STUDY STRATEGY AND METHODOLOGY REPORT FOR THE STUDY OF THE COST-EFFECTIVNESS OF THE DOC RESEARCH LABORATORIES

Prepared for:

The Department of Communcations
Ottawa, Ontario

Prepared by:

The DPA Group Inc.
Vancouver, B.C.

Our File: DOC 085101

January 11, 1989

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1.0 INTRODUCTION

The DPA Group Inc., operating under contract with the Program Evaluation Division of Communications Canada, has been instructed to conduct a cost-effectiveness study of the Department of Communications (DOC) research laboratories. This report combines the first two deliverables for the study: Study Strategy, and Methodology Report. The primary objectives of this study are:

i) to establish the real costs of maintaining the DOC research laboratories; and

ii) to develop and implement a methodology for estimating the economic benefits associated with DOC research and, based on the results, evaluate the likelihood that the benefits derived from the DOC research labs exceed the costs incurred (i.e., that the labs are cost-effective).

The following details our activities during the sample selection phase of our analysis (activities 1 through 3 in the work plan contained within our proposal). Section 2 details the methodology to be employed to determine the cost-effectiveness of DOC research labs. Sections 3 and 4 describe the case study sample criteria and proposed sample of projects selected for the study, respectively. Section 5 details our proposed activities for data collection.

2.0 METHODOLOGY

The methodology selected for the cost-effectiveness evaluation of DOC research laboratories involves, in general terms, the following:

- development of an estimation framework;
- a definition of how specific benefits and costs are measured;
- the identification of data and information sources; and
- the identification of possible problems arising from the use of the methodology and the derived estimates.

The following sections outline the types of information required for the evaluation of the cost-effectiveness of DOC research and the reasons for using that information.

2.1 Estimation Framework

The cost-effectiveness of DOC research laboratories is evaluated by determining whether the benefits derived from DOC directed research at least equals the costs of financing that research. In accomplishing this task, it is acknowledged that it would be immensely difficult to attempt to evaluate each and every research project within DOC. Fortunately, we are able to draw inferences, based on the quantified benefits derived from a subset of DOC research projects, as to the magnitude of benefits to be expected from those research projects that we are unable to quantify and thus the cost-effectiveness of the DOC research laboratories. It is for these reasons that we have adopted a case study approach.

2.1.1 Case Study Selection

Through an interview process with members of DOC (a process more thoroughly described in section 3), DOC research project(s) were reviewed and characterised according to:

- identifiable links to a product or service arising from the research project;
- actual marketing of the product or service;
- knowledge of present and potential market size;
- identification of end-users;
- expected life-cycle of the product or service (time frame of benefits);
- identification of linkages between research results, application and economic benefits;
- type of economic benefits and ability to quantify them;
- the significance of the benefits; and
- the timing from research results to application by the end-user.

The specific DOC projects chosen vary in their outcomes and the degree to which benefits can be quantified. For instance, the transfer of technologies from DOC laboratories to other government agencies or departments (an inter-government transfer) is much harder to quantify than technologies transferred to the private sector where the sale of products takes place. The research projects chosen as case studies are those we feel will have significant quantifiable benefits. A more thorough explanation of our sample selection process is provided in Section 3.0 below. The projects selected for evaluation as case studies are listed in Section 4.0.

2.1.2 Estimation Techniques

The cost effectiveness of the DOC laboratories will be estimated through the net benefits of selected DOC research projects. This methodology entails the following procedures:

- estimate the gross economic benefits of a selected group of DOC research projects where benefits are expected to be large;
- estimate the costs of production, implementation and marketing associated with those projects' benefits;
- estimate the research and development costs of the selected projects (DOC support costs);
- determine the net economic benefits of the selected projects;[1]
- compare the gross economic benefits of the selected DOC research projects and the research costs of all DOC-supported research.

Exhibit 2.1 shows a simplified diagram of how case study benefits are combined to form an overall minimum total estimate of quantifiable DOC benefits.

The cost effectiveness or benefit:cost ratio of individual projects will generally not be estimated for two reasons:

- in order to solicit information from many respondents in the private sector, it will be necessary to guarantee that data will only be presented in aggregate form;

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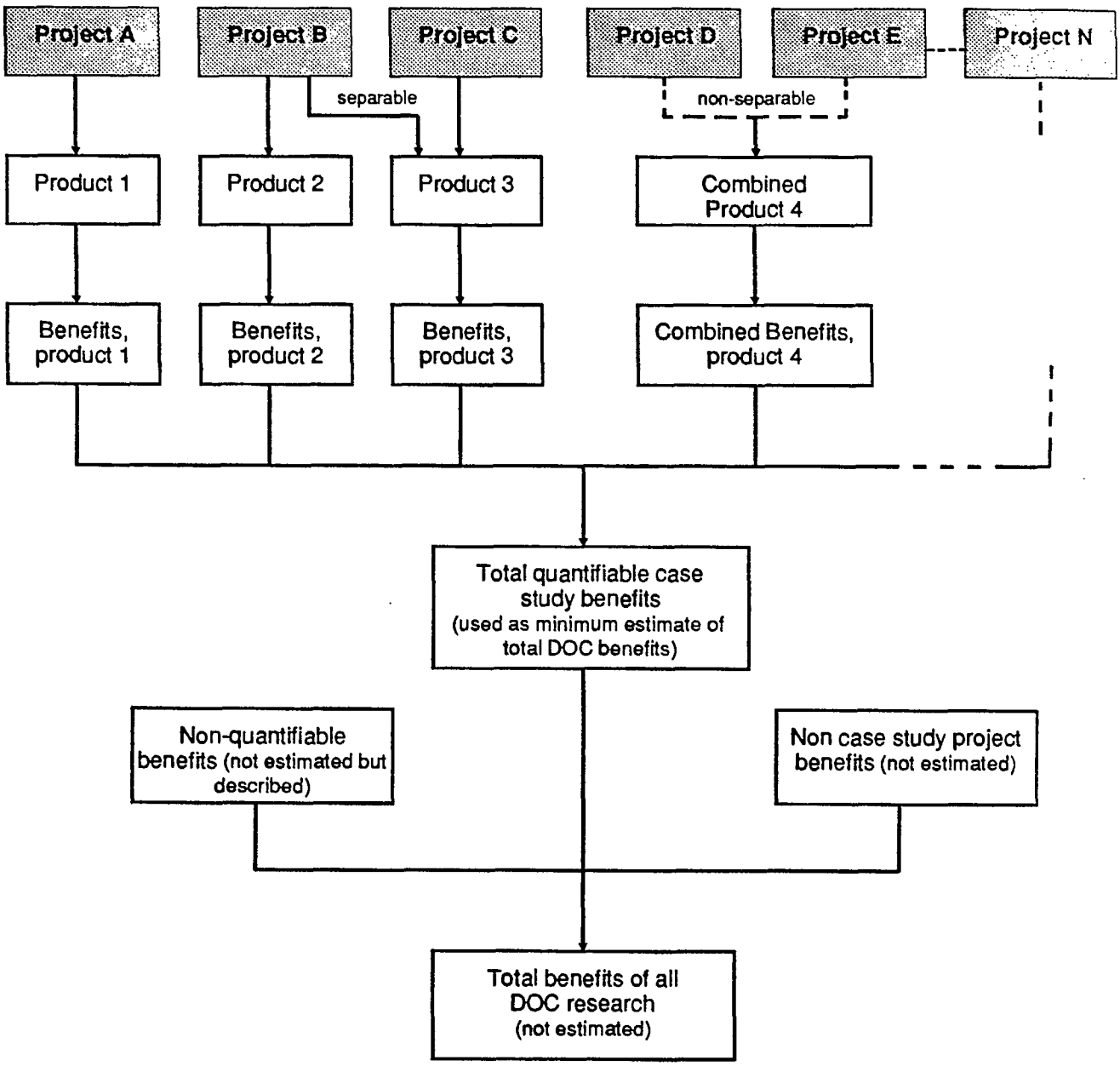
1 Net economic benefits of each case study equal: gross economic benefits; minus production and marketing costs; minus DOC project research costs.

Exhibit 2.1: Overview of Measurement of Benefits



- many final products will have links to more than one DOC project; the allocation of benefits and costs to individual projects will frequently be very difficult or impossible (e.g. the "non-separable" projects in Exhibit 2.1).

If data for some projects is neither confidential nor difficult to allocate among projects, then the cost effectiveness of those individual projects may be discussed.

It is not necessary to estimate the benefits of all DOC projects. The selection of a group of DOC projects whose net benefits are expected to be large is a starting point from which more projects may be added, if necessary and budget permits, until the costs of all DOC supported research are covered. If all DOC costs cannot be covered through case study benefits, an estimate will be made of how likely it is that other benefits may cover costs.

2.1.3 Incrementality

Incrementality is an important consideration in the evaluation of DOC research. It identifies the degree to which economic and social benefits and costs are attributable to DOC research.

Incrementality and Economic Benefits

The evaluation of incrementality revolves around the question as to what producers and end-user have would done in the absence of DOC research laboratories and whether "parallel" research in Canada would have occurred and produced the same results.

If parallel research in Canada would have occurred then the same set of benefits would have arisen without DOC research. In this case, DOC research would not be considered incremental. To ensure that benefits are properly captured, the case studies selected for examination were required to exhibit a high degree of incrementality.

The situation is more complex if parallel research occurs outside of Canada. Using the Canadian satellite communications industry as an example, the benefits presently derived from DOC research and the services provided by DOC would still accrue to end-users even in the absence of DOC because other such labs provide similar technology. Simply, end-users could obtain the same product and services elsewhere; thus, strictly speaking the benefits are not incremental to DOC. However, Canadian economic benefits associated with the development of a domestic telecommunications industry within Canada, and the associated domestic and foreign sales of Canadian products are incremental since without the industry these benefits would accrue to non-Canadians.

Incrementality is also important in the determination of the effect DOC research may have on the timing of research results. If, in the absence of DOC research activities, the technology would have been developed but over a longer period of time, then the benefits that would be generated would not accrue until much further into the future. Through discounting, these future benefits are assigned a lower present value than nearer term benefits. Thus if DOC conducts parallel research which affects the time distribution of benefits, then the incremental value of the research is derived from the difference in the present value of the alternative benefit streams.

In the determination of economic benefits, incrementality will be used to access the overall qualitative aspects of each case study. That is, do the benefits attributed to individual projects have a high, moderate or low incremental value? Determination of incrementality will be based on information obtained from DOC researchers, communications experts and producers.

Incrementality and Economic Costs

The determination of the incrementality of research costs depends on: whether non-DOC funds would have been spent on the same project if the DOC research did not take place; and the alternative use of the DOC funds. This opportunity costing of research expenditures, however, first requires the determination of a value of the research, which is the purpose of this study. Therefore, the determination of the incrementality of research costs is not practical within the bounds of this study and the cost of research will be assumed to be incremental.

2.2 Economic Benefits

2.2.1 Overview

Economic benefits from DOC related research can arise in different forms (lower costs, enhanced knowledge, increased productivity, increased sales, etc.), at different levels (researcher, producer, end-user) and over time (immediate benefits, future benefits or both). These economic benefits may, or may not, be quantifiable depending on the availability of data. For instance, data for the estimation of economic benefits derived from a product for which a market currently exists should be available and serve in the valuation of the benefits. Alternatively, the economic

benefits derived from the following may not be easily quantified:

- benefits derived from training research staff;
- benefits derived from enhanced research capability;
- benefits derived from improved safety in the work place;
- benefits derived from improved quality of and access to information; and
- benefits derived from enhanced environmental protection.

In addition, difficulties may arise in that the benefits derived from the sale of products or services may be quantifiable in aggregate, but they cannot be attributed to particular research activities. This can arise when benefits cannot be assigned to a specific DOC project or service because the benefits flow from a number of separate projects and allocation of benefits to specific projects is impossible. This can also arise when benefits are shared between DOC and other groups or individuals also involved in the research project.

Finally, products or services that have not as yet been placed on the market, or have not reached their full market potential, many have potential benefits that are difficult to estimate.

Because the real and potential benefits of DOC research products encompass a wide range of quantifiable and non-quantifiable benefits, each project studied must be identified and measured separately. The quantifiable benefits examined are:

- end-user benefits
  - cost savings
  - resource savings
  - improved productivity
- producer benefits
  - sales revenue
  - spin-off products
- researcher benefits
  - royalties

The techniques or procedures for estimating these benefits are discussed below.

2.2.2 End-user Benefits

Ideally, end-user benefits provide the most complete picture of total benefits flowing from a project. Unfortunately, they are typically very difficult to measure because of problems in identifying end-users and estimating individual or aggregate user benefits.

Three types of end-user benefits have been identified as quantifiable.

Cost Savings

Cost savings may occur in a production process or within business operations. DOC projects usually provide a cost savings in business operations through lower communications cost. Cost savings are estimated by measuring the difference in the costs generated by the DOC research related product relative to the costs entailed in the use of the prior product. An estimation of the market size in which these savings apply must also be determined.

Cost savings per product can be expressed as a dollar value. This can be determined through interviews with producers and end-users. The market size must be defined in order to estimate potential total cost savings. This can be achieved through information obtained from researchers, producers and

end-users and published statistics of specific industry sectors' estimated market size. Market size of the cost saving is easiest to estimate when the end-users (real and potential) are an established, well defined group.

Both the market size and the size of the end-user group will vary over time as the product evolves from initial market penetration to market saturation. To evaluate benefits, a time profile of market growth is needed. Data or estimates are required for:

- the time when maximum market size is reached;
- the pattern of market expansion; and
- the life of the product or service.

This information can be obtained from researchers and producers. For some projects market forecasts have already been made and will be used.

Most of the DOC projects examined are expected (or are likely to) generate cost savings.

Resource Savings

Resource savings are similar in concept to cost savings: the value of economically important natural resources that are saved through the use of the products are a constituent of attributable benefits. Given that our frame of reference is the Canadian society, the resources that are included within the benefit calculation involve only Canadian resources. Information on the resources used or lost before and after the product is marketed can be estimated from information obtained from producers, end-users and resource managers. The economic benefits are calculated as the total dollar value of resources saved.

DOC projects are not expected to provide significant direct resource savings. Indirect resource savings from DOC projects do exist such as through improved management of forest fire fighting using remote communications receivers and transmitters. We will examine indirect resource savings to see if they are quantifiable.

Increased Productivity

Increased productivity or efficiency benefits are generated from better use of the existing natural resource base, the labour force and the stock of capital equipment within the Canadian economy. This includes:

- the ability to provide a greater level of goods and services from given supply of natural resources, labour and capital equipment; and
- the ability to produce a given level of goods and services at a lower cost.

An estimate of the value of increased productivity also requires knowledge of the product's market size. Information on potential increased productivity are the same as for cost savings analysis: researcher(s); end-users; and purchasers.

2.2.3 Producer Benefits

Producer benefits arise from increased revenue from sales of existing products and services, and the creation of new goods and services which evolve from transferred technological knowledge.

Increased Revenue

Increased revenue can be generated by the sale of an improved product or service or from the development of new products or services. Factors that need to be accounted for when estimating increased sales include:

- attribution to the research project of only those sales generated by it;[2]
- measurement of increased sales for all producers using the technology;[3] and
- inclusion of only increased sales flowing to Canadian companies.

Benefits from increased sales are easier to estimate than end-user benefits and will be used as a partial measure of social benefits when end-user benefits are not quantifiable.

Estimates of increased sales due to DOC research will be derived from information provided by producers. Sales benefits from new communications products sold on the market are expected to be significant.

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2 Total sales revenue is the measure for new products but for improved products only the sales revenue resulting from the improvement should be included.

3 In most cases DOC technology is transferred to an exclusive rights holder. However, in some cases, as in the provision of DOC services, several companies may realize benefits from the same set of DOC developed technology.

Secondary Benefits

Secondary benefits arise from products developed from DOC research used other than for their original purpose.[4] Estimation of benefits is done as for increased sales revenue. Other benefits may accrue through improvements after the initial application of the technology, through the development of new technology based on the accomplishments of the initial DOC research and technology transfer, or through generally increased sales because of higher company prestige and visibility.

Estimation of any secondary benefits resulting from a DOC research project will be conducted from information and data collected from researchers and producers.[5] Only secondary benefits that arise in Canada and accrue to Canadians should be measured. Secondary benefits that occur elsewhere should only be measured if they result in benefits to domestic end-users or result in the good or service being produced in Canada.

2.2.4 Researcher Benefits

Researcher benefits arise from new research and technology that result from original DOC research (a spin-off effect discussed above) and royalties received by the researcher as payment for the use of the technology. License fees may also be paid.

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4 For example, DOC technology used in communications is applied in another field.

5 Spin-off products and technology can occur within DOC as well as from producers. A spin-off need not occur from the producer who holds propriety rights to the initial technology.

Conversations with DOC Branch Directors indicate that DOC technology transfers usually involve the transfer of proprietary rights to the private sector. Although DOC holds some patents, royalties or license fees are rarely received. Canadian researcher benefits will be determined from information obtained from DOC researchers and producers. Direct research benefits are not expected to be large.

2.3 Economic Costs

The costs of DOC research programs are two-fold:

- research costs of any DOC project.
- implementation costs for producers and end-users of the technology;

These costs are incurred separately. First research and development costs are incurred within DOC. Implementation costs are incurred by the recipient of DOC based technology, although DOC and IRAP funds may be involved in the implementation process.

2.3.1 Research Costs

The costs of research for any DOC project include:

- administrative costs;
- expenditure on the DOC project in question; plus
- value of the portion of any previous or subsequent DOC project that contributed to the project results; plus
- expenditures (Canadian) from other government departments and/or agencies, research institutions and the private sector that directly contributed to the project results; plus

- DOC costs directly related to the administration of the project.

Research costs of a project include all monies spent towards the research. This determines the total costs of the project to Canadian society.

The estimation of research costs for an individual DOC project is somewhat judgmental. Encompassed in any project is the cumulative knowledge from research extending back to basic scientific concepts. The research costs examined in this analysis are those that are directly incurred in the generation of specified project results. The direct contribution examined is broadly defined as the portion of previous project costs which contributed to the case study outcomes[6]. In practice this can be difficult to determine. In some cases, it may be necessary to include all costs of such previous projects if reasonable cost allocations cannot be made. This may overstate the actual cost of research for some individual projects but will provide a conservative estimate of cost-effectiveness.

Research costs on specific projects are required for the possible estimation of the cost-effectiveness or benefit:cost of project case studies (subject always to concerns of data confidentiality). This information will be obtained from the DOC.

The evaluation of the cost-effectiveness of DOC laboratories in aggregate requires an estimate of the total costs of all research. Total research costs are estimated in the same manner as individual projects. This includes:

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6 A narrow definition of research costs would be only those costs incurred by the DOC laboratories.

- value of DOC expenditures on research; plus
- value of non-DOC contributions to the research; plus
- administrative costs.

DOC information should be available from DOC files. Non-DOC research costs may or may not be available. If they are not available an estimate will be made based on the average percent contribution of non-DOC funding to the examined case studies applied to the total value of DOC research expenditures. This procedure is only an approximation and may overestimate the value of non-DOC costs since the case study projects represent "winners": these likely have higher non-DOC participation than "non-winners".

2.3.2 Implementation Costs

The implementation costs of DOC research are any costs incurred from the time the technology is transferred from the research laboratory until benefits are received by the end-users. They include all the costs incurred by the producer in providing the product or service to the end-user. This includes:

- administrative costs;
- costs of acquiring the technology;
- further costs associated with research and development of the technology and the product or service in which it is encompassed;
- testing and evaluation;
- marketing and promotion;
- capital costs (equipment, facilities) for its manufacture or set-up; and
- production costs (labour, materials) or costs of providing the service.

End-users also incur implementation costs associated with the implementation of a new technology, including:

- costs of purchasing the product or service;
- capital costs of adapting existing equipment to conform with the new technology; and
- operating costs associated with the new product.

These implementation costs are specific to each product or service that results from a DOC research project. This is a major reason for the use of a case study approach for the evaluation of cost-effectiveness.

Information and data on the implementation costs will be obtained from producers and end-users, and extrapolation to non-case study projects will be done as for research costs.

2.4 Cost-effectiveness

Estimates of the cost-effectiveness of each of the selected case studies and overall DOC research will be made. The evaluation of the cost-effectiveness of individual projects is not essential to the evaluation of the overall program. However, insights into individual projects or programs can be gained that may be of value in the determination of future research programs, and the case study methodology results in the same estimates of gross benefits and implementation costs used for the evaluation of the overall cost-effectiveness of DOC research. Individual case study cost effectiveness will be estimated for projects not subject to proprietary data concerns.

Estimates of cost-effectiveness are based on consistent information on benefits, implementation costs and research

costs for all projects. Simply, all attributable benefits and costs of each project must be estimated according to the criteria and guidelines outlined above. These estimates will be converted into a common base year, 1986, to provide a real dollar estimate and discounted to 1986 present value (PV) equivalents using a social discount rate.[7]

2.4.1 Cost Effectiveness of Individual DOC Research Projects

The net benefit of a particular DOC project is equal to:

- PV of gross benefits; minus
- PV of implementation costs; minus
- PV of research costs.

If the resulting value is non-negative, the project is deemed cost-effective. If the value is negative, the project may or may not be cost-effective.

A project can still be considered cost-effective though the quantitative result outlined above is negative since some quantitative aspects may be impossible to estimate (e.g. diffuse end-user benefits), or qualitative aspects (e.g. enhancement of knowledge, etc.) are excluded and may be highly valued. In the event of negative results, a sensitivity analysis will be conducted to determine the sensitivity of our conclusions to a variety of factors.

Note that for reasons of confidentiality and difficulty in allocating benefits and costs among various projects that may have contributed to a final product, it is likely that only a

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[7] The appropriate social discount rate will be determined through consultation with DOC officials.

few individual projects can be assessed for cost effectiveness.

2.4.2 DOC Program Cost-effectiveness

The evaluation of the cost-effectiveness of overall DOC research is the same as for individual project cost-effectiveness except all DOC project research costs are substituted for individual project research costs. Therefore, the net benefit of all DOC research equals:

- PV of gross benefits case study projects; minus
- PV of implementation costs of case study projects; minus
- PV of total costs of all DOC research.

The program is cost-effective if net benefits exceed zero. The overall benefits of the program may be negative since the gross benefits of all DOC research projects will not have been estimated. Budget permitting, the evaluation of additional research projects' benefits will be attempted should this occur. In addition this procedure does not account for qualitative aspects of DOC research. The key to our final conclusion will come from an estimate of whether non-quantified and qualitative benefits are likely to be sufficiently large to cover costs not covered by the case study benefits. These non-quantified, qualitative benefits will be described for the most important projects.

3.0 CRITERIA FOR SAMPLE SELECTION

The nature of the activities conducted within the DOC research laboratories may be roughly dichotomized into a research function and a service function. The research conducted within the laboratories is largely project driven, and is often conducted in conjunction with universities and/or private industry. Service activities are generally concerned with technology transfer, ranging from short-term consultation to government and industry, to facilitation of product/component testing, and product review and marketing.

In order to conduct the cost-effectiveness analysis, we will employ a case study approach which requires selecting a sample of research projects from the historical population of DOC research activities which would adequately reflect the activities of each research Branch. Following an extensive series of interviews with the Directors General of the various Branches, the Directors of the various Directorates within each Branch, and a number of project managers, an initial sample of projects was collected. Our final sample was drawn from this collection through a comparison of each project on the following indicators:

i) Incrementality: the research entailed within the selected project, and the resulting economic benefits, had to contain a unique characteristic which could be directly attributed to a DOC research activity. Research activities which were largely a replication of existing research activities by other government organizations or private concerns were excluded from the sample unless the activity significantly affected the time horizon over which results were to be expected.

ii) Uniqueness: the DOC research laboratory had to provide a unique and significant contribution in terms of the research conducted or the service provided in order to have the project included within the sample. Research activities performed in conjunction with other government organizations (such as the National Research Council) and/or university research departments were generally excluded due to the difficulty entailed in attributing resulting economic benefits to distinct research activities. In most such cases, DOC contributed money towards the activities but virtually no actual research time and only limited consulting time; deciding the importance of DOC's role in these instances would be very complex and unfeasible within the scope of this study.

iii) Identifiable Benefits: the selected DOC research projects had to maintain a strong and identifiable link to a series of identifiable economic benefits. DOC/CRC projects which could only be related to a continuum of potential benefits were generally excluded due to the element of arbitrariness that is involved.

iv) Large Quantifiable Benefits: in addition to the requirement that the selected research projects exhibit links to identifiable economic benefits, we also required that the economic benefits generated by the research project be quantifiable and large. This requirement has caused us to select projects exhibiting commercial potential and to select a majority of our sample from past rather than current DOC research projects. This in no way implies that we do not foresee a number of benefits

arising from current DOC activities, but rather that it is too early to reliably estimate those benefits.

v) Non-Department of Defence Projects: to avoid confidentiality restrictions, and the difficulty they impose in gathering hard data on economic benefits, we have restricted our sample to non-defence projects except for the rare instance where the project may be defence-related but not classified.

Through the interview process we were able to gain information on forty individual research projects. By carefully considering each project with reference to the five indicators mentioned above, we were able to consolidate our initial sample to nineteen projects. It should be noted that although we have identified a tentative sample of nineteen projects, a number of these contain a subset of further projects which could potentially be included within the sample as distinct case studies. For example, we shall be considering the Telidon program which has produced a number of interesting technological advances such as the North American Presentation Level Protocol Syntax (NAPLPS), the Videotext system and the Teletext system, each of which could potentially be considered as a separate case study. Yet, due to the overlap in technical knowledge which produced these advances, it is more appropriate to begin the analysis with an evaluation of the initial research as it was initiated through the Telidon program. This same reasoning applies to our selection of portions of the MSAT program and the David Florida Laboratory as distinct case studies.

Note that there is potentially some confusion over the terms "project" and "program". In some instances a case study will

involve a "project": that is, a relatively small, discrete activity with only a few outputs. In other instances a "program" may be studied: that is, a relatively large and complex set of activities with a potentially large set of outputs. So long as they satisfy the criteria above, both types of case study may be equally well studied.

Furthermore, it should also be noted that, although every effort consistent with this phase of our study has been made to ensure that our tentative sample will suffice for the purposes of this study, we may have to exclude an additional number of projects from our sample due to factors such as an inability to gain reasonably objective information, or the unwillingness of private companies to release proprietary data, even though all benefits data.

4.0 TENTATIVE SAMPLE

The following projects have been selected for inclusion as case studies because they best satisfy the criteria discussed in Section 3.0.

1) **HF Data Mini/Maxi Terminals:** DOC/CRC has successfully transferred its existing HF terminal technology (which is required for low-cost HF voice communications) and is continuing to develop the technology. The "Mini-terminal" (300 baud) technology has been acquired by Ultimateast Data Communications Ltd. in St. Johns, Newfoundland and forms the basis for their "DATAHAIL" systems and related communications systems. RACE Technologies in Victoria, British Columbia received the "Maxi-terminal" (1200 baud) technology which is incorporated within their communications products.

2) **Voice Compression Technology:** DOC/CRC has successfully developed Linear Predictive Coding Voice Compression technology which takes advantage of the redundancies and constraints of speech reproduction and perception to encode and transmit speech economically. The voice compression technology is being transferred to Spilbury Communications Ltd. of Vancouver, allowing Spilbury to develop a low-maintenance Digital Voice Logger System to record incoming and outgoing phone calls.

3) **Common Visual Space Network (CVSNET):** The CVSNET technology allows for three or more graphics terminals to be linked interactively, and allows for alterations entered at one terminal to be transmitted to all other terminals within the linked system. DOC/CRC has successfully developed and subsequently transferred its

CVSNET technology to IDON Corporation and Crawley Recherche Ltee. who are interested in its possible applications within training and instruction environments.

4) **FET Amplifiers:** in conjunction with the NASA/DOC Hermes Communications Satellite Program, DOC/CRC developed the first GaAs field-effect-transistor (FET) amplifiers to fly in space. Such components are now common on communications satellites as well as all earth terminals.

5) **E-Plane Technology:** in 1978, DOC/CRC initiated research into a new EHF circuit technology known as E-Plane. The resulting technology has been transferred to industry, including the design and fabrication technology required for the development of E-Plane passive components transferred to Bolriet Technology Ltd, and technology for high power millimeterwave components transferred to Mitec Ltd. The transfer of E-Plane technology has also permitted a third firm to capture a major segment of the Radar Warning Receiver market, and is currently aiding in enhancing the product base of a fourth.

6) **Monolithic Microwave Integrated Circuits (MMIC):** in 1981, DOC/CRC initiated research in MMIC development and in 1985 realized the first all Canadian MMIC. This technology is currently being used to support one company in the development of foundry capabilities, and has successfully assisted several firms in the development of component design capability.

7) **Low-Cost Video Satellite Receiver:** DOC/CRC has successfully transferred the required technology for the development of the low frequency portion of Direct-to-

Home Television Receive-Only (DTH TVRO) terminals to NEXUS Engineering.

8) **Direct Broadcast Satellite TVRO Terminal:** DOC/CRC has successfully transferred the microwave design technology for DTH TVRO frontends to Beltronics Ltd.

9) **Surface Acoustic Wave Devices (SAW):** DOC/CRC conducted the initial research and development, design, fabrication and testing of surface acoustic wave devices which filter HF communications. Design and fabrication technology for SAW devices has successfully been transferred to ComDev Ltd. of Cambridge, Ontario allowing ComDev to develop not only SAW devices but also general microelectronic and component fabrication abilities.

10) **Optic Fiber Coupler Program:** DOC/CRC has successfully developed the Optic Fiber Coupler which has proven to be the major contribution by Canada to optics communications technology and has become the preferred mode of combining visual communications. The technology is held under patent with CPDL, who has licensed Canstar Communications to produce the product. The optic fiber coupler is now actively used by AT&T, Bell, and British Telecom.

11) **Design Technology For High-Quality Photomasks:** DOC/CRC has successfully developed and transferred the GaAs technology and the computer-aided design techniques required for the development of state-of-the-art photomasks which are crucial to the fabrication of microelectronics. Precision Photomask Ltd. is the industrial recipient of this technology.

12) **Narrow Band Digital Voice Technology:** The MSAT program was initiated to foster the development of a satellite-based mobile communications service. In order to provide cost effective communications on land, air and sea terminals, cost-effective mobile radios had to be developed at CRC which would use power and band spectra efficiently and allow for the economic viability of MSAT communications. The resulting research in narrow band digital voice technology led to the development of the "Vocoder". The Vocoder radio technology has been transferred to Glenayre Electronics and SkyWave Electronics and the radio systems are currently undergoing field trials with the Ontario Air Ambulance Service. The Vocoder radio technology is being further developed for application in helicopters and for the development of air traffic control satellite terminals.

13) **Telidon:** The Telidon program was initiated for two general purposes:

i) to develop a coding system for the transmission of visual and graphic data; and

ii) to transmit a text/graphic information service to Canadian homes and businesses by phone-line and broadcast.

The Telidon program as a whole will be treated as a case study with special attention being directed towards the development of the following technological achievements which emerged from the Telidon program:

A) **North American Presentation Level Protocol Syntax (NAPLPS):** DOC/CRC developed a sophisticated and efficient coding structure

within the Telidon program (the NAPLPS code) for storing and communicating graphic, visual and text data over transmission lines.

B) **Videotex:** through the use of personal computers and special terminals, users are able to receive, over existing transmission lines, up-to-the-minute information displayed in clear text and graphics. Videotex is based on the Telidon/NAPLPS coding structure and forms the basis of the current ALEX trials being conducted in Montreal by Bell.

C) **Teletext:** the teletext technology enables television broadcasts to carry data communications signals without adversely affecting television reception.

14) **Foundry Access Program:** Proposed initially to the Department of National Defence in 1985, the Foundry Access Program is intended to address apparent fabrication deficiencies within the Canadian electronics industry. DOC's intention was to instruct and train interested firms, provide fabrication equipment, fabrication shops, access to foundries and access to DOC/CRC personnel. Eight companies are currently participating in the program, including ComDev, MPR, SPAR, PRL, Canadian Aeronautics Ltd., Telesat and Beltronics.

15) **Research Partnerships:** DOC has recently initiated a Research Partnership Program to allow for joint research and development between the CRC and interested industrial parties. Although a number of partnerships have been approved or are currently being negotiated, we

shall evaluate the following individual partnership as being the most promising for our purposes:

. CRC/NovAtel Communications Ltd.: The CRC and NovAtel signed a memorandum of understanding in January, 1988 to conduct joint research and development with respect to:

  i) monolithic microwave technology;
  ii) UHF power amplifiers; and
  iii) in-building communications.

16) **David Florida Laboratory (DFL):** the DFL is Canada's national facility for spacecraft assembly, integration and testing. The DFL generally does not initiate research projects; rather, its primary function is to make its facilities available on a cost recovery basis to the Canadian and foreign aerospace and communications communities for use on domestic and export projects. In addition, the DFL does make its facilities available to general industrial users as a vibration and environmental testing facility. Given that the DFL is primarily a provider of service, we were unable to uncover any well-defined projects to include within our analysis. Yet, the DFL has contributed significantly to the development of the Canadian aerospace and satellite communications industries. Thus, we have decided to treat the DFL in its entirety as a case study, while paying particular attention to the role of the DFL in the development of ANIK-C2, D1 and D2, CANADARM, and Brazilsat S1 and S2.

17) **Suitcase Satellite Terminal:** DOC/CRC developed the concept and the initial prototype of a field voice access mobile satellite station providing reliable satellite communications wherever Ku band satellite

coverage is available. The necessary technology was transferred to SkyWave Electronics Ltd. who further developed and subsequently marketed the product. The key to the product is the baseband unit, a portable amplitude companded single sideband/differential shift keyed (ACSSB/DMSK) satellite channel unit. The amplitude companded single sideband voice-modem modulation technology, which allows for a substantial reduction in satellite usage cost (or antenna size) and forms the basis of the unit was initially developed by the DOC/CRC. The technology was transferred to SkyWave Electronics Ltd. The terminal is currently being used by the Ontario Ministry of Natural Resources and Northern Development, Ontario Hydro, Ontario Provincial Police, and the Department of National Defence.

18) **Visual Handicap System (Nightstar):** Development of software to support a computer system for the visually impaired.

19) **Satellite News Gathering (SNG):** The DOC/CRC, acting on a request from the Canadian Broadcasting Corporation, developed the technology and designed and built a prototype mobile satellite dish. The DOC/CRC was the first in the world to develop the mobile dish, which Telesat currently produces commercially.

We had earlier proposed using the MSAT program as a case study. We now believe this program to be too new, and to have benefits which are likely to be too diffuse, to allow reliable estimation of benefits. We have, however, included two portions of MSAT work - vocoder and suitcase satellite terminals - as case studies numbered 12 and 17 above, respectively.

We have attempted to select case studies from all Branches as shown in Exhibit 4.1. As may be seen there, however, the number of studies is proportionally high for the Communications Devices and Components Reliability Branch, and low for the Office Automation (CWARC/CCRIT) and Space Technologies Branches. This reflects the nature of the work done by different Branches (and for CWARC, its short time in existence) rather than the success of the projects completed.

EXHIBIT 4.1: REPRESENTATION OF BRANCHES AMONG CASE STUDIES (MOST IMPORTANT BRANCH SHOWN FOR EACH STUDY)

Case Study #	Branch				
	Broadcast Technologies	Communications Devices & Components Reliability	Communications Technologies	Office Automation	Space Technologies
1	x				
2			x		
3	x				
4		x			
5		x			
6		x			
7		x			
8		x			
9		x			
10		x			
11		x			
12			x		
13	x				
14		x			
15		x			
16					x
17			x		
18				x	
19			x		

5.0 DATA COLLECTION

The data and information required for the evaluation can be obtained through the use of a comprehensive questionnaire and interview process involving the key individuals and firms of each case study. The data sources are:

- DOC Branch Directors and DOC employees directly linked to specific research projects;
- individuals and private sector firms involved in the development and use of the DOC project results; and
- other government departments and agencies involved with DOC in research or recipients of DOC research.

Further information on the communications industry, economic sector profiles and market structure will be obtained from statistical sources, IRAP reports and market studies conducted for the implementation of specific DOC-based technologies.

DOC researchers will be surveyed first. They will be asked to provide information on actual or potential producers and end-users as well as limited data on benefits and costs. To aid in this task, they will be mailed a questionnaire (see Appendix A) some time before a personal or telephone interview. Producers will be subsequently interviewed. Based on information provided by the researchers and producers, end-users will be surveyed.

The questionnaire for the researcher covers the following subject areas:

- type of end product or service;
- extent to which the project would have been carried out

in the absence of DOC laboratories;
- cost of the research;
- effect of DOC laboratories on industry research and development;
- possible negative effects of the research program; and
- commercial applications arising from the research.

The questions for the producers of products or services encompassing the DOC research results deal mainly with:

- cost of implementation of the research results;
- expected effect of the research results in the firm's growth and viability as a result of the research;
- expected market potential; and
- extent to which the research results would have been carried out in the absence of DOC laboratories.

Finally, identified end-users will be asked:

- cost of acquisition, implementation and maintenance of the technology;
- expected cost savings or productivity improvements due to the new technology;
- alternative product options;
- interaction with DOC laboratories and producers; and

Producers and end-users will not be mailed questionnaires as our previous experience indicates they are too busy to complete them. Instead, interviewers who are experienced with the economic methodology to be employed and the type of data required will conduct telephone interviews (or personal interviews in the Ottawa and Vancouver area) with respondents named by the DOC researchers. An interview guide is found in Appendix B. A very similar guide was successfully used in the review of NSERC's Strategic Grants Program.

Effort will be concentrated upon projects which seem to have the largest quantifiable benefits for which reliable estimates can be found. The degree to which complete information can be gathered for all case studies will be determined by factors such as the study budget, the reliability and availability of data, and the willingness of private firms to divulge information. Some proposed case study projects may turn out, in fact, to be unusable because of such limitations when studied in detail.

APPENDIX A

QUESTIONNAIRE FOR RESEARCH PARTICIPANTS

QUESTIONNAIRE FOR DOC RESEARCH PARTICIPANTS

BASIC INFORMATION;

Name: _____
Title: _____
Branch and Directorate: _____
Telephone: (_____)_____

Listed below is a DOC research project for which you were/are involved as a researcher. The following questions refer to this project and the subsequent implementation of projects using that technology.

Project/Technology:_____
_____
_____
_____
_____

BACKGROUND

1. In this study, we are trying to determine the economic impacts of research supported by DOC. As a starting point, please briefly describe **in layman's terms:**

   a) The results of your DOC project_____
   _____
   _____
   _____

   b) The application(s) of your DOC project_____
   _____
   _____
   _____

   If you require more space, please use the back of this page.

2. Dates of research: From _____ (month) _____ (year)
   To _____ (month) _____ (year)

3. What were the major other DOC research projects (if any) that contributed information or technology to the project under discussion?

   _____
   _____
   _____
   _____

4. What industry or other group (.e.g, a government agency) has been or will be the main users of the results of this project?

a) Please be as specific as possible (e.g., specify "radar detector manufacturers" rather than "electronics")

_____
_____
_____
_____

If you require more space, please use the back of this page.

b) Are the results of your DOC project applicable to the whole industry or group specified above?

Select one and enter (1, 2 or 3) -> [ ]

(1) Yes
(2) Don't know
(3) No

What portion?_____
_____

CONTACTS

5. What other government/agency (if any) participated significantly in the research project?

1. Name:_____
Position:_____
Company/Organization:_____
City:_____
Telephone:(____)_____

2. Name:_____
Position:_____
Company/Organization:_____
City:_____
Telephone:(____)_____

6. What industry firm (if any) participated in the research project?

   1. Name:_____
      Position:_____
      Company/Organization:_____
      City:_____
      Telephone:(____)_____

   2. Name:_____
      Position:_____
      Company/Organization:_____
      City:_____
      Telephone:(____)_____

7. To what industry firms (if any) has this technology already been transferred:

   1. Name:_____
      Position:_____
      Company/Organization:_____
      City:_____
      Telephone:(____)_____

   2. Name:_____
      Position:_____
      Company/Organization:_____
      City:_____
      Telephone:(____)_____

   3. Name:_____
      Position:_____
      Company/Organization:_____
      City:_____
      Telephone:(____)_____

   4. Name:_____
      Position:_____
      Company/Organization:_____
      City:_____
      Telephone:(____)_____

8. Have you discussed the application of this technology with representatives of any other industries or groups not specified in Question 7 (i.e. other potential users)?

1. Name:_____
   Position:_____
   Company/Organization:_____
   City:_____
   Telephone:(____)_____

2. Name:_____
   Position:_____
   Company/Organization:_____
   City:_____
   Telephone:(____)_____

3. Name:_____
   Position:_____
   Company/Organization:_____
   City:_____
   Telephone:(____)_____

4. Name:_____
   Position:_____
   Company/Organization:_____
   City:_____
   Telephone:(____)_____

9. Does any one company have the responsibility of promoting the commercial application of your results?

Enter Y or N -> [ ]

If Yes, please specify name of company and contact person, address and telephone number.

Company Name:_____
Contact person:_____
Address:_____
_____
Telephone (____)_____

10. Have economic or market analyses (including a prospectus for investors) been undertaken for products or services embodying the results of your project?

Enter Y or N [ ] If No - go to Question 11
If Yes, continue

From whom may we obtain a copy of such analyses?

1. Name:_____ Position:_____
Company/Organization:_____
City:_____
Telephone (___)_____

2. Name:_____ Position:_____
Company/Organization:_____
City:_____
Telephone (___)_____

TYPES OF BENEFITS EXPECTED

11. What are the important economic benefits to industry or government users of the results of this project? Please indicate order of importance in the list below by marking 1 for the most important, marking 2 for the second most important, and so on.

_____ Cost Savings
_____ Increased sales revenue, with no change in product or service
_____ Increased sales revenue, as a result of new product or service
_____ other (specify)_____
_____

What are the other benefits to Canada of this project? Please indicate order of importance in the list below by marking 1 for the most important, marking 2 for the second most important, and so on.

_____ Environmental enhancement
_____ Reduced health and safety risks
_____ Improvements in quality of life
_____ Improved quality of and access to information
_____ Other (specify)_____

12. If cost savings are expected, what cost items are or will be affected by this technology?

_____
_____
_____

Can you give us an indication of how much these costs have been reduced (e.g., as costs per year, as a percentage of total costs, as a percentage of selling price, or as dollars per unit of product or service sold)?

_____
_____
_____

13. If increased revenues are expected, can you give us an indication of how much these revenues have been or will be increased (e.g. as revenue per year, as a percentage of total revenues, as a percentage of selling price, or as dollars per unit of product or service sold)?

_____
_____
_____

14. Has this project already had commercial applications?

Enter Y or N [ ]

If yes, when were results first applied commercially by industry or in the public sector (e.g., for health protection, environmental enhancement, resource management)?

Specify year [ ]

If no, how likely is it that some of the results of your project will be applied in the future by the industry/group specified in Question 4?

Specify and enter (1,2,3,4,5 or 6) for each period.

Within the next year	_____	(1)	very likely
Within the next 2 years	_____	(2)	moderately likely
Within the next 5 years	_____	(3)	50/50 chance
Within the next 10 years	_____	(4)	moderately unlikely
Within the next 20 years	_____	(5)	very unlikely
Never	_____	(6)	don't know

COSTS OF IMPLEMENTING RESEARCH RESULTS

15. Once results have been obtained, certain costs may be necessary to make the results known and available to potential industry and government users. What kinds of expenditures are necessary (by you, or associates of yours, or a "middleman") before industry and government are likely to apply your results?

Check all that apply or enter "DK" (don't know) -> ☐

_____ None
_____ Further research and development
_____ Test production (e.g., proto-type production)
_____ Promotion
_____ Other (specify)

If you have estimates for any of these other costs, please provide them below:

Further research and development_____
Test production _____
Promotion_____
Other_____

16. In order to obtain the economic benefits discussed in the previous section, what kinds of implementation costs would the industry or government user incur?

Check all that apply or enter "DK" (don't know) -> ☐

_____ None
_____ Fees for acquisition and use of research results
_____ Further research and development
_____ Marketing
_____ Installation and equipment (e.g., new equipment or retooling)
_____ Labour
_____ Materials
_____ Other. Please explain._____
_____
_____
_____

17. Do you have estimates for any of the costs listed in Question 16? Costs should represent only those attributable to implementation of the research results.

Enter Y or N -> [ ] If No, - go to Question 18
If Yes, continue

a) How much does it cost to acquire and be able to use the results of your project (e.g., royalties, licence fees)?

Select one and enter (1, 2, or 3) -> [ ]

(1) [$] (Please specify the basis of this cost, e.g., dollars per unit or one time charge)._____

(2) Nothing
(3) Don't know

b) How much is or will be spent by industry and government users on further research and development in order to apply the results of your project?

Select one and enter (1, 2, or 3) -> [ ]

(1) [$] (Please specify the basis of this cost, e.g., dollars per unit or one time charge)._____

(2) Nothing
(3) Don't know

c) If you have estimates for any of the other implementation costs, please provide them below:

Marketing_____
Installation and equipment_____
Labour_____
Materials_____
Other_____

ADOPTION AND DISTRIBUTION OF RESEARCH RESULTS

18. The life cycle of a new product, technique or innovation has several different milestones:

Start-up: Start-up is the time when concrete action is initiated to commercialize the research results or to bring results to the user group. At start-up, marketing strategies may be initiated, production facilities and operations planned, etc.

Initial Application: Initial application refers to the time when the research results are first applied (.e., put into use) by the user group.

Maximum use: Market saturation is the time when the research results have been widely dispersed through the user group and have become the "industry norm." After market saturation, use of the research results increases with the general growth in the industry/user group. Maximum use generally occurs sooner where the new product, technique or innovation is easily transferred and applied by the user group.

End of product life: End of product life refers to the time when the research results are no longer in use, having been replaced or significantly modified by new products, techniques or innovations.

For the results of your DOC project, please estimate the year in which each milestone is likely to occur or has occurred. Call the start-up year "Year 1."

Select one code and enter (1,2,3,4, etc.) for each milestone (e.g. year 10 is code 8).

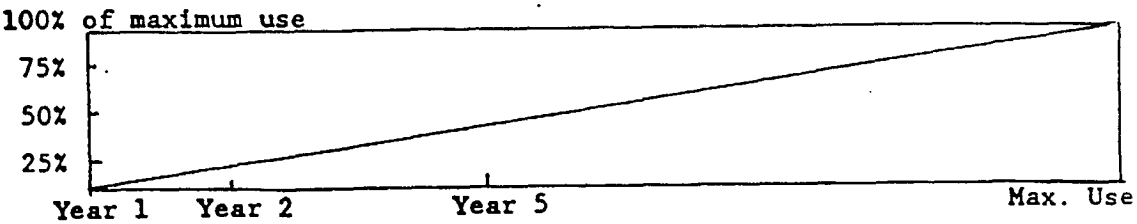
(1)	Year 1	(8)	Years 9 and 10
(2)	Year 2	(9)	Years 11 and 12
(3)	Year 3	(10)	Years 13 or 14
(4)	Year 4	(11)	Years 15 - 20
(5)	Year 5	(12)	Years 21 - 25
(6)	Year 6	(13)	Years 26-30
(7)	Years 7 or 8	(14)	after Year 30
		(15)	Don't know

Start-up __1__ Market Saturation _____
Initial Application_____ End of product life _____

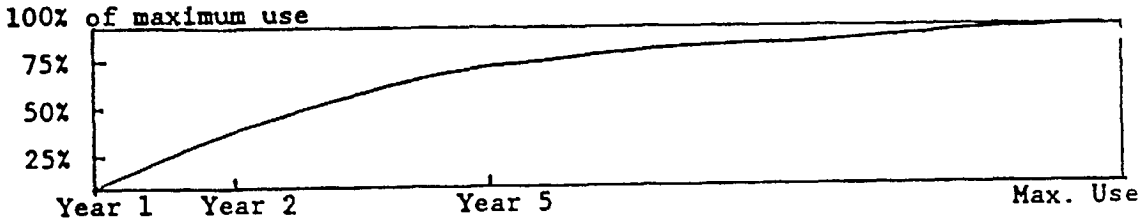
19. Please choose what you think is the most likely pattern of adoption of your research results by the industry or group specified in Question 4.

Select one and enter (1,2,3, or 4) ->

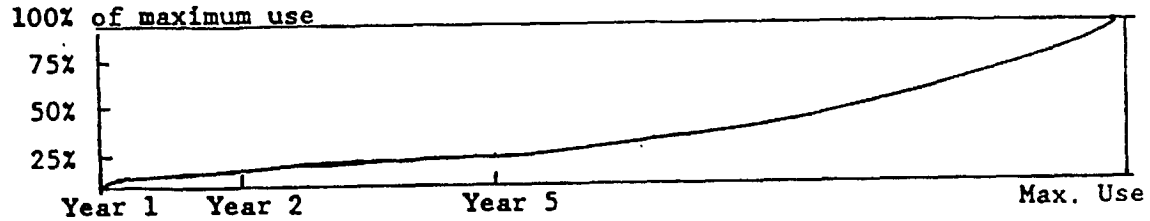
1.



2.



3.



4. Don't know

20. Are the results of your project likely to generate new export revenues for Canada either as a result of fees for the acquisition and use of the research results or through new sales of products or services embodying those results?

Select one and enter (1,2 or 3)->

(1) Yes
(2) No
(3) Don't know

INCREMENTALITY

21. Are you aware of similar research that was being carried out independently on this topic at the same time?

Enter Y or N -> [ ] If no - go to Question 22
If yes, continue

Was this parallel research being carried out in Canada?

Enter Y or N -> [ ]

22. What proportion of these research results would have been generated to date (by other researchers) if DOC labs had not worked on this topics?

Select one and enter (1,2,3,4 or 5) - [ ]

(1) None
(2) A minimal amount
(3) A moderate amount
(4) Most
(5) All

23. In the absence of the DOC program, would the same research results have become available at the same time?

Enter Y or N -> [ ] If yes go to Question 24
If no, continue

The same results wouldn't have become available until [ ] (fill in)
year(s) later.

24. Do you have any other comments or information on the economic relevance of your DOC project?

_____
_____
_____
_____

FINANCIAL INFORMATION

25. What is the total amount the research project cost, by category of funding? (note: DOC costs should include effort by all Directorates involved in this project. To nearest thousand dollars only.

	Provided by DOC		Provided by Other Agencies		Provided by Industry	
Year	Cash	In-Kind	Cash	In-Kind	Cash	In-Kind
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______
Total	________	______	______	______	______	______

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

Please return it to:

Mr. John Martin
The DPA Group Inc.
Suite 800
220 Laurier Avenue West
Ottawa, Ontario K1P 5Z9

APPENDIX B

DRAFT INTERVIEW GUIDE FOR PRODUCERS AND END-USERS

DOC PRODUCERS/END-USERS INTERVIEW GUIDE

NAME _____
COMPANY _____
PROJECT _____

1. RESULTS/APPLICATIONS

---

2. ECONOMIC IMPLICATIONS
   - benefits
   - users
   - substitutes

---

3. ECONOMIC BENEFITS
   TO MEASURE

---

4. STAGE OF APPLICATION
   - when applied
   - researcher involved
   - diffusion method
   - further work required

---

5. GROSS BENEFITS
   - unit benefits
     - sales
     - user benefits
   - timing
   - market size
   - incrementality
   - estimate benefits

---

6. COSTS OF IMPLEMENTATION
   - promoter/manufacturer
   - user
   - total

---

7. COSTS OF RESEARCH
   - project funding
   - previous funding
   - timing
   - grand admin.
   - incrementality
   - research costs

---

8. B/C