brought a knowledge of the large scale production of consumer electronics, but CRC had to provide all the technical knowledge required for the design of the IDU. A year later a \$10,000 contract was let to Electrohome for the fabrication of two tunable IDU's. Both contracts were funded from CRC's base funds. It would have been preferable to let a larger contract at the time of the paper study but funding was not available.

In the meantime a second demonstration unit was built at CRC. Abandoning the Cassegrain antenna design, this unit used 4 ft. and 2 ft. antennas with a prime focus 90° high efficiency scalar feed, designed in cooperation with the University of Manitoba, which is mass-producible in plastic. This unit included an all-alumina MIC in the prime focus-mounted receiver and a surface acoustic wave (SAW) filter in the IDU. A third demonstration unit used an all-duroid MIC (as it is appreciably cheaper than the all-alumina version) and a novel low cost temperature compensated oscillator, which is now the subject of a patent application.

Up to 1978 consideration had been concentrated almost entirely on the problems of broadcast quality reception. In that year it was realized that for direct-to-home broadcast reception a much lower quality signal was quite acceptable. As a result a request for proposals for the low cost outdoor units was issued by

CRC and following an evaluation of the proposals received a \$122,000 contract was let to SED for the development of two "developmental models" outdoor units and a preliminary investigation of volume production techniques. It may be noted that, to a large extent, SED was able to bid successfully on this contract as the result of a contract awarded to SED three years earlier to establish itself as a supplier of microwave components for earth stations to be used in satellite communication systems. A second contract to SED in 1979 (\$375,000) called for system performance studies, the planning of the pilot production of 100 LCET's and the fabrication and delivery of 100 LCET's using 1.2 m. and 1.8 m. antennas and Electrohome IDU's. (As a result of this contract, SED offered later in 1979 to supply LCET's, in quantities of 100, at a cost of \$2500. each). Electrohome was to manufacture 25 units to their original design and 75 units having improved design and performance. An additional smaller contract (\$66,000) has been placed with Electrohome to examine further improvements and to perform a market study to determine the feasibility of Electrohome entering the very large LCET market that is foreseen.

The technical difficulties which have been experienced by Electrohome were generally anticipated and the company has required considerable assistance from CRC as, indeed, has SED. In spite of some technical difficulties, an enormous amount of technology has been transferred to SED and to Electrohome but more is likely to be required before either company can expect to capture an appreciable part of the consumer market that is likely to develop. Nevertheless, the technology transfer which has already taken place has enabled SED to bid successfully on contracts to supply about a hundred higher quality earth terminals.

It should be noted that while the CRC-generated information has been made available to SED, as a result of winning a contract in a competitive situation, and to Electrohome as a result of directed contracts, the technology generated at CRC has frequently been drawn upon by manufacturers not only of LCET's but of larger Television Receive Only earth terminals.

Conclusions

From a study of this case history a number of considerations affecting the transfer of technology can be identified:

- (a) the existence of a company which had been funded earlier to establish itself as a supplier of microwave components for satellite communication system earth terminals;
- (b) the cooperation with a university researcher;
- (c) the importance of government purchases to consolidate the technology transfer;
- (d) the availability, later in the program, of funds intended to facilitate the early development in industry of sub-systems;
- (e) the problem of finding companies, where large scale manufacture is foreseen, with both a manufacturing and technical capability;
- (f) the necessity, in situations such as (e), of extensive direct interaction between the company and CRC.

FIELD EFFECT TRANSISTOR AMPLIFIER

Introduction

A field effect transistor (FET) is a solid state device used to obtain amplification at microwave frequencies. It first became available in the early 1970's. This case history refers to the first use made of a FET amplifier in a spacecraft. FET devices are now used widely, not only in spacecraft, but in the ground stations of space systems.

History

About the middle of 1973, a U.S. company, ran into problems with the 12 GHz Transferred Electron Amplifier, which the company was building for inclusion in the payload of Communications Technology Satellite (later HERMES). CRC microwave specialists were asked to look at the problem and agreed with the manufacturer that it was unlikely that the difficulties could be overcome quickly. It was decided, therefore, to use a Field Effect Transistor (FET) Amplifier instead. None of the U.S. companies active in the field, was prepared to guarantee performance and schedule and to accept a fixed price contract. Since CRC had a better microstrip technology base and a greater MIC capability than existed elsewhere in Canada, it was agreed between RCA and CRC in October 1973 that the amplifier be built by CRC, with a May 1975 completion date. An attempt was made to integrate engineers from RCA Limited (now Spar Aerospace Limited) which was building the spacecraft transponder in the development work.

Fairchild was the only supplier of completely packaged devices (the FMT 940) but when a number were bought and tested it became clear that, at that time, the company could not measure the performance adequately. Meanwhile it was found that Plessey in the U.K. was willing to supply devices in chip form. Samples, produced on a laboratory, rather than a production line basis, were made available by Plessey and CRC designed and produced the chip package.

Work at CRC on the Fairchild device and on Plessey device amplifiers continued in parallel. As Fairchild supplied a packaged device, progress with this was quicker and the first operational amplifier was available in April 1974. However the narrower gate structure used by Plessey provided a better device and, although the device was not packaged, the amplifier design proceeded quickly. By the fall of 1974 the first engineering model using a Plessey device was followed by a qualification model using a Fairchild device. Eventually CRC produced engineering, qualification and protoflight amplifiers using Plessey devices and the same amplifiers with Fairchild devices. All this was done in eighteen months by a design team which totalled nineteen at its peak, including two RF design engineers and three technicians, with good support in packaging and power supply design and in reliability analysis. This technical team could not have achieved such remarkable results without full administrative support and the help of the Department of Supply and Services in expediting requisitions.

Redundant FET amplifiers, each using either the Plessey or the Fairchild device, were flown on Hermes. In its life in space of nearly four years, the Hermes satellite used only the FET amplifier with the Plessey device and no abnormalities in performance were reported.

No licensable or patentable technology was developed at CRC in the course of this development work - circuit techniques generally are not patentable - although a good deal of technological innovation was involved, as, for example, in the use of kovar to design packaging capable of meeting the temperature specifications. Much was learned on RF design (including the design of butterfly bias networks and filtercons - bias-feed through networks with RF shunting) and the failure mechanisms which can lead to degraded reliability. After the CTS deputy project leader (an RCA employee who had been seconded to CRC and who was convinced of the value of FET amplifiers in space applications), returned to RCA, the climate for technology transfer was greatly improved. All the knowledge which had been acquired at CRC was made available to RCA and contributed to the success the company had in designing FET amplifiers for use in the RCA Satcom (6/4 GHz), the Anik B (6/4 GHz) and the TDRSS.

Another spin-off occurred when in 1975, a contract was awarded to SED Systems Ltd. (SED) to establish itself as a supplier of microwave components for earth stations to be used in satellite communication systems. As a result SED have built 4 and 12 GHz low noise amplifiers using FET's. In the course of this development CRC personnel spent weeks at SED and SED engineers and technologists visited CRC to make use of the knowledge acquired in the design of the FET amplifiers for Hermes.

It is apparent that the technology transfer which occurred during and after the development of the FET amplifier was not achieved by transfer of information by licence but rather in repeated interchange of information between engineers over a long period of time.

Conclusions

In examining this case history, several events and attitudes which facilitated or hindered the successful transfer of technology can be identified:

- (a) the existence of a small strong team with excellent R&D facilities at CRC;
- (b) the speedy development of the technology, with full management support, to meet strict time constraints;
- (c) the existence of a chosen instrument after the CTS (Hermes) contracts were let;
- (d) the reluctance of the chosen instrument to initially accept the value of the technology;
- (e) the receptiveness of the chosen instrument after the return of senior staff seconded to CRC for the duration of the Hermes program.

DELTA CODEC

A Delta Codec is the hardware implementation of a system for the digital coding and decoding of an analogue signal, commonly a voice signal. The technology considered here is concerned with an adaptive form of the system whereby the input analogue signal is sampled periodically and a binary bit generated. The logic level of the bit is dependent on whether the sampled signal is greater or smaller than the signal of the previous sample. Decoding to recover the analogue signal is achieved by periodically charging and discharging a capacitor integrator by predetermined variable steps.

This development work began in 1969 when the Communications Research Centre (CRC), then the Defence Research Telecommunications Establishment, needed a codec to demonstrate the properties of digital voice transmission. With about $\frac{1}{2}$ Person Year of work spread over two years, the High Information Delta Modulator (HIDM) was built. In 1970 consideration was given to the choice of coding techniques for UHF satellite communications. The HIDM was not suitable for high quality voice transmission and during the summer of 1970 a digitally modulator was developed. In 1972, as a result of its requirements for a thin route system in the North, Telesat discussed with CRC the possibilities of using a digital voice system and specifications were generated. There existed no capability in Canadian industry and U.S. industry could not meet the specifications. As a result of the Telesat interest, Canadian Patents and Development Ltd. (CPDL), to whom the CRC suggestion had been disclosed, considered patent action but declined to act because it could see little hope of financial return. The matter was not pressed by CRC engineers because they thought improved systems were in the offing. However, in January 1973, CRC published a Technical Note describing performance tests on the delta codec and about that time requested competitive bids for the conversion of the experimental circuit into a production-oriented unit and the building of two codec units. The successful bidder, SED Systems Ltd. (SED), redesigned the analogue circuits while retaining the CRC digital circuits and produced two units (MODEL 6090 CODEC) by mid-summer. Although nearly 50 units were sold to various government departments, the unit was not suitable for large scale manufacturing.

In these early models the feed-back loop in the coder, which provided the signal to be compared with the

incoming signal, was implemented in analogue form. In 1974 it was decided to consider a fully digital implementation and a \$30,000 contract was awarded to SED for a study of digital coding techniques. During the course of this contract, it became apparent that a University of Saskatchewan professor, Prof. D.E. Dodds was carrying out work, under an NRC operating grant, which bore on the digital codec, and he was awarded a small CRC contract to consider the application of some of his ideas. From interaction between Prof. Dodds, Mr. A.M. Sendyk of SED and Mr. D.B. Wohlberg, the CRC Project Engineer, evolved the idea of an Exponentially Variable Slope Delta (EVSD) Codec. With the digital implementation of the Delta Codec a more stable performance, with lower manufacturing costs, can be achieved so that the EVSD Codec gives a better performance than the more conventional Continuously Variable Slope Delta Codec and at equal or lower cost. The EVSD Codec has now been patented in the U.S.A. and will be patented in Canada.

Following the study contract at SED, the RCMP, who had a requirement for a low-cost low-power digital codec for voice transmission systems, gave SED a contract for less than \$20,000, for the design implementation using Large Scale Integration (LSI). Technical support was provided by CRC. One of the few Canadian companies capable of fabricating the required integrated circuits, Bell Northern Research, was awarded an CRC contract (about \$80,000) in 1977, to develop the necessary IC's based on the SED design. With the success of this development, the CRC is now about to let a \$60,000 contract to Northern Telecom for the iteration of the design and the production of about 3000 codec units, for use in CRC communications equipments. SED retains the rights to exploit the codec in markets outside the Government.

The biggest application of the EVSD codec is likely to occur in digital mobile communications for users such as the police and the military and in satellite communications, especially in the upgrading of Telesat thin route services. To meet the satellite communication requirements, CRC investigated the implementation of a full duplex system and in 1979 let a directed contract (\$30,000) to SED for the design of a toll quality full duplex LSI version. CRC is now (December 1979) awaiting responses to requests for bids for the IC's based on the SED design. SED is to be the sole source contractor to generate the specifications for the IC's, to manage the contract and to evaluate the devices. Providing the development of the IC's

proceeds satisfactorily, the manufacturer will be required to sell the LSI codecs to SED, which sees a large requirement for several years for incorporation in SED manufactured communication equipment. SED will pay royalties to the CPDL.

The transfer to industry of codec technology has been under way since 1973. Under present plans, CRC hopes to complete, by 1981, the transfer of its technology in this area.

Conclusion

The following elements which facilitated this successful transfer of technology can be identified:

- (a) the continuing codec design work undertaken at CRC in support of a satellite communications R&D program;
- (b) the parallel work at the University of Saskatchewan under an NRC operating grant;
- (c) the ability to transfer laboratory hardware;
- (d) the operational requirement of, and the development funding by the RCMP.

RESEARCH SECTOR

CASE HISTORIES

TELIDON

Introduction

Telidon technology allows users to retrieve information from any number of data banks plugged into the system or eventually to have direct terminal-to-terminal contact with another user. The main components in Telidon are slightly modified television set or display monitor, the phone and/or cable, and a computer. The federal communications department announced in August 1978, the development of a key component in the system -- an interactive device between the communications system and the television set -- and was able to give laboratory demonstrations of the system. Telidon makes it possible for a user to employ his full home TV set to access information on anything from antique cars to zoology. A user can, for example, phone a data bank and by punching a few buttons on a key pad retrieve pages of information for display on his modified TV set. The information can be in textual and/or graphical form and can be transmitted to the user via the telephone line, coaxial cable, optical fibre or off-air broadcast for instant display.

Attached to the TV set is a special interface device which receives instructions from a computer and converts these signals into texts and images to appear on the screen. For home use, a key pad, or for business use, a key board (like a typewriter) can be wired to the device or operated by remote control.

History

Work in this area started around 1969 with computer-aided design for the CRC Space Program. After the transfer of the laboratory from DND (DRTE) to DOC, emphasis shifted to interactive graphics for communications purposes. From 1969 to 1973 considerable effort went into building special hardware and in producing the necessary software to establish a capability in interactive graphics. This led to the development of an interactive graphics programming language and later to the picture description instructions. The latter represents an efficient protocol to interact graphics from one computer terminal to another over narrow band systems.

In September 1975, CRC became aware of NORPAK Ltd. through work they had performed for DREO. CRC initiated a contract with NORPAK for \$15K for the development of hardware and software components for future interactive colour display systems based on the CRC developed technology. In November of the same year, a contract with NORPAK was initiated to further develop, in close collaboration with CRC, a prototype colour display system for a total of \$19K.

From 1974 to 1976 a close working relationship developed between DREO's electronic warfare section, NORPAK Ltd., and the CRC image communications section. At that time, CRC provided assistance and consultation to the former under the Military Communications Research Program. The military requirements for advanced display helped to focus some of the research at CRC. War gaming at the Royal Military college (RMC) provided the first application of the concept of the common visual space. A small system was set up to test some of the ideas of graphic communications using CRC, DREO, RMC and the University of Manitoba as the nodes.

At the same time, the Image Communications Program was given approval to replace its existing computer (PDP-9) and display system (home-made) with a new system. CRC was so impressed with the ability and progress made by NORPAK on the development system that DOC decided to order the total computer display system from NORPAK at a total cost of \$57K of which only \$19K represented the display component. The other \$38K covered the purchase of the PDP-11/40 computer system.

The total funding provided to NORPAK in 1975 by CRC was \$91K, of which only \$72K represented development funding.

By 1976/77, the work at CRC was sufficiently advanced to produce three patent applications:

- (i) An Interactive Visual Communications System - February, 1976;
- (ii) A Touch Sensitive Input Device for Computer Graphics Displays - January, 1977 (DND sponsored work);
- (iii) An Interactive Graphics Programming Language - March, 1979.

In 1976, NORPAK Ltd. applied and obtained a license on (i) and in June 1976, NORPAK Ltd. submitted an unsolicited proposal to DSS for the development of an Incremental Graphics Processor. The proposal was accepted and CRC, with assistance from MRC, acted as scientific authority. The contract was valued at \$124K including \$10K from CRC during FY 1976-77 and \$5K in FY 1977-78, the remaining being DSS bridging funds. This proposal was accepted by the DSS review committee because it was very strong technically (all digital, micro-computer driven) and represented a new approach to traditional black and white display system design. NORPAK's strong technical ability was again demonstrated by completing this 12 month developmental program approximately three months early.

NORPAK applied for and was awarded the Department of Industry, Trade and Commerce's PAIT grant in July of 1976 for \$360K, with \$180K being supplied by the company. This funding was to be used to bring the products developed, in conjunction with CRC and DSS, to a production stage. This project was sufficiently productive and IT&C extended the project under the new EDP program for another six months. Then in August 1978, DOC announced its version of the Canadian Videotex System called TELIDON and launched a \$97M four year program. The corner stone of the program was the equipment developed and built by NORPAK Ltd. based on CRC technology.

It is clear that the technology transfer which occurred during and after the development of TELIDON was not achieved only by the transfer of information by license, but rather in repeated and continuing interchange of information between DOC and NORPAK engineers over a long period of time.

Conclusion

In examining this case history, several events and attitudes which facilitated or hindered the successful transfer of technology can be identified:

- (a) the existence of a small strong team with excellent R&D facilities at CRC;
- (b) the existence of a company which had been funded earlier to establish itself and which was able to further develop the technology;
- (c) the importance of government purchases to consolidate the technology transfer;

- (d) the continuing design work undertaken at CRC in support of the R&D program;
- (e) the availability, later in the transfer process, of funds intended to further develop the TELIDON system;
- (f) the availability of government program to assist high technology companies in further developing the technology;
- (g) the necessity of extensive direct interaction between the company and CRC; and
- (h) the speedy development of the technology, with full management support.

FIBRE OPTICS COUPLER

Introduction

Interest in fibre optics at CRC dates from about 1970, when the optical group became aware that glass fibres with sufficient purity capable of carrying light with losses of less than 20 db/km were being produced. This was considered to be the threshold for practical use of fibre optics for communications systems. The optics group began to look at fibre optics by concentrating on the propagation characteristics of fibres and also considering questions on how to launch and receive the light beam and techniques of coupling it from one fibre to another.

History

A coupler consisting of twin bi-conical tapers held together with epoxy was developed at CRC in 1976. The performance of the coupler was not considered good enough for practical use, and although it was reported in the literature, the work was left dormant for a time. A later review of the literature indicated a second type of coupler, produced by two scientists in the U.S., in which two fibres laid side by side were fused to produce a coupler junction. The performance of this coupler was also poor. Scientists at CRC led by Dr. B.S. Kawasaki found, however, that by using a combination of these and other techniques, a coupler having unsurpassed performance could be fabricated. This work on the Fused Bi-conical Taper Coupler was reported in March, 1977. Since then, several other novel devices based on CRC coupler technology have been reported that considerably enhance its range of utility.

Under the military communications research program carried out at CRC for DND, some work had already been done to show the application of fibre optics on board ships. DND was interested in fibre optics as an alternative to conventional cabling on board the Canadian patrol frigate and other future ships. Efficient and cheap coupler devices would be required to make an effective data bus. It was decided that DND would fund a contract with industry under the military communications program at CRC to develop commercial versions of several devices based on the bi-conical taper coupler technique.

Representatives from Bell Northern Research (BNR) and Canada Wire and Cable (CWC) were invited to CRC to see the coupler and witness demonstrations of the technique.

CWC won the bid for a \$157K contract in 1977. (BNR did not bid but is fabricating couplers using CRC technology.) For the duration of this contract which was successfully completed in 1979, frequent advice and assistance was given by CRC scientists to CWC personnel both at CRC and the CWC plant. Canstar, a subsidiary of CWC, is now selling a family of devices based on the coupler in Canada and the U.S. These devices should make possible the implementation of versatile local area networks using optical fibre in industrial control applications, for data networks and to meet other peripheral terminal interconnect requirements.

Conclusion

The following elements which facilitated or hindered the successful transfer of technology can be identified:

- (a) the continuity of personnel was considered important from the invention through to the transfer;
- (b) the frequent contact between government and industrial scientists was considered essential; and
- (c) the operational requirements of and development funding by DND was very valuable.

MOBILE RADIO DATA SYSTEM

Introduction

The Mobile Radio Data System (MRDS) is a computer based, data communication system for mobile units using radio links. The user (one of a fleet of mobile units) can report his position and status to and/or request information from a central control facility by using a specially designed computer terminal located in the mobile unit.

History

Late in 1972, Mr. W.L. Hatton, Director of Communications System R&D recommended that CRC undertake a project based on the recommendations of the Computer/Communications Task Force. These recommendations included the concept of government laboratories fostering selected areas of computer/communications technology and applying these to Canadian needs via industry.

Combining these task force recommendations with the "make or buy" policy and the expertise of the government scientists, the project was begun by making several studies to determine the capabilities of the Canadian electronics industry, the user needs and market situation, standards, and the extent and sophistication of technology in use.

A market study conducted under contract by Woods, Gordon & Co. identified mobile radio data terminals as one of the best areas to address. This choice was doubly appropriate because the department's mandate to manage the use of the spectrum requires an intimate knowledge of developing communications technologies and because CRC had existing expertise in radio communications.

The major objectives of the resulting Mobile Radio Data System project were:

- To foster the development and use of advanced communications systems of value to Canadian users, specifically, the use of mobile radio links for data transmission.
- To provide information of use in the management of radio spectrum and in development of standards.

- To support the development of the Canadian communications industry.

The leaders in the application of this new technology and its most sophisticated users were identified as the police forces. The major users, however, were likely to be in the transportation sector of the economy -- bus, railways, taxis, etc. Other identified users were utility companies, ambulances and fire brigades, delivery companies, etc.

In October, 1974, DOC approached the RCMP who agreed with a proposal to cooperate in a joint project to specify, design and develop a modular radio communications system which would satisfy the major requirements of the Canadian Policy Forces. The expertise which was to be established through the development of this police communication system would then provide the base for the development in industry of mobile data communications systems for police and non-police users.

The design and development work for a demonstration system was to be done by Canadian industry. Early in 1975, industry was briefed on the program which included a requirement that the selected contractor commit himself to enter the Mobile Radio Data Systems (MRDS) business. MacDonald, Dettwiler and Associates (MDA) won the Phase I contract to develop detailed systems specifications and trial plans. This contract showed that an MRDS supported by all the latest computer aids was beyond both the means and the requirements of most police forces, and consequently a smaller system was selected for implementation and installation as a test case. The Vancouver Police Force was interested. An agreement was reached between DOC, RCMP, and the City of Vancouver, wherein the city agreed to pay for all hardware components of an operational system with the federal agencies paying for the development work.

The Phase II work was divided into two contracts. Phase IIA (\$0.6M) was intended to produce an operational system for the Vancouver Police Force. This system when completed and tested would be available for immediate use. Phase IIB (\$0.6M) was intended to produce a completely Canadian built terminal and system, designed to meet police needs and those of the transportation sector. In the case of the police, this included the capability of accessing the RCMP data base from their vehicles and the capability for headquarters messages to the field force.

In 1978, MDA in consultation with Ventures West Ltd. (partially owned by the Canadian Development Corporation) and others, were instrumental in creating International Mobile Data Incorporated (IMDI). MDA transferred the necessary technology and personnel to IMDI to produce and market the system. The new system includes a microprocessor-based controller, the mobile terminals, and the base station controller. IMDI is now in the process of marketing systems. Based on the success of the trail system, the Vancouver Police Force is buying a complete set of the new Canadian-manufactured terminals for their fleet. Other potential markets include various German and American police forces and some non-police applications as well.

With the successful completion of Phase IIB (the development of the advanced equipment and software) and the setting up of a Canadian company dedicated to the exploitation of this technology, a major objective of this project is considered to have been achieved.

Conclusions

The following elements which facilitated or hindered the successful transfer of technology can be identified:

- (a) the existence of a small active company looking for a new marketable product line;
- (b) the presence of a strong manager who guided the project initially and sold the idea of government-industrial cooperation on the joint venture to higher management; and
- (c) the operational requirements of police forces and active assistance of the RCMP.

SYNCOMPEX

(Synchronized Compressor and Expander Voice
Processing System for Radio Telephone)

Introduction

Fading on HF communications circuit has always been one of the major disadvantages of HF radio communications networks. The British LINCOMPEX (Link Compressor and Expander) system has been developed to help overcome this fading by transmitting a compressed voice signal in which the voice amplitude information was carried as an FM signal in a frequency-adjacent, control channel and used to reconstruct the signal at the receiving end. The system worked well but because of its analogue design and its requirement for highly stable frequency devices it was large and expensive. Although recommended by CCIR, it has found use only on major international radio telephone circuits. The problems of fading remain for the average HF users, some of whom, like those in Northern Canada, depend heavily on HF communications as their only link to outside areas.

History

In 1975, the Director of the Communications Systems Directorate, Mr. L. Hatton, assigned S.M. Chow the task of designing a small and inexpensive equivalent to LINCOMPEX using digital techniques. The result was the SYNCOMPEX design which among other things digitized the information carried on the control channel and did not require highly stable frequency sources. It could be added on to existing radio sets. Potential sales for such a device could be large including Third World countries, in addition to the Canadian users in Northern and isolated areas.

Since no technical assistance was available within the directorate to build and test the design, discussions were held with industry leading to an unsolicited proposal by the Canadian General Electric Co. (CGE) in August, 1975, to produce three breadboard models. A \$79K contract was awarded in January, 1976, and completed by December. CGE, having no marketing mechanism for the devices, decided not to proceed beyond the R&D stage.

A request for proposals resulted in Canadian Marconi receiving a six month \$49K contract to test and evaluate the device over a radio network. This contract was completed in August, 1977. The tests indicated that further design work on the control channel would be required to make it more robust when selective fading is encountered.

A new \$91K contract was let with Marconi to redesign the channel to overcome the observed deficiency. This included computer simulation of the coding schemes and some on-the-air tests of the digital portions. This contract ran from January, 1978, to September, 1978. It was intended to have Marconi continue with follow-on directed contracts to build and test models based on the new design leading to a pre-production prototype.

Unfortunately, although the design and tests were successful and the company was willing to continue (expecting to have a marketable product), delays in contract negotiation resulted in Marconi's subsequent withdrawal from the negotiations and dispersal of their design team in January, 1979.

Further in-house work was carried out in the fall of 1978, by the engineer in charge with the assistance of a technician. The resulting design model was then transferred to Miller Communications Ltd., under a contract to produce test models of the syncomplex design. These models will be fully tested over actual HF links. DND contributed funds for this last contract and will participate in the tests with the intention of possibly using these devices in the Canadian Forces.

Conclusion

The following elements which facilitated or hindered the successful transfer of technology can be identified:

- (a) the lack of in-house technical assistance and equipment forced an earlier than optimum approach to industry;
- (b) the speed of the contracting process was sometimes too slow for industry, resulting in a lack of continuity of industrial personnel in the transfer process; and

- (c) visits by the CRC engineer were considered essential for the limited success of the first two industrial contracts and is proving to be very important with the current firm.

APPENDIX

MAJOR THEMES OF DISCUSSIONS WITH
SCIENTISTS AND MANAGERS ON DOC RESEARCH TEAMS

Technology Transfer Study

The following are some suggested topics for further discussion in considering the successful transfer of technology in the case histories chosen for the study.

1. Local Environment

(a) Training and Experience of CRC team

- presence of outstanding scientist or engineer on the team
- fields of training
- industrial experience
- previous experience of technology transfer
- experience in intra-establishment interaction
- experience in interaction with groups outside the establishment (university, industry, others)
- continuity of personnel

(b) Management Policy

- support of senior management
- consideration of technology transfer in merit assessment and career progression
- flexibility of resource control (internal redistribution, contracts, business travel, conference travel)
- provision of adequate R&D facilities
- provision of "national" facilities
- contracting in (R and D in CRC laboratories on behalf of industry and other departments)
- role of departmental industry development directorate

2. Government Policy and Procedures

- importance of Government procurement
- role of CP & DL
- "chosen instrument"/"prime contractor" considerations
- role of DSS - contracting procedures
- role of special industry development funding e.g. COPI or ICF

3. Transfer Mechanisms

- Transfer of knowledge
- Transfer of hardware
- Transfer of personnel
- Exchange visits
- Personal relationships
- Use of developmental or research contracts (competitive, directed, unsolicited)
- Importance of publications, national and international conferences and meetings

4. The Company

- Ownership
- Size and prosperity
- Technical capability
- Receptiveness
- Marketing capability
- Peculiarities of industry environment in which company exists

Appendix
cont'd

FACTORS CONTRIBUTING TO TRANSFER OF DOC INNOVATIONS TO INDUSTRY

Factors contributing to Technology Transfer of
DOC Innovations to Industry.

		CRC Innovations/Technologies							
		Syncomplex	MRDS	Fibre Optics	Telidon	Scanning Electron Microscope	Low Cost Earth Terminals	FET Amplifier	Delta Codec
1. Local Environment									
a) Training and Experience of CRC team									
- presence of scientific excellence on the team	Important	Not a real factor	Not a real factor	Important	Important	Important	Important	Important	Not a real factor
- fields of training	Engineers	Engineers	Scis & Engs.	Engineers	Engs & Phys.	Engineers	Engs (Elec.)	Engineers**	
- industrial experience	Moderate	Very limited	Moderate	Very limited	Nil	Nil	Nil	Nil	Nil
- previous experience of technology transfer	Moderate	Limited	Limited	Limited	Nil	Limited	Nil	Nil	Nil
- experience in intra-establishment interaction	Moderate	Moderate	Nil	Limited	Moderate	Good	Good	Nil	Nil
- experience in interaction with groups outside the establishment (university, industry, others) ^{U=I=}	Not Important	Not Important	Not Imp.	Limited Imp.	Not Imp.	Not Imp.	Limited Imp.	Very Imp.	Very Imp.
- continuity of personnel	Important	Important	Important	Important	Nil	Not Imp.	Not Imp.	Imp.	Imp.
	Excellent/Very Imp.	Very Good/Essential	Excellent/Essential	Very Good/Very Essential	Good/Very Imp.	Good/Could have been better	Excellent/Vital	Good/Necessary	
b) Management Policy									
- support of senior management	Moderate (Low funding & time lag)	Very Good	Excellent "V. Supportive"	Excellent "Critical"	Moderate	Good	Good	Good	Moderate (Low Priority & time lag)
- consideration of technology transfer in merit assessment & career progression	Implicit	Explicit	Explicit	OK for engs. but not RESS	Implicit	Explicit	Explicit	Implicit	Implicit
- flexibility of resource control (internal redistribution, contracts, business travel, conference travel)	Adequate	Very Good	Good	Good	Adequate	Very Good "Infinite"	Good	Adequate	Adequate
- provision of adequate R&D facilities	Minimal (no labs-no technicians)	N/A	Good	Good (NORPAK has better equipment)	Excellent	Adequate	Adequate	Excellent (minimal tech support)	Excellent (minimal tech support)
- use of CRC "national" facilities	N/A	N/A	N/A	N/A	Important	N/A	Important	N/A	N/A
- contracting in (R&D in CRC laboratories on behalf of industry & other departments)	Yes (DND)	None	Yes (DND)	Yes (DND)	None	None	None	Yes (RCMP)	Yes (RCMP)
- role of departmental industry development directorate	Not signif.	N/A (capitalized project)	Limited	Not signif.	N/A	N/A (ICF funding)	N/A (GTS funding)	Limited	Limited
**In most of the transfers, particularly the ones involving the transfer of hardware, the support of experienced CRC technologists (model shop) was very significant. This often compensated for lack of industrial experience. This often compensated for lack of members									

CRC Innovations/Technologies

	Syncompex	MRDS	Fibre Optics	Telidon	Scanning Electron Microscope	Low Cost Earth Terminals	FET Amplifier	Delta Codec
2. Government Policy and Procedures								
- importance of Government procurement	Important (Potential)	Important (if it includes Police Forces)	Important	Important (\$2-3M sales by Norpak)	Important	Most Imp.	Important	Important
- role of CP & DL	"Minor"	"Supportive"	"Satisfied"	Really needed	V. Important	Satisfactory	N/A	Very helpful
- "chosen instrument"/"prime contractor" considerations	N/A	N/A	N/A	N/A	N/A	N/A	Yes	N/A
- role of DSS - contracting procedures	Unsatis.	Satis.	Satis.	Satis.	Insignif.	N/A	Key Role - V. supportive	Satis.-role critical
- role of special industry development funding e.g. COPI or ICF	Nil	Nil	Nil	Nil (later COPI)	Nil (IRAP)	Key Role (ICF)	Nil (CTS)	Key Role (RCMP)
- relevance of departmental/govt'al application	Significant (DND, DOT)	Significant (Police Forces)	Significant (DOC)	Significant DND & others	Significant (Satt. Comm.)	Significant (Satt. Comm.)	Significant (Satt. Comm.)	Significant (RCMP)
3. Transfer Mechanisms								
- Transfer of knowledge	Yes-extensive	Yes-extensive	Yes-extensive	Yes-extensive	Yes-extensive	Yes-adequate	Yes-extensive	Yes-secondary
- Transfer of hardware	Yes-little	None	None	Yes-little	None	Yes-primarily	None	Yes-primarily
- Transfer of personnel	None	None	None	Yes-personnel joined NORPAK	Yes-primary	None	Yes-secondary 1 PY-SPAR	None
- Exchange visits	Vital	Vital-visits extensive	Very Imp.	Vital	Very imp.	Important	Important	Important
- Personal relationships	Important	Vital	Important	Very imp.	Very imp.	Important	Important	Necessary
- Use of developmental or research contracts (competitive, directed, unsolicited)	Yes C- Yes D- - U- Yes	Yes Yes Yes	Yes Yes -	Yes Yes Yes Yes	Yes - - -	Yes Yes Yes -	None N/A - -	Yes Yes Yes -
- Importance of publications, national and international conferences and meetings	Low/Minor	Low/Not Imp.	Low	Low/Minor	Low/Not Imp.	Low	Low	Low
- Dominant Mechanism of Transfer	Developmental Contracts	Developmental Contracts	Developmental Contracts	Developmental Contracts	Personnel Transfer Thru CPDL	Developmental Contracts	Personnel & Info exchange	Developmental Contracts

