TELECOMMISSION

Study 4(b)

Research and Development Policies and Programs

The Department of Communications

TELECOMMISSION STUDY

4 (b)

1. RESEARCH AND DEVELOPMENT POLICIES AND PROGRAMS

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This Report was prepared for the Department of Communications by a project team made up of representatives from various organizations and does not necessarily represent the views of the Department or of the federal Government, and no commitment for future action should be inferred from the recommendations of the participants.

This Report is to be considered as a background working paper and no effort has been made to edit it for uniformity of terminology with other studies.

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Research and Development Policies and Programs

Introduction

This report has been organized into two general investigations, one quantitative and the other qualitative. The quantitative part which is contained in Chapter 1 consists of an examination of the level of research and development (R&D) activity in the communications sector in Canada. Communications and particularly telecommunications is perhaps unique in that there is a high level of activity conducted in the universities, by industry and by government. R&D expenditures as a percentage of total sales of manufactured products is perhaps higher in the telecommunications industry than in any other secondary manufacturing field in Canada. Our study suggests that this is the result not only of the structure of the industry, with the relatively few and vertically integrated groupings in the telephone field, but also results from the accumulated expertise particularly of that part of the industry utilizing electronics technology. It also reflects the very high rate of change and development which has taken place in the sector.

The qualitative portion of this study which is covered in the last four chapters of the report constitutes an attempt to appraise the effects of R&D and to judge whether current policies and programs are adequate or contributing effectively to the development of both scientific knowledge and Canadian industry's capacity to maintain a high technological level of competence in the communications field. To specialize, even to focus particularly on one sector, was difficult but offsetting this difficulty was the constant realization that generalization by the Project Team would result in very shallow findings when compared to the scholarship that has gone on in this field in Canada in recent months. The Project Team was aware of the work undertaken by and for the Science Council of Federal Government in the Support of Research in the Canadian Universities. Many of the members of the Project Team had participated at various levels of the work of the committee of the Senate investigating science policy (Lamontagne Committee) and there was at times a feeling that perhaps too much has been added to the rhetoric of science policy and not enough emphasis has been placed on the examination of the mechanics of its implementation.

During the course of the discussions which resulted in the drafting of this report there was a recurring debate as to the relationship between R&D and the fabrication of new products for telecommunications systems. At various times it was suggested that the key to development was not research but innovation or perhaps more properly the economics of applying technology which is available. While there was no profound examination of the innovative cycle as it applied to the communications sector, the TCTS representative suggested that the organization and structure of an industry had a great determination on the ability to innovate and apply new technological processes. In the final analysis there was no clear cut consensus whether the fruits of research were either predictable or whether the level and activity of research could be accurately related to the product cycle of any industry dealing in communications products or services. Like many other study groups this one was left with the enigma of not knowing whether research results can be optimized through planning or whether its creative aspects leave it essentially a non-predictable happening.

Notwithstanding the large caveat on the certainty of the pivotal role of research and development in the production cycle, the Project Team did take a look at future requirements. This was done with the realization by the members of the group that companies in the communications sector must be technologically competent and, if they are to remain competitive, must also be able to anticipate technological change. Technology is global and the competition is not confined to a supplier's domestic or protected market. To this point research and development activity has to some measure been able to aid in the anticipation of technological change. There was some suggestion that other dimensions in addition to technological research and development must be isolated and analyzed by decision makers if there is to be accurate evaluation of future requirements for communications services.

Chapter 1

A Review of Present Communications Research and Development Activity in Canada

1. Research and development in communications in Canada is a multi-million dollar business. It is estimated that total activity in 1969 was in excess of $94 million. Precise figures are difficult to obtain because of problems of definition, competitive security, and lack of current information. However the following is a reasonably well informed estimate of the situation.

A rather broad definition of research and development relevant to communications is used; in general it includes any research for which a potential telecommunications application can be foreseen, even though the application may not be immediate. It also includes research into devices and techniques that may be used in telecommunications systems or equipment.

1.1 The level of communications R&D activity in Canada

1.1.1 Government - supported research and development

The government supports communications R&D in government laboratories, in industry and in the universities.

1.1.1.1 Intramural

The bulk of the in-house government R&D is provided by the Communications research Centre of the Department of Communications. The CRC has an annual budget of about $7.5 million for in-house research, and about $4 million for contracts (primarily spacecraft development). The main areas of research are Communications, Satellite Technology, and Research supporting Radio Spectrum Management (see appendix A for details).

1.1.1.2 Grant programmes to industry

There are several categories of government aid programs that foster research and development in communications; Defence Industry Productivity (DIP), Program for the Advancement of Industrial Technology (PAIT), Defence Industrial Research (DIR), Industrial Research Assistance Programs (IRAP), and Industrial Research and Development Incentives Act (IRDIA). Under these programs the industrial recepient is usually required to make a contribution at least equal to the government grant (see appendix B).

In 1967, the last year for which information is reasonably complete, approximately $82 million in communications research and development was carried out in industry. For that year, government grant programs paid for some $22 million worth of the work and government contracts for about $4 million. It appears that the 1969 figures will be approximately the same as those for 1967.

These figures are expected to be accurate to about 10%. (see appendix C)

1.1.1.3 Grants to Canadian universities

The major granting agencies are NRC and DRB; additional grants are provided by other sources, but the amounts are relatively small. During 1967-68, the support to universities for research was as given in Table 1. This is for research in the physical sciences and engineering; the sources of communications research support are expected to be similar.

Table 1

Research Support to Universities in 1967-68

NRC	75%
Other government agencies	9.6%

Industry	3.4%
Private foundations	10.2%
University funds	1.7%

For purposes of this study the government university grants for research that is judged to be of communications interest have been divided into three categories; direct, long term, and very long term relevance (see appendix D for definitions). The level of communications research and development during 1968-69 is given in Table 11.

Table 11

Grants to Universities for Communications R&D, 1968-1969

Very long term relevance	$ .66 million
Long term relevance	$1.93
Direct relevance	$2.15
Total	$4.74 million

1.1.1.4 Summary

The total government funded research and development in communications in 1969 was:

Intramural	$ 7.5 million
Industry	$ 26.
University	$ 4.7
	$ 38.2 million

More detailed analyses of the distribution of these funds are given in appendices E and F of this study.

1.1.2 Industry - supported research and development in communications.

It has been difficult to obtain accurate figures for the amount of industry-supported R&D, partly because problems of definitions and partly because of the difficulties in making a comprehensive survey. For this study figures were collected from two sources; from the R&D reported under the government aid programs of Industry Trade and Commerce (IT&C) and from a special survey carried out by the Electronics Industries Association of Canada (EIAC). Neither source is expected to give the complete picture, since some companies may not apply for government grants, and hence not be covered in the IT&C figures, and since the EIAC survery may not completely cover all the communications industry.

The level of R&D in the electrical & electronics industries supported by government programs in 1969 is summarized in Table 111, and is derived from the IT&C figures, (see appendix C) and from the addition of known government contracts ($4.0 million).

Table 111

Level of R&D in the Electrical & Electronics Industries		Financed by government support programs	
Commercial applications	55.5	Government aid	$16.8 million
Defence	20.6	IRDIA	5.2
Space and Communications	1.4		22.0
	$77.5	Government contracts	4.0
			$26.0 million
Government contracts	4.0		
TOTAL	$81.5 million		

The EIAC survey (see appendix G) indicated that the R&D expenditures in Canadian industry for the past three years were:

Year	Total expenditure
1967	$ 50.5 million
1968	$ 48.7 million
1969	$ 60.6 million

The two sets of figures do not agree, for the reasons stated above. However, one item is clear from both the IT&C and EIAC figures: about $49 Million were spent on telecommunications R&D supported directly by the telephone industry. The major portion of Canadian R&D in the communications sector is performed by business organizations that are corporately integrated and which have a manufacturing capability to support their service functions (see Appendix H).

Table 1V

Communications R&D in Canada

Government financed R&D

Intramural		$7.5 million
In-Industry		
Aid Programs	$16.8 million	
IRDIA	5.2	
contracts to industry	4.0	
	$26.0 million	26.0
Grants to Universities		4.7
	Total	$38.2 million
Industry financed R&D	approx.	$56.0
Total R&D effort		$94.2 million per annum

Total R&D carried out in industry

government financed	$26.0
industry financed	$56
TOTAL	$82.0 million

1.2 Areas of concentration of communications R&D in Canada

The areas of concentration are heavily weighted toward communications devices and systems, on the part of research done by industry and research funded in industry. In other words, as pointed out above, by far the most of the R&D done in industry, and over half of the total communication R&D done in Canada, is the development of systems or equipments for the telephone industry. This is largely a result of a decision within the telephone industry to retain control in Canada of the R&D done to meet their needs for advanced systems and plans, and to build up the required manufacturing capability in Canada. A 1967 EIAC study (appendix G) showed the areas of concentration, of a total R&D expenditure of $50.5 million, to be:

1.	Telephone and telegraph equipment and components	85.5%
2.	Radio Communication Equipment	10.0%
3.	Television and Radio Receivers	1.6%
4.	Electronic Computers and related equipment	1.3%
5.	Telecommunication Wire and Cable	1.0%
6.	Television and Radio Broadcast and Distribution Equipment	.6%

Both the radio communication equipment and telecommunication wire and cable categories include work directly related to research conducted in connection with the needs of the telephone industry; making this sector of the industry the predominate beneficiary of research activity.

Government and university R&D, which according to the figures gathered in this study accounts for roughly 1/6 of the total effort, tends to be primarily research rather than development. Intramural government research is primarily in communications, satellite technology, and research-supported spectrum management (see appendix A). University research tends to be primarily in the areas of: properties of semiconductors and solids, interaction of electromagnetic radiation with matter, properties of plasmas and the ionosphere, network design, information retrieval, and information-handling techniques using computers (see appendix D).

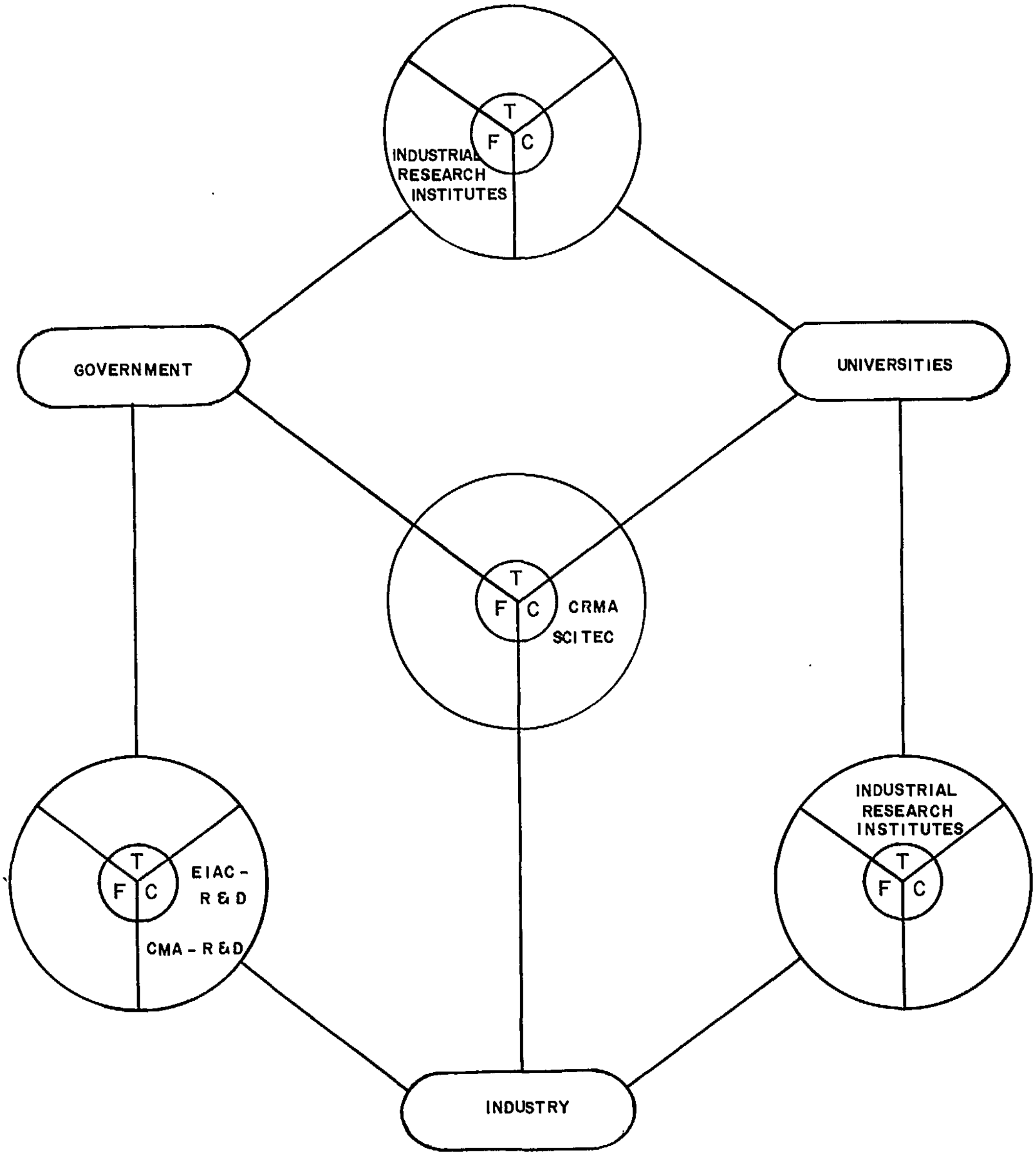
1.3 Coordination between government, industry and university research and development programs.

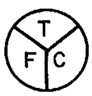
Coordination between government, industry and the universities in the R&D activities pertaining to communications takes many forms, and is the goal of several organizations.

The following schematic diagram is an attempt to summarize the relationships and interactions of the seven organization-types described in appendicies I to M.

1.3.1 Summary

The total R&D effort in Communications in Canada is summarized below in the diagram.





- DOMINANT FORMS OF INTERACTION

T - TECHNICAL

F - FINANCIAL

C - COMMUNICATING, INFORMATIVE

Chapter 2

Why Canada engages in telecommunications R&D

2. The electronics industry in general, and the telecommunications branch of it in particular, are keys to the survival and advancement of our society in the modern technological environment. Consider a single situation such as would develop if overnight the telecommunications used by the world airlines were to be rendered inoperative by any circumstance. Aircraft would be immediately reduced to the visual flying rules of the 1930s. Schedules would disintegrate. Business travel would return to the ground. We would be set back 30 years in time. An analogous situation would develop 20 years from now if all R&D in telecommunications ceased at this point in time. The following typical examples of reasons for continued Canadian R&D in telecommunications may be cited:

- to continue to enhance the strength of the economy through the strength of the telecommunications industry;

- to sustain an effective measure of independence from other economies in the event of a national or international crisis;

- to advance the effectiveness of Canadian industry at home and in world markets;

- to maintain centres of interest for the activities of our creative scientists and technologists.

2.1 Why the Government engages in telecommunications R&D

The role of the Government in communications R&D relates to both national needs and international commitments. R&D activities by the Government are based upon the need to maintain its body of scientific knowledge so that information is available upon which public policy and planning can be formulated. These activities may be classified as "In-House Research" and "External Research" and are designed to:

- introduce advanced technological skills into Canada;
- relate to the fulfilment of national objectives that cannot be reasonably undertaken in a commercial or university environment;

- augment the establishment of international science programmes in which Canada participates or supports;
- maintain sovereignty and freedom of action in international negotiations.

2.1.1 In-house research

The government must have the competence and ability to independently judge the relevance and implications to Canada of advances in the science and the technology of communications. Competence is secured through maintenance of research staff engaged in research programs as well as studies. Personnel are thus made available to interpret and evaluate current scientific and technological progress, to provide an interface with non-government experts and to produce forecasts. Principally, however, the research programs are mission oriented so as to advance knowledge in selected areas and on a predetermined scale.

Programs are initiated through a feed back process between management and research staff. Whereas senior management define the broad areas of interest, detailed project plans are initiated by senior levels of scientific staff. Specific proposals are judged against recognized requirements using the criteria of technical scope and scale, priorities, alternatives, suitability to available technical and staff resources.

2.1.2 External research

There are two types of programs

a) Those carried out under direct contract with the Government.
b) Those initiated under grants and development schemes.

Both classes of programs are designed to support the overall Government objectives. Additionally programs are favoured which will assist industry and the universities to staff and maintain centres of knowledge or expertise in communications technology or science (see appendix M).

2.2 Why industry in Canada engages in telecommunications R&D

Industry objectives are to produce and market goods and services with a favourable return on investment. Operations are normally conducted in a highly competitive environment, and companies must engage in research and development to maintain their products as to quality, performance, and price, and to foster diversification and expansion into new product areas. Within the telephone industry services are provided in a regulated but monopoly market. Within this environment the industry's objectives also include the provision of service, taking into account interests wider than the economic conditions of the local market.

The product range of most technology-based industries consists of something between 50 and 80% of products which did not exist ten years ago. There is therefore a continuing need for replacement of technology. This can be done by importing new technology or by Canadian research and development. Both means are used in Canada. More applied research than basic research is conducted in Canada. To some extent basic research is a cultural activity which adds to our fundamental scientific knowledge, but cannot always be economically justified within Canadian industry. Because of its association with the generation of new scientific knowledge, research is often an activity best suited to the environments provided by universities and government laboratories where the production of goods and services is not the prime objective. Further, modern research tends to require expensive facilities beyond the power of a single company to support. Notwithstanding the difficulties, industry is now recognizing that some of the basic research necessary to ensure continuity of business must be done in industry where it can be product-/or mission-oriented. The amount of basic research conducted in Canada can thus be expected to increase (see appendices N and O).

To some extent research projects, but more often development projects, originate as a result of problems reflected from the production lines. By this means product improvements are made which incorporate the latest advances in technology. Research programs are undertaken before any radical product changes are made. Such research is usually related to the technologies in which the company is already expert. Products which require a radically different technology base are nowadays usually acquired by purchasing, either through license or another company rather than starting a new research program.

2.3 Why the universities engage in telecommunications R&D

The most obvious functions of the universities are teaching from the accumulated store of knowledge, and professional training. The universities also have always given leadership in adding to the store of knowledge. This is done by all forms of research conducted by the academic staff and the students. The best teachers from the university point of view are those who are up to date in their subject and who maintain contact with the latest developments through research. Post-graduate training for students uses research studies to develop their reasoning faculty as well as their store of knowledge. An important motivation in university research, insofar as it rests with the staff and not the university organization, is the desire of the individual faculty member for advancement in his professional hierarchy. Research is one of the best ways for demonstrating an individual's excellence to his peers and especially to advance his reputation in the professional community at large.

Research conducted in the universities has the characteristic that it is done in a climate in which principally excellence counts, and there is no commitment to the solution of any particular problem and thus, no risk element in the economic sense. However, there is the concomitant characteristic that the university environment is not the most suitable for mounting large elaborate research programs, because the facilities used for research work are usually also used for teaching and training. (see appendix P).

Chapter 3

The initiation of research and development policies and programs

3.1 DOC Research and Development Program Review Procedures

Policy direction in the Department of Communications is concentrated at senior management level, but policy implementation and program-definition machinery is necessarily more diffused. The areas of research are determined as a matter of departmental policy. Within these research areas, there are inevitably a number of specific research projects that are immediately related to departmental objectives, and considerable flexibility normally exists in the assignment of research resources. This flexibility allows the Department to build up or cut back previously established research programs, and to maintain a research program in each area that reflects the changing achievements of the field of research, and any change in the priorities of the Department.

3.1.1 Management of Program

The management of a research program necessarily differs in many respects from the management of other operations. Because research is a creative activity which produces some form of innovation, the results often cannot be foreseen when the project is initiated, and it is often difficult to measure progress during the process of the research.

At present, the bulk of departmental R&D is done in the Communications Research Centre at Shirley Bay. The Director-General of CRC is responsible for the direction and management of the continuing research program. He is responsible for assessing the research program as a whole and its relation to external programs, and for making appropriate adjustments. This control involves a number of levels of line-responsibility within the laboratories. Information generated and exchanged between these levels usually has a powerful influence on the decision-making process in the direction and management of the research and development activity. Useful information for program assessment originates from many sources; from the results of the work already in progress; from the external environment, both national and international; from the explicit or implicit interest and competence of the scientific staff of the laboratory; and from the potential users of the scientific output.

The Director General of CRC reports to the Assistant Deputy Minister (Research) for the Department, who in turn coordinates the total departmental research activity with other departmental work. A Directorate for R&D is responsible for the policy implications of the research program and has the prime responsibility of coordinating departmental research activities with other government agencies.

The formal channel through which external inputs to program decisions are received is through the ARM(R), but in practice, much of this input arrives informally, at the working level, with the result that external information and advice on specific projects is more often directed to group and section leaders or directors of laboratories. This mechanism for acquiring planning information from outside is informal but real and valuable; its effectiveness depends critically upon the competence and accessibility of the laboratory staff.

3.1.2 Program Planning and Budgeting

The departmental program of which R&D is one activity is budgeted according to the Program Planning and Budgeting method used throughout the federal government for the past two years. PPB calls for continuing analysis at all levels of the resources required to achieve a particular objective. In other words, alternative ways of achieving the objectives are considered, and the plan that gives optimum results or outputs and benefits for a given cost is adopted. A five year forecast is an important feature of this concept.

PPB can assist in the management of basic research although it is generally accepted that the eventual output or benefit of research usually cannot be accurately quantified. As a case in point, the research leading to the invention of the laser has paid off in medicine by providing a new and versatile technique for welding detached retinas in the human eye; but the main goal of this research was and still is the attainment of amplification at optical wavelengths for a new generation of communications systems.

For research oriented to a specific application, i.e. applied research, and in experimental development, PPB can be helpful in the establishment of priorities and in determining the allocation of manpower and money. Although changes can be made during the life of a project, the main inputs by which competing projects are analyzed such as timeliness, chance for success, duration impact, and cost, can be estimated with a <u>useful</u> measure of confidence.

3.1.3 Program Review

Departmental programs are reviewed twice a year by both the Department and Treasury Board. The Program Review is submitted to the Treasury Board in May, and contains a summary account of the forecast for the next five fiscal years. The principle research activity is listed as "Communications and Space Application Research and Development". In October the Department submits its Main Estimates for the next fiscal year.

The Program Review prepared in the spring and the main Estimates which are considered each fall are the culmination of the program formation process; they reflect a formal judgment of the programs calculated to secure the objectives of departmental policy, and are regarded as the definitive statement of the research plan.

3.2 The initiation of R&D in industry programs

3.2.1 The role of systems engineering in the communications sector

The telecommunications carrier network is a complex entity continually undergoing change and evolution. Systems engineering is a vital function in the R&D process, with the task of optimizing the economic and technical design of the overall network, taking into account both initial capital requirements and ongoing operating and maintenance expenses. This involves the introduction of changes in the form of new products, or new designs of existing products, which must be suitable for and integrated into the network. The public telecommunications network is like a living organism. While it is constantly changing, it is important that all new equipment be compatible with the existing network which represents an investment of many billions of dollars. Systems engineering, from a slightly different viewpoint, has the task of deciding what should and can be done, optimizing the use of resources for this purpose. As a bridge between the user and the developer, the systems engineer must interpret the user's requirements to the developer, and interpret the state of the art and development capabilities to the user (see appendix Q).

3.2.2 Economics of research and development

Two important aspects of the economics of R&D for a manufacturer are: the costs of R&D in terms of total costs of sales, and the benefits that can be anticipated.

The costs of R&D as a function of total start-up costs are heavily influenced by the nature of the production process. For those products which are amenable to the production-line approach, a significant part of the start-up cost may be in tooling and manufacturing set-up. This can cause R&D costs, i.e. those costs up to and including the costs of producing manufacturing drawings, to be as little as 15% of the total costs of producing a marketable product. Because such products are in general directed to a diverse market, sales are likely to be large, so that R&D costs can be as little as 1%,of potential sales.

Products fabricated on a job-shop basis, on the other hand, are usually directed towards less diverse markets and have more limited sales. Because of this, and because their production set-ups are less capital-intensive, R&D costs might be as high as 50% of start-up and 8% of sales. Total start-up costs will run as high as 20% of potential sales for products of this nature.

Although many of the factors influencing decisions on the ultimate profitability of new product development can be only roughly estimated, techniques of calculating for decisions are being increasingly used. These make use of estimated innovation costs and time, production costs, sales volume and commercial life, and use a discounted-cash-flow calculation. This generally produces a return-on-investment ratio, which is then one of the factors used in deciding whether or not to proceed with the development.

3.2.3. How companies carry out R & D programs in Canada

Procedures governing industrial R & D programs tend to vary with company size and ownership. In large companies, the flow of ideas, plans and proposals is generally upward through the organization, whereas in small companies it is usually downward from the senior officers. This may be so regardless of the ultimate origin of the ideas for new products, which can be from many sources, including customers and marketing departments. In any program, large or small an idea must evolve into a program plan to consider technical, economic and human factors collectively The risks of success or failure must be estimated, and the profitability of the venture assessed. It must represent a reasonable use of available resources.

Financial approval is handled in varying ways. In large companies with an R & D establishment, there will usually be an overall R & D budget approved on an annual basis by the President and board of directors. Within this budget, each major project will be given separate approval at various levels. Smaller companies may require corporate approval for all projects.

The development process itself may begin with an exploratory phase, in which more than one approach to the final design may be tested for its ability to meet the technical and economic requirements. Close interaction is necessary in this period between the development team and the systems engineers or their equivalents. The exploratory phase may be considered complete upon the demonstration of technical and economic feasibility, when a working prototype meets design requirements and when satisfactory costs are predicted for the design based on this prototype.

"Hard development" begins at this point, and is characterized by tight goals in time and expenditures, with product characteristics firmly specified. There must be sufficient flexibility to permit changes offering cost reduction. There should be close involvement, at this stage, of those responsible for the design of tools, test fixtures and production facilities, and of marketing and installation people as well, so that the design is more likely to meet its targets of manufacturing cost and salability.

Development may be considered complete after successful field trials of a sample product made from standardized drawings by the production methods to be used in full-scale manufacture. To reach this stage requires the successful completion not only of the engineering design but also of the tooling and manufacturing set-up. These are all parts of the innovation process, as is marketing, and they must be done successfully in a sufficient number of cases if the company is to stay in business. While basic R & D, either in-house or purchased, is essential to new-product development, it is only one factor. It must be supplemented by the processes of design and tooling, and the provision of adequate manufacturing facilities and marketing capability in order to successfully bring products into use (see Appendices R & T). A schematic explanation of the industry decision process is contained in Table V.

Table V

How Companies carry out R and D programs

	Large		Small	
	Canadian Owned	Foreign Owned	Canadian Owned	Foreign Owned
1. Origin of Ideas	Engrg or Scientific Marketing Middle Mgmt Customer Owner Individual	Parent Engrg or Scientific Marketing Middle Mgmt Customer Individual	Senior Mgmt Single individual customer	Parent to subsidiary or - individual or customer to sub- sidiary to parent
2. Program Plan Corporate	President & Planning Staff	Corp HQ	President	Corp HQ
Technical	Canadian Engrg & Scientific Staff	Cndn or Foreign Engrg & Scientific Staff	Own Engineering Staff	Corp Engrg Staff
Marketing	Marketing Staff	Canadian & Corp International Staff	Own Marketing Mgr	Canadian Marketing Mgr
Manufacturing	Manufacturing Staff	Cndn Mftg Staff	Production Foreman	Parent technology set-up
Financial	Comptroller	Corp HQ & Cndn Comptroller	President	Corp Comptroller
3. Program Approval	President, Comptroller & V/Presidents	Corp HQ	President	Corp HQ
4. Funding Source	Own Responsibility	From Cndn Resources and/or Corp Resources	President (respons- ibility)	Corp HQ
5. Program Execution R & D & Mftg data transfer	Engrg & Scientific Staff	Cndn and/or Foreign Staff	Chief Engineer	Nil
Technical Data (Imports) transfer	"	"	"	Production Foreman

	Large		Small	
	Canadian Owned	Foreign Owned	Canadian Owned	Foreign Owned
5. cont'd Modification Program	Engrg & Design Staff	Cndn Engrg & Design Staff	"	Nil
Mftg Program	Mftg Staff	Canadian Mftg Staff	Production Foreman & Purchasing Agent	Production Foreman & Purchasing Agent
Marketing Development Program	Marketing Staff	Canadian Marketing Staff	President & Marketing Mgr	Manager & Sales Staff
Sales/Shipments	Marketing Staff Mftg Staff	Canadian Marketing Canadian Mftg and/or Corporate Mftg	President, Marketing Mgr Production Foreman	Manager & Sales Staff Production Foreman
Customer Feedback	Marketing	Canadian Marketing	Top Management	Manager & Sales Mgr
Plan Modification	Marketing, Engrg & Scientific Staff Manufacturing Top Management	Canadian Marketing, Engrg & Scientific Staff Cndn Mftg Cndn Management Corp HQ	Top Management	Corp HQ

3.3 The initiation of R & D programs in universities

It is convenient to divide research programs in universities into two catagories: (a) small and (b) large.

3.3.1. Small programs.

The characteristic feature of small programs is that they are the personal research of an individual university staff member. There may be collaboration with other staff members, but this is unusual. An individual will choose such a program because it excites his curiosity or will advance his reputation within the university. His next step is to find money to finance it. Sometimes special facilities are needed and these may already exist in the university (which would be an incentive to choose that particular program), or they may have to be sought or bought.

The usual source of funds is the National Research Council, and the staff member makes application to NRC in December. His application is reviewed by a "grant screening committee" and funds are granted for a period of one year from 1 April to 31 March. The most important factor in the choice of a "small research project" is the intellectual curiosity of an individual; the principal criterion used by the N R C grant screening committee is its scientific value. The amount of the award is rarely more than $10-15,000 and is not large enough to build an establishment or to pay much in the way of salaries.

3.3.2 Large programs.

Large research programs may require up to $1 million or more. They involve a research team, or collaboration between several staff members, and depend on a commitment by the university and the granting agency to continuity for several years.

These programs are usually proposed by individual staff members (or by groups of staff members) prompted also by intellectual curiosity, but a pre-requisite is some indication that such an effort has a chance of sucess. The negotiated development-grants program of the N R C is an example.

Contracts with industry are another source of funds for large-scale research programs in universities. It is difficult to establish any pattern but again the initiative often comes from the university staff member. Some universities have fostered the appearance of organizations that actively seek industry funded research projects to be carried out by university staff using the universities labratory facilities.

Chapter 4

The effectiveness of present research and development policies and programs.

4.1 The need for establishing specific goals and objectives

The previous chapters have described a variety of activies which together constitute the total R & D effort related to communications in Canada. While not organically coordinated, this total activity constitutes an existing system. To measure its effectiveness one must either know or assume criteria against which effectiveness can be assessed, a method of measuring existing performance, and means of estimating whether the output of the system is the result of existing mechanisms or some other contributing factor.

For criteria against which one can measure effectiveness, a baseline can be established by assuming a set of overall goals for research and development activities in the communications sector. For the purpose of this study and the exercise of measuring the effectiveness of R & D policies and programs, the following goals are assumed. They are not introduced as definitive, or even suggested as being complete, except for the purpose of this study. R & D capabilities must be on a scale:

- to maintain national communications systems and networks;

- to maintain Canadian industry at a competitive level, both domestically and internationally;

- to develop a pool of skilled manpower able to comprehend and analyze the effects of scientific advances in communications and their impact on national, political, social and economical goals;

- to enhance the ability to predict future communications-technology advances and problems

Measured against these broad goals, R & D activity in industry, universities, and government in past years has contributed positively and has been relatively effective. In the communications sector, Canada is among the world's technologically advanced nations. Proportionately to other advanced nations such as the United States, Canada can call on a large number of highly trained, imaginative, and competent researchers.

To establish more specific criteria of effectiveness is difficult, not only because of the subjective judgments that must be made on the capacity of individuals or groups, but also because the large amount of activity in a system that is not tightly coordinated or inter-related. But some general observations on the effectiveness of present activity can be made. First, there is a recognition that any organized R & D activity produces results which tend to maintain the system; this is applicable not only to the development of large program objectives in government laboratories but equally to isolated research activities in universities, or to the R & D of industrial groups. An example of the self-feeding effect is the N R C university grant program, which usually favours small grants to individual researchers for individual projects. This program has tended to concentrate university research activity in isolated research effort; for this purpose, the system is most effective, although whether this was the intention of the program, or whether it is a desirable end, has not been examined.

In larger and more integrated R & D activities there is the recurring difficulty of trying to determine when the program is no longer effective and should be terminated. The tendency for R & D to be self perpetuating is real. Managemnet of R & D is still as much an art as it is a science. In chapter 3, the way in which R & D activities are initiated in various environments was outlined. There is no doubt that in recent years the determination and selection of research projects by measurement against specific objectives, so as to increase their effectiveness, has increased. However, the goals and objectives of one research group often do not relate to the goals and objectives of other groups, and in many cases R & D activities in communications in Canada do not relate to the objectives established in this study as a possible baseline for measuring national activity.

To meet national goals a minimum level of activity must be maintained. Within the industrial sector there seems to be little agreement between companies as to the level of R & D activity needed to maintain competitive capability. While there has been some investigation in the past, which has been rather disheartening in its result, there seems to be an argument for further research to determine whether the relationship between R & D activity and technological capability in the communications industry can be effectively judged.

4.2 Desirability of establishing a measurement to establish priorities between objectives

The establishment of goals and objectives does not ensure that R&D programs become effective. There will have to be strategies devised for achieving agreed upon goals, and one of the first problems in organizing those strategies is the determination of a measurement that will establish a ranking or priority listing between several objectives. This will be a difficult task and will be accomplished only by a recognition that any ranking of objectives can be accomplished by accepting both objective quantitative analysis and subjective value judgments. For example, while at the present time there is increasing support for shifting emphasis in R&D from basic research to applied research (the phrase 'mission-oriented' is used as a synonymous term), the accomplishment of that goal should be assessed not individually but in the context of total research aims. If 'mission-oriented' is interpreted as meaning that all research should be fitted into a specific overall plan with fixed objectives, the result would be detrimental to long-term national needs. Over-emphasis on applied research programs could channel activities into too few lines and leave Canada dependent on foreign sources for science and in technologies not foreseen when objectives were established. R&D effort is not a prestige activity;it should be related to economic and social ends but, in the creation of policies to support R&D, there is a constant risk of being limited to the enunciation of generalities, or at times mere slogans, which do not in the end aid in the determination of programs or activities that bear any relationship to national needs.

The increasing complexity of R&D activity and R&D management suggests that, for a true determination of priorities between objectives, there will have to be a closer degree of association between universities, government, and industry, with a clear understanding and, more importantly, agreement on the means to attain objectives. Devèlopment of strategies, as well as development of goals and priorities, will probably entail not only a sharing of knowledge between different sectors of research activity but also a sharing of risk. It will also call for better utilization of available manpower and, not least, the development of administrative machinery to review strategies and goals periodically, so that resources can be shifted and priorities reconsidered for maximun benefit.

4.3 Extent of coordination

With the exception of the telephone industry, and particularly the Bell-Northern electric complex, any large-scale coordination of Canadian R&D has been more fortuitous than planned. In the former case R&D activity has been built into an industrial structure that provides products and services on a national scale. This coordination has been achieved by integrating the planning, engineering and manufacturing stages with R&D activity and has in the opinion of the companies been facilitated by the vertically integrated corporate structure of the companies. In other sectors, what coordination of activity has taken place has been attributable partly to the relatively small size of the community of researchers, which eased the problem of exchanging information.

In some ways the NRC grants committees have acted as coordinating bodies, particularly with respect to university research. The government support programs to industry have also had salutary effects as an information clearing-house. However, as the level of activity has increased, as new laboratories opened, and as the body of knowledge to be explored widened, ad hoc arrangements have become fragile, and the relationship of research activity to national goals is becoming more accidental than planned.

Chapter 5

Communications R&D policies and plans for the 70's

If the industrial revolution was essentially an extension of man's muscular capabilities, then the technological revolution is really an extension of his intellectual capabilities and more specifically, his ability to organize, manipulate and use large amounts of information.* This technological revolution has led us directly into a further, and more fundamentally important change which can be called the "communications revolution". In terms of techniques and facilities, this latter is just a part of the technological revolution but in terms of the effect upon our society, the availability of modern facilities for near instantaneous transfer of large volumes of information directly between individuals and to mass audiences it is also producing a social revolution of major proportions. To give but one example, the communications revolution has given an individual the ability to view, in nearly real time, events and conditions in any part of the world. It has also given people throughout our society the ability to organize and participate in particular social or political functions, in a way that was not even remotely possible before the advent of the telephone and television. The ability of the society to react quickly and en masse to a particular stimulus has introduced new dimensions into our civilization, and we have only begun to experience the changes that this communications revolution is likely to bring.

By the very nature of its involvement with the rapidly advancing field of electronics, communications is intimately involved in advanced technology, and with the research and development that leads up to the introduction of advanced systems. At present, the relationship between research and the implementation of advanced communications systems is evident. What is less clear is whether a manufacturer of telecommunication products or a supplier of services must, to remain competitive, have his own research capability or at least access to a research base that relates to determined needs. This is a point clearly made by the telecommunications industry, particularly the common carriers, to the extent that they argue that the research and development functions must be vertically integrated with the operating and manufacturing functions.

*Reference (J.J. Servan-Schreiber) "The American Challenge" - Athenerm - 1968.

This intimate relationship between R&D and the implementation and operation of systems has an important effect upon R&D policies. Considering that at least half of the present R&D activity is closely associated with the operating companies, it follows that it is very closely geared to the needs of existing communications systems, and to the expected needs of the future, as predicated by the operating companies themselves. The other half of R&D activity is less specifically directed. However, the effect upon R&D policies and activities of the presence of an existing vast and expensive communications system can hardly be overestimated. It means that any R&D that is done by industry on advanced systems and techniques is inevitably constrained by the existing system, and by the fact that many elements of that system were installed many years previously.

The study team agreed that R&D in the communications sector is of direct and primary relevance to the establishment of advanced communications systems in Canada. Since the facilities that these systems provide are creating a communications revolution of very real proportions, R&D policies and plans in this area are of paramount importance to the country. The factors that govern the R&D policies and plans, and the effect that the existing policies and plans may have on our society, through the impact of the resulting technically advanced communications are difficult to determine or analyze. In Canada most of the R&D policies have evolved out of the particular goals of the unit or sector in which the research is done, usually more or less divorced from other units or sectors, seldom in a national context. This has unduly complicated a rational examination of R&D at the policy level. Certainly none of the sectors have so far tried to relate their R&D activities to a serious consideration of the sociological effects of communications systems that may be based on the results of R&D. This is a factor that can no longer be ignored and new methods of policy formation, both with respect to methodology and quantitative analysis techniques are needed. Much of this work will have to be focussed on future requirements, forecasting possible future technologies and the needs and emerging living patterns of society. This factor is so important that we must begin, by trial and error if necessary, to develop the required techniques for taking these effects into account in R&D policy formation. (See appendicies U & V).

The project team also considered that the time has come to establish a set of communications goals, defined in a national context, from which the various sectors of the communications community can operate, and against which industrial, academic and government R&D policies and programs can be established. These goals could be general, rather than specific. The need is that they be articulated and made known so that they can be discussed and debated. Once a set of goals has been enunciated, techniques of planning exist for optimizing the progress toward meeting those goals.

The project team realized that, at present, each of the three sectors, university, industry and government, play particular and rather separate roles in communications R&D. However, it is evident that the present attitudes and approaches in all three sectors must change, and become more flexible if we are to achieve our goals, better utilize our manpower and financial resources, and improve the effectiveness of our policies and plans. All three sectors must accept reponsibility for accomplishing all national goals. It seems hardly satisfactory for one sector to assume that it does not have a responsibility to ensure that its R&D policies and programmes contibute to and take into account <u>all</u> of the communications goals. In the end this may lead to different types of research being undertaken at various sector of activity. This type of integrated approach would mean a continuing reexamination of the degree and form of public funding of good directed R&D activity. To be effective there must be a continuing interaction between the industrial, government and university research communities so that goals and objectives are understood and pursued. To this extent more formal mechanisms of liaison and cooperation appear warranted. At present some sectors of the manufacturing industry cannot sustain adequate R&D programs even though they have demonstrated an ability to make a contribution to the national R&D effort.

R&D policies must flow out of long term planning that clearly measures future requirements and which considers the impacts of future technologies. The communications revolution is a mental or intellectual revolution -- a revolution in the exchange of ideas and information -- and we can optimize our chances of shaping it to desirable ends only as we work from a base of both technological and social knowledge. It does not seem possible to stop technological development. The most that can be done is to either slow it down, or perhaps divert it from one channel to another. Communications is an area in which we must have a high level of research activity, higher than we have now achieved, if we expect to be able to benefit from the technology in a knowing manner. We need the advanced and improved systems of communications that our R&D can evolve. They can enrich our lives and our culture in valid and exciting ways. Advanced communications systems can give the individual an exciting and satisfying sense of participation in events and projects of real significance. But at this stage we are far from knowledgeable in the consequences of piece-meal implementation of such systems, or of the other changes that need to be made to our society to allow it to cope with interim systems, and to adjust to the new dimensions that we can clearly see are available.

Appendix A

Communications Research and Development At CRC, 1969-70

The in-house budget of CRC is about \$7.5M. In addition during the current fiscal year about \$4M has been approved for industrial contracts managed by CRC.

1. Communications Research — 33% of Total Effort

1.1 Cable, Radio and Optical Communication Techniques

Research on the efficient and economical use of communication channels includes applications relevant to current systems (microwave, troposcatter, narrowband cables and wire channels) and basic work on future systems (wideband satellite cable channels, optical systems). Digital techniques and digital switched systems are emphasized, because of their importance to future communication systems (such as the "Wired City").

1.2 Satellite Communication Techniques and Systems

Research on satellite communication techniques and systems for future domestic civilian requirements, including problems relating to communications with small ground terminals, aeronautical communications and navigation, and direct broadcast systems.

1.3 Northern Communication Techniques

Research on communication problems peculiar to the Canadian North over the entire frequency spectrum; including VLF, LF, Broadcast, Short-Wave, VHF scatter, UHF radio relay, microwave communication satellite, and optical laser systems. A present emphasis is the evaluation of northern communication requirements in the light of new technology, with particular reference to the second generation TELESAT.

1.4 Computer and Information Systems.

CRC staff designed, built and used the first Canadian solid state computer. Digital computer systems form an integral part of many CRC research projects. The CRC now uses a SIGMA 7 computer.

Applications of coherent optical systems (holography) for data processing and storage are being developed. Digital computers are being applied to sophisticated signal-processing with specific reference to data collected by direction-finding arrays.

1.5 Radar Techniques and Systems

The current program on radar techniques and systems is presently connected with military systems, with emphasis on problems connected with remote sensing of military targets.

2. (a) Satellite Technology 32% of Total Effort

2.1 Space Mechanics

The design of spacecraft structures for the Alouette/ISIS program, TELESAT, and proposed future Canadian satellites includes: large antenna systems, extendible booms, flexible extendible solar-cell arrays, attitude control systems, and space propulsion systems. Related theoretical work includes the thermal design of satellites, and the analysis of station-keeping and of the dynamic behaviour of flexible satellites.

2.2 Space Electronics

Research on electronic systems in spacecraft - such as command, control, programming, telemetry, power-supplies, on-board computers and data-storage, sensors, probes, etc. Studies are under way for future satellites.

2.3 Reliability Analysis

Spacecraft systems must be at least one order of magnitude more reliable than conventional electronics. Intensive examination of individual components and integrated circuits is essential at all stages of the development and engineering of a spacecraft. CRC has recently established a scanning electron-microscope facility, and associated research devices, for examining the detailed behaviour and physical properties of microelectronic and integrated circuits under their anticipated operating conditions.

2.4 Integrated Circuits

Integrated solid-state circuits offer the advantages of small size, reliability, and low power consumption of spacecraft electronics. An experimental facility has just been established at CRC for made-to-order integrated circuit components.

2.5 Satellite Development

Research on problems in space electronics and mechanics which arise from current industrial development contracts, and operation of the industrial-contract management office.

The first operational use in Canada of the project evaluation and review technique PERT was made on Alouette II, and PERT has since been imposed on the contractors for ISIS-I and ISIS-B. A multiple-incentive type of contract was arranged for ISIS-B, and indications are that this will result in substantial savings. This topic covers the work performed by CRC for TELESAT Canada.

2.6 Satellite Operations

Alouette I, Alouette II, and ISIS-I are operated under CRC control. The Satellite Controller's Office schedules satellite operations throughout the world. Ground telemetry receiving stations are installed at Ottawa and Resolute Bay, and the CRC Data Processing Centre reduces the telemetered data to a format suitable for scientific analysis and for use by World Data Centres. The Prince Albert Radar Laboratory is being examined as a potential receiving station for earth resource satellites.

2. (b) Spacecraft Development Contracts 20% of Total Effort

The Alouette II and ISIS-I satellites were built and ISIS-B is now under construction in Canadian Industry.

3. Research Supporting Radio Spectrum Management 15% of Total Effort

3.1 VHF, UHF, Microwave and Optical Radio Propagation

CRC is the Canadian national centre for propagation research across the entire radio spectrum, including the laser region. The research program concentrates on propagation problems peculiar to Canadian latitudes, with a view to applying the results to current and future domestic communication systems. In the VHF, UHF, and microwave part of the spectrum the main interest is in the limitations of the trasmission medium, particularly the lower atmosphere, and the effect of such limitations on the allocation and sharing of the radio frequency spectrum.

3.2 VLF, LF, Broadcast and Short Wave Radio Propagation

Propagation research at the lower radio frequencies, the short-wave band and below, is particularly concerned with applications to radio predictions and forecasting for domestic communication systems. The most critical propagation problems here are associated with the properties and behaviour of the ionospheric and, accordingly, the program includes basic research on the disturbed Canadian ionosphere.

The VLF and topside-sounder experiments in the Alouette/ISIS satellites form part of this program.

3.3 Radio Noise and Interference

Research on radio noise sources and the observation and interpretation of noise and interference, in relation to practical communication systems.

3.4 Radio Prediction and Forecasting

CRC provides a radio prediction service to domestic users of long-distance LF, HF, and short-wave communication systems. These systems are affected by ionospheric variations, and their operational efficiency can often be greatly improved through the use of the prediction service. CRC also provides computer programs to users who wish to prepare their own predictions on a routine basis. The program includes research on improved methods of prediction, and on the development of techniques for short-term forecasting of communication circuit conditions.

Source: Department of Communications.

Appendix B

Government Programs supporting R&D in Communications

The largest support program is the Defence Industry Productivity Program (DIP) approved in 1968. The immediate objective of DIP is to develop and sustain the technological capability of Canadian industry for the purpose of defence export sales or civil export sales arising from that capability through a variable cost-sharing between the department and the industry for selected projects. Up to 1968 DIP commitments in the telecommunication field amount to $29.5 million.

The Program for the Advancement of Industrial Technology (PAIT)

The Program for the Advancement of Industrial Technology was initiated in 1965, to help industry help itself to improve its technological capacity and to expand its innovation activity by underwriting development projects which involve a genuine technical advance and which, if successful, offer good prospects for commercial exploitation. If the project is successful, the contributions are written off. However, PAIT has been recently expanded and financial support can take the form of a grant. The costs of the project are normally shared between the government and industry. Up to 1968, PAIT expenditures in the telecommunication industry amounted to $346,000.

The Defence Industrial Research Program (DIR)

The Defence Industrial Research Program administered by the Defence Research Board began in 1961 and was designed to improve the ability of Canadian companies to compete for research, development and production contracts in the United States and NATO defence markets. Preference is given to long-term projects which offer good potential for achieving major advances in performance and techniques. Up to 1968 program expenditures amounted to $7.4 million in telecommunications.

The Industrial Research Assistance Programs (IRAP)

The Industrial Research Assistance Program was initiated early in 1962 to create new research facilities within the industry and to expand existing facilities, to improve communications between research workers in government and industrial laboratories. The government through NRC pays direct salaries of approved research programs undertaken by industry for five years. Up to 1968, expenditures under IRAP totalled $569,000 in telecommunications.

The Industrial Research and Development Incentives Act (IRDIA)

The three year old Industrial Research and Development Incentives Act (IRDIA) provides general incentives to industry for the expansion of scientific research and development, and is administered by the Department of Industry, Trade and Commerce. The program provides applicants with tax-exempt grants for increased R&D, and equals 25% of the aggregate of a company's R&D capital expenditures and of the increase in the current R&D expenditures during the fiscal period over the average of the preceding five fiscal years. In 1967, grants totalling $5.2 million were provided for the telecommunication industry.

Source: Department of Industry, Trade and Commerce.

Appendix C

The R&D Industry - Quantitative Analysis by Dept. of IT&C

R&D expenditures in Electrical & Electronics Industry

Total intramural R&D expenditures by industry in 1967 were $94.7 million of which $11.5 million were capital expenditures on R&D facilities. Of the current R&D expenditures, $5.6 million were spent in the field of nuclear energy, $1.4 million on space and communications, $20.6 million on defence and $55.5 million on commercial applications. For 1968, these expenditures were projected to be $93.7 million and $7.8 million respectively.

Of these 1967 expenditures, $16.8 million were funded by the Canadian Government and $1.5 million were funded by foreign governments. These government-funded sums do not include grants received under Industrial Research and Development Incentives ACT (IRDIA), under which industry claimed $10.2 million in 1967.

In 1967, the total R&D expenditures in communications electronics (i.e. telecommunications, detection and navigation, computers and instrumentation and parts) if based on IRDIA claims, were $74.2 million. Out of this $49.860 million were claimed to be in the telecommunications field and were therefore eligible for grants amounting to $5.2 million. Seventeen companies were involved in IRDIA grants in the telecommunication field as against 62 for the whole electronics industry.

Government support for R&D in telecommunications

Federal Government expenditures on R&D for the years 1968-69 amounted to $11 million for work in the communication field undertaken by DRB, NRC and CRC. However, the Department of Industry, Trade and Commerce finances R&D by sponsoring special assistance programs designed to increase R&D capability of Canadian industry. At present, there are five continuing programs of government support in operation.

Source: Department of Industry, Trade and Commerce.

Appendix D

Level of R & D Activity in the Communications Sector in Canadian Universities

For the purpose of this section grants have been divided into three categories:

(1) Direct relevance. Research projects with direct relevance are those which attack some specific problems in telecommunications.

(2) Long-term relevance. Research projects in this category are directed towards the extension of knowledge in a field known to have some relevance to communications at the time it was initiated (an example would be studies of impurity states in semiconductors). Although the person proposing the project may be interested only in certain fundamental solid-state physics problems, he is well aware that its results could have an immediate bearing on transistor technology.

(3) Very-long-term relevance. In this category are research projects which have no obvious connection to telecommunications at the time of their inception. Yet they are in fields where some application in telecommunications may well be found. Almost any project involving the interaction of matter with radio-frequency radiation might come under this category.

It should also not be forgotten that long-term and very-long-term projects may have some relevance to telecommunications but direct relevance to other problems; therefore when the support given to these projects is computed it should be recognized that there may be an overlap with the computation of support given in other fields.

The areas of concentration of research in communications comprise:-

Properties of semiconductors and solids
Interaction of electromagnetic radiation with matter
Properties of plasmas and the ionosphere
Network design
Information retrieval and information handling techniques using computers.

The pattern of R and D in the universities has remained constant for several years. About 75% of the support comes from

NRC, and the other 25% from other agencies; in communications these are D.R.B. and A.E.C.B. The total level of support is about

$2.2 million on projects of direct relevance
$1.9 million on projects of long-term relevance
$0.7 million on projects of very-long-term relevance.

The total for all projects relevant to communications is $4.8 million.

The sum spent on salaries is about $1.6 million, made up of

- $214 thousand for graduate student support, (at present about 5.6% of the NRC total).
- $955 thousand for technical salaries (about 20% of the small or personal grants and 50% of the large or block grants).
- $455 thousand for professional salaries (Ph.D. or higher).

The rest is spent on equipment, supplies, and operating expenses.

Geographically, this support is distributed in the following way:-

Maritimes	$156,000
Quebec	$881,000
Ontario	$1,725,000
Prairies	$1,381,000
British Columbia	$546,000

The support on all aspects (including very long term) of communications research in the Universities comprises about 5.3% of total University support. It can be reasonably estimated that this involves a total of 260 scientists and engineers. Technical and support staff would be in addition to this number.

The following figures, indicating the pattern of research support in the universities in general, are taken from the MacDonald Report.*

Table I

Support to Universities in 1967-68

	(in million$)	
N.R.C.	66.3	75 %
Other government agencies	8.6	9.6%
Industry	3.0	3.4%
Private Foundations	9.0	10.2%
University funds	1.5	1.7%
Graduate Student support:-		
(a) from N.R.C. grants	3.8	5.6% of the N.R.C. support
(b) from N.R.C. scholarships	4.1	

Although the total may change from year to year, this pattern is approximately constant.

From a list of grant titles supplied by NRC and DRB the support for research and telecommunications through those bodies and the Atomic Energy Control Board has been listed in Table II.

Table II*

N.R.C. Categories	Very Long Term	Long Term	Direct
Physics & Nuclear Physics	$217,752	$ 181,525	$ -
Space & Astronomy	162,119	166,490	631,470
Electrical Eng.		841,896	848,817
Mechanical Eng.		38,590	89,620
Mathematics		58,490	13,590
Computing		159,440	34,044
N.R.C. Negotiated Major Grant		125,000	254,980
A.E.C.B.	227,550		
D.R.B.	48,200	358,094	276,764
Totals	$655,621	$1,929,525	$2,149,285
Grand Total	$4,734,431		

*The Role of the Canadian Government in Support of Research in Canadian Universities, Special Study #7 The Science Council of Canada & The Canada Council 1969.

Out of the total support of $4.73 million, NRC. supplies 73% in small grants, 8% in large grants, a total of 81%. The DRB contribution is 14.5%, and the AECB contribution 5%. This breakdown is very similar to that shown in Table I.

Table III gives an estimate of the amount spent on salaries. Very little of this money goes towards professional salaries in universities, but a substantial amount goes towards technical salaries and graduate-student support. It is difficult to get an accurate estimate of this breakdown without access to the auditor's reports of the grantee institutions. However, it is fairly easy to estimate the level of support for graduate students as 5.6% of the N.R.C. total on the assumption that it follows the established pattern for all NRC grants. It is probably correct to estimate technical salaries as being approximately 20% of the small grants and 50% of the large grants (N.R.C., D.R.B., and A.E.C.B.). The results of this computation are shown in Table III.

Table III

Estimated amount shown on salaries

Graduate students	5.6% of N.R.C. Total	$ 214,000
Technical salaries (i)	20% of small grants	765,000
Technical salaries (ii)	50% of large grants	189,990
Salaries	50% of D.R.B. and A.E.C.B. grants	455,304
		$1,624,294

Source: Dr J.M. Daniels, University of Toronto

Appendix E

NRC and DRB University Grants, 1968-69

Research Relevant to Communications

University	NRC Long-Term Relevance Funds	Direct Relevance Funds	Total	DRB Funds	Grand Total
Acadia		3,430	3,430		3,430
Alta.	124,345	87,740	212,085	8,500	220,585
Bishops	1,600		1,600		1,600
U.B.C.	327,248	93,130	420,378	43,511	463,889
Calgary	201,340	250,184	451,524	8,000	459,524
Carleton	13,720	38,780	52,500	16,200	68,700
C.M.R.				11,700	11,700
Dalhousie	3,480	5,390	8,870		8,870
Lakehd.	10,310	7,350	17,660		17,660
Laurentian	10,190	13,050	23,240		23,240
Laval	77,910	117,960	195,870	52,994	248,864
Lethbridge	3,920		3,920		3,920
Loyola	4,249		4,249		4,249
Manitoba	49,880	71,790	121,670	18,700	140,370
McGill	114,710	126,712	241,422	28,800	270,222
McMaster	94,670	57,865	152,535	32,600	185,135
Moncton	3,430		3,430	20,000	23,430
Montreal	145,320	16,860	162,180		162,180
Mem. U. Nfld.	14,450		14,450		14,450
New Br.	33,120	34,650	67,770	12,900	80,670
N.S.T.C.	36,750	17,640	54,390		54,390
Ottawa	32,340	22,050	54,390	11,800	66,190
Polytech.	12,250		12,250		12,250
Prince of Wales		3,430	3,430		3,430
Queens	50,260	39,730	89,990	9,000	98,990
RMC				31,353	31,353
Sask.	247,450	326,660	574,110	32,300	606,410
Sherbrooke	29,570	12,720	42,290	6,500	48,790
Simon Fraser	16,390	30,100	46,490	42,600	89,090
Sir Geo. Wms.		7,350	7,350		7,350
St. F. X.	1,1960	1,960	13,920		13,920
Toronto	209,140	332,340	541,480	86,900	628,380
Trent				7,000	7,000
Victoria		4,000	4,000		4,000
Waterloo	91,206	155,390	246,596	26,200	272,796
Windsor	21,870	38,910	60,780	10,600	71,380
W. Ont.	57,010	161,785	218,795	52,000	270,795
York	16,170	14,000	30,170	6,000	36,170
TOTAL	$2,066,258	2,092,956	4,159,214	576,158	4,735,372

Appendix F

NRC Grant to Universities 1968-69

Research Relevant to Communications
by Activity

I. Physics and Nuclear Physics

A. Long Term Relevance		B. Direct Relevance	Total
Acadia		3,430	3,430
Alberta	23,900		23,900
British Columbia	51,778	6,660	58,438
Calgary	8,330		8,330
Dalhousie	3,000	3,430	6,430
Laurentian	6,270		6,270
Laval		67,240	67,240
Loyola	4,220		4,220
Manitoba	2,400		2,400
McMaster	42,890		42,890
Moncton	3,430		3,430
Montreal	13,720		13,720
M.U.N.	12,450		12,450
New Br.		26,270	26,270
Simon Fraser	16,390	28,470	44,860
St. F. X.	11,960	1,960	13,920
Toronto		1,960	1,960
Waterloo	6,170	37,660	43,830
Windsor		35,480	35,480
W. Ontario	34,460	7,875	42,335
York	9,700		9,700

Appendix F-2

NRC Grant to Universities 1968-69

Research Relevant to Communications
by Activity

II. Space Research and Astronomy

	A. Long Term Relevance	B. Direct Relevance	Total
Alberta	19,120	5,000	24,120
Bishops	1,600		1,600
British Columbia	30,870	20,180	51,050
Calgary	50,490	79,130	129,620
Carleton		11,070	11,070
Dalhousie		1,960	1,960
Lakehead	7,810	7,350	15,160
Laurentian	3,920	13,050	16,970
Lethbridge	3,920		3,920
Loyola	29		29
Manitoba	15,190		15,190
McGill	41,450	23,420	64,870
Montreal	79,480	16,860	96,340
Nova Scotia T.C.		4,900	4,900
Prince of Wales		3,430	3,430
Saskatchewan	69,870	216,860	286,730
Toronto	19,110	64,190	83,300
Victoria		4,000	4,000
W. Ontario	3,000	146,070	149,070
York	6,470	14,000	20,470

Appendix F-3

NRC Grant to Universities 1968-69

Research Relevant to Communications
by Activity

III. Electrical Engineering

	A. Long Term Relevance	B. Direct Relevance	Total
Alberta	68,485	47,240	115,725
British Columbia	100,100	61,900	162,000
Calgary	17,520	46,580	64,100
Carleton	13,720	27,710	41,430
Lakehead	2,500		2,500
Laval	77,910	50,720	128,630
Manitoba	24,370	66,890	91,260
McGill	70,030	103,292	173,322
McMaster	47,860	57,865	105,725
N. B.	33,120	8,380	41,500
Nova Scotia	33,320	12,740	46,060
Ottawa	25,970	22,050	48,020
Polythechnique	12,250		12,250
Queens	41,170	34,960	76,600
Saskatchewan	56,170	9,800	65,970
Sherbrooke	26,570	6,500	33,070
Sir George Williams		7,350	7,350
Toronto	88,420	159,770	248,190
Waterloo	68,926	117,730	186,656
Windsor	18,720	3,430	22,150
W. Ontario	14,250	3,920	18,170

Appendix F-4

NRC Grant to Universities 1968-69

Research Relevant to Communications
by Activity

IV. Mechanical Eng.

A. Long Term Relevance		B. Direct Relevance	Total
Alberta		32,020	32,020
McGill	3,230		3,230
McMaster	3,920		3,920
Nova Scotia T.C.	3,430		3,430
Saskatchewan	31,240		31,240
Toronto		57,600	57,600
Sherbrooke	3,000		3,000

V. Pure and Applied Math.

A. Long Term Relevance		B. Direct Relevance	Total
British Columbia		960	960
Dalhousie	480		480
Manitoba	960		960
Queens	8,610	4,780	13,390
Saskatchewan	3,000		3,000
Simon Fraser		1,630	1,630
Sherbrooke		6,220	6,220
Toronto	42,570		42,570
Waterloo	2,590		2,590
W. Ontario	3,830		3,830
Windsor	3,150		3,150

Appendix F-5

NRC Grants to Universities 1968-69

Research Relevant to Communications by Activity

VI. Computing

	A. Long Term Relevance	B. Direct Relevance	Total
Alberta	12,840	3,480	16,320
British Columbia		3,430	3,430
Calgary		9,494	9,494
Manitoba	6,960	4,900	11,860
Montreal	52,120		52,120
M.U.N.	2,000		2,000
Ottawa	6,370		6,370
Saskatchewan	4,120		4,120
Toronto	59,040	8,820	67,860
Waterloo	13,520		13,520
W. Ontario	1,470	3,920	5,390

VII. Negotiated Major Grants

	A. Long Term Relevance	B. Direct Relevance	Total
Calgary	125,000	114,980	239,980
Saskatchewan		100,000	100,000
Toronto		40,000	40,000

VIII. Atomic Energy

	A. Long Term Relevance	B. Direct Relevance	Total
Saskatchewan	83,050		83,050
P. C.	144,500		144,500

Appendix G

Estimated R & D Dollars Expenditures in Canadian Industry Total Combined Current and Capital

CATEGORY	1967	1968	1969
1. * Telephone & Telegraph Equipment	41,773,779	40,158,159	47,170,728
2. Radio Communication Equipment	5,058,125	4,829,665	4,224,474
3. Television and Radio Broadcast and Distribution Equipment	292,747	501,680	330,000
4. Television and Radio Receivers	832,000	700,000	630,000
5. Telecommunication Wire and Cable	500,000	724,000	939,000
6. Electronic Computers and related equipment	649,900	642,400	712,500
7. Components for all of the above telecommunication equipment catagories	1,360,942	1,126,384	6,561,949
Total Research and Development Expenditures	50,467,493	48,682,288	60,568,651

Source: Electronic Industries Association of Canada.

* Includes switching, transmission and station apparatus for telephone and telegraph equipment

Appendix H

R & D in the Trans-Canada Telephone System

An excerpt from the TCTS Submission to Telecommission Study 4(b)

The Canadian telecommunication carrier industry, besides having a very high degree of Canadian ownership, has also traditionally obtained most of its technical facilities from domestic manufacturers. It is a very capital-intensive industry making heavy demands on the Canadian financial resources but has also contributed very substantially to the growth of Canadian manufacturing industry and other industries supplying the telecommunications carriers. For many years most of the telecommunication equipment manufactured in Canada was of foreign design but increasingly Canadian manufacturers of telecommunications equipment have developed their own designs and are rapidly increasing their R & D capability to support their own manufacturing operations.

The market for Canadian telecommunication equipment is largely dependent on the spending on technical equipment and supplies by the telecommunications carriers, although export sales are becoming increasingly important in some sectors.

Current experience appears to be that R&D expenditure in the order of 8 to 10 percent of total product sales is required to keep pace with the rapid advances in technology and in the resultant requirements of the public as identified by the telecommunication common carriers.

Future projections are always uncertain but it is expected that the total value of telecommunication plant of the TCTS companies will rise from $6.5 billion in 1970 to $17 billion by 1980 and $42 billion by 1990.*
This will call for a tremendous amount of new equipment and it is of paramount importance to the telecommunications manufacturing industry that the bulk of this investment in new plant be spent on equipment of Canadian design and manufacture. Very directly therefore the amount of sales of equipment to the Canadian telecommunication carriers will determine in very large measure the financial health of the manufacturing industry and the amounts this industry can afford to spend on R&D. Conversely, unless a very much enlarged R&D effort is undertaken by Canadian manufacturers of equipment for the telecommunication carrier companies, it will be necessary to rely much too heavily on

*This estimate was developed by the TCTS Companies and is in Telecommission Study 4(a) imported designs and may indeed make it impossible to satisfy the need for technically sophisticated equipment from Canadian manufacturing sources.

In considering the need for R&D in the telecommunication field it should also be emphasized that a host of new input/output devices, business machines, computer terminals, etc. will increasingly be connected with the telecommunication carrier network. Most of these devices will probably be owned by telephone customers, and this class of equipment will probably call for a very considerable R&D effort if Canadian manufacturing industry is to compete in this sector of the market.

SPECIAL CANADIAN REQUIREMENTS

The importance of the Canadian telecommunication network is such that the very functioning of our national institutions, business, news media, and cultural activities are highly dependent on the reliable availability of these services. In a world of changing military commitments, uncertain peace, and internal upheavals in many countries it would be dangerous for the Canadian telecommunication carriers to be too highly dependent on foreign suppliers. This is particularly true of our basic telecommunication services both locally and as regards toll facilities. On the other hand Canada will never be entirely self-sufficient - nor will any other developed nation, nor is it desirable to be so. This need for reliable sources of supply goes further than a mere need to assure a continued supply of equipment and parts used in the network. Today there is a growing need for knowledgeable technical back-up from industry to the service industries as equipment is becoming steadily more sophisticated. It is often not sufficient that such back-up be provided by the manufacturing plant as it is frequently necessary to know the design intent of a particular piece of equipment - knowledge which can normally only be supplied by the development laboratories responsible for the original design.

The Canadian telecommunications carriers carry out very extensive planning activities, combining studies of technology, traffic growth, changing population patterns, ecology, industrial and business development, etc. in order to anticipate the requirement for new services, changes to existing services, network extension and modernization, expansion of services, introduction of new concepts of service and operation and so forth.

Out of this mass of planning data emerge short term and long term plans for expansion of services, construction of new plant, and a time table for these various steps. The details of this planning process may differ somewhat within the industry but the basic steps are the same. A very important part of this planning is the technical specification of new equipment, and the overall planning of new systems. Due to the rapid advance of new technology such plans are best developed in cooperation with the manufacturing companies, particularly with the System Engineering Department of the R&D arm of the manufacturer. If any new system is to be developed in Canada, it is essential that the manufacturing companies know 5 to 21 years in advance of the requirements of the carrier companies and that extensive cooperation takes place to develop specifications, cost estimates, delivery schedules, plans for field testing and system implementation. In the case of major systems, such as e.g. the introduction of an electronic stored program switching machine, the cost of the R&D itself is extremely high and a tremendous amount of planning must be undertaken to ensure the smooth change-over to the new facility. While the risk element is correspondingly less for other products requiring less R&D or less investment in manufacturing plant it is nevertheless extremely hazardous for a manufacturer to develop new equipment without close contact with the carrier industry.

Vertical and horizontal integration of the Canadian telecommunication industry.

The existing organizational structure of the Canadian telecommunication industry has a major impact on the performance of this industry, particularly in encouraging manufacture of electronic equipment in Canada and in creating a strong R&D base for the industry.

The major organization in this field is the Bell Canada - Northern Electric complex which combines telecommunications operations, manufacturing and R&D within a single corporate structure. Another important integrated structure is the relationship between The British Columbia Telephone Company, Quebec Telephone, Lenkurt Electric (Canada) and Automatic Electric (Canada) which all belong to the same parent organization, The General Telephone & Electronics Corp. of New York, either as direct subsidiaries or through the holding company, The Anglo Canadian Telephone Company.

These organizations manufacture a wide range of telecommunication equipment for the Canadian market and for export, supplying all of the Canadian common carriers and not just their affiliated operating companies. To illustrate this point it may be useful to look at the distribution of the sales of the Northern Electric Company for the year 1969. In that year the Company had total sales of $482.5 million, of which sales to Bell Canada accounted for $248.5, domestic non-Bell $183.4, and export $50.6. Nor is there any rigid rule within any of these integrated corporations that they will necessarily be self sufficient in all areas. Thus Bell Canada will make purchases of technical equipment from companies other than Northern Electric if a more appropriate product is available. Similarly, the B.C. Telephone Company will obtain certain types of equipment from companies other than Lenkurt or Automatic Electric, e.g. certain types of switching equipment.

By far the greater portion of Canadian R&D in the telecommunication field is performed by these integrated corporations. Thus in 1969 Bell-Northern had gross R&D expenses of $52.9 million, not counting R&D in the social sciences or on business information systems. This included both R&D performed in Canada and the value of purchased R&D. Northern Electric in 1969 performed $41.3 million R&D in its own laboratories and purchased technical information for $2.9 million, while Bell Canada performed R&D worth $2.6 million and purchased R&D for $5.9 million (from A.T.&T.Co.). In addition Northern Electric had capital expenditures of $6.2 million for R&D and Bell had capital expenditures of $.5 million.

Similarly, Automatic Electric (Canada) Ltd. is currently spending approx. $1 million annually on R&D in Canada and about $1 million annually for purchased R&D information. Lenkurt of Canada is currently spending $1.4 million on R&D in Canada and $.2 million on purchased R&D.

These figures are a guide to the magnitude of the current R&D activities in the integrated telecommunication organizations. It should be noted however that such data are never directly comparable because of the many different transfer arrangements for technical information in effect throughout the industry, thus sometimes a parent organization will charge its subsidiaries in full for license information, technical know-how etc. while in other cases such information is transferred freely without any special charges being made. The intricacy of these arrangements is illustrated by examining the Bell Canada-Northern Electric organization for R&D.

Because of the large size of this organization and its central position in the R&D field it would appear appropriate to describe briefly the main features of this corporate structure.

Bell Canada is almost entirely Canadian-owned in that 95% of the equity capital and 98% of the shareholders are Canadian. Its main operating subsidiaries are: The Newfoundland Telephone Company, New Brunswick Telephone Company, and Northern Telephone Limited. Bell Canada also has majority ownership in the Maritime Telephone and Telegraph Company Limited but is restricted to voting 1000 shares only under Nova Scotia legislation. Northern Electric Company Limited is the main manufacturing subsidiary and is 100% owned by Bell Canada. The Northern Electric Company holds controlling interest in a new corporation, Microsystems

International Limited, which has been established for the purpose of developing and manufacturing microcircuits for an international market and for use in domestic Canadian equipment. Up to the present time the R&D effort has been conducted by the Northern Electric Research and Development Laboratories with main laboratories in Ottawa and branch laboratories in Montreal, Lachine, Belleville, Kanata, London, and Toronto. These are the largest industrial laboratories in Canada, employing more than 2,000 persons, and performing R&D covering most of the telecommunications field. The establishment of these laboratories as a separate company has been planned, and preliminary steps have been taken towards the creation of Bell Canada - Northern Electric Research Laboritories. This would give the Laboratories a stronger voice vis-a-vis Bell and Northern, and it might also be an advantage for non-Bell telecommunication carriers to be able to contract directly with the Laboratories for R&D in support of their operations and planning.

Northern Electric was reorganized in 1969 essentially along product lines. Thus both marketing and manufacturing of Switching Equipment were combined in one Company division, while similarly structured divisions were established for Transmission, Wire and cable, and Apparatus, respectively. The product line organization is somewhat modified by the establishment of a separate division for International Operations and another for Distribution Sales which will provide special marketing assistance and services for the product line divisions. Under this organizational concept each product line division will work with the R&D Laboratories and with Bell Canada in determining R&D programs for each product line and will provide funding in support of such R&D. Such program determination is mainly performed by Product Planning Committees, one for each product line, with the Systems Engineering Department of the Laboratories providing strong support through the preparation of a Prospectus for each project, coordination of market forecasts, technological data etc. The principal involvement of Bell Canada is through the Planning and Research Department of Bell Canada HQ. Microsystems International Limited will also undertake a very agressive R&D program, part of which will be performed by the R&D Laboratories and part by MIL directly.

As previously mentioned, Bell Canada is particularly interested in exploratory development work which is performed by the Laboratories in advance of actual development work to provide insights and data for use in planning future development projects. Bell Canada funds 70% of such exploratory R&D with Northern Electric paying the other 30%. Development costs are in general recovered by Northern Electric through sales of equipment.

Prior to 1957 the Western Electric Company of the U.S. held a 43.6% interest in Northern Electric, the remaining stock being owned by Bell Canada. Partly as a result of the Consent Decree entered into in 1956 between the U.S. Department of Justice and the A.T.&T. Company, Western Electric sold its investment in Northern Electric to Bell Canada. Bell Canada acquired 89.97% ownership of Northern Electric in 1957, increased to 99.99% in 1962, and 100% in 1964.

Up to 1959 the Northern Electric Company had operated mainly as a manufacturing plant using design information originating with Western Electric Company and Bell Labs. It was felt this was not a desirable permanent situation, and in 1955 a study was made by Dr. C. J. Mackenzie, former President of the National Research Council, on the establishment of a centralized research and development laboratory. The R&D Laboratories were formally established in the summer of 1958.

Under a Service Agreement entered into in 1923 with the A.T.&T. Company on Services, Licenses and Privileges, and succeeded by a Service Agreement of 1949 which is still in force, Bell Canada has access to results of Bell Laboratory research and advice and assistance from the A.T.&T. Company on a wide range of matters, including general engineering, plant, traffic, operating, commercial, accounting and other matters and has the right to furnish such information to other operating companies in Canada. The agreement also gives Bell Canada the right to use of Bell Lab. and Western Electric patents and licenses and it may extend this right to its subsidiaries. Under agreements between Bell Canada and other Canadian telephone companies these companies also receive such information (excluding patents and licenses) but all companies do not contract for the same amount of information. It should be noted that the information received under the Service Agreement is not design information. It serves a very useful purpose in facilitating coordination of North-American telephone services and keeps us abreast of developments within the Bell System but does not contain the detailed manufacturing information nor design calculations and manufacturing know-how.

Northern Electric has for many years had a Patent License Agreement and a Technical Information Agreement with Western Electric. Prior to 1959 Northern Electric under the terms of the Technical Information Agreement had rather free access to Western Electric design information and manufacturing know-how. When the T.I.A. was renewed in 1959 for a further five years, and again in 1964, the amount of information obtained by Northern Electric under the T.I.A. was greatly reduced, and the economic terms became much less favourable. Essentially, Northern Electric is now in the same position vis-a-vis Western Electric as any other manufacturing company, as any manufacturer may obtain patents and technical information from Western Electric on equal terms under the Consent Decree of 1956. The flow of information under the T.I.A. entered into in 1969 between Northern Electric and Western Electric has dwindled to a trickle and mainly comprises certain types of information on electronic switching. No manufacturing know-how is included under the T.I.A.

The Technical Information Agreement may be considered a straight commercial agreement of decreasing significance to Northern Electric as most of Northern Electric's new designs are based on independent Canadian R&D. It will, however, be of some importance for some time to come because so many of Northern Electric's current products are based on original Western Electric designs or make use of W.E. patents.

The main significance of the A.T.&T. Company - Bell Canada Service Agreement to Northern Electric is that under the terms of this agreement Northern Electric makes use of W.E. patents without paying royalties on sales to Bell Canada or its operating subsidiaries but has to make a charge to cover royalty payments on sales to other companies if any W.E, patents are used in equipment sold.

It will be evident from the above that the special relationship which once existed between Western Electric and Northern Electric has undergone a drastic change in the past ten years and that today nothing more than a straight commercial relationship remains. Fortunately, the R&D capability of Northern Electric has now expanded very significantly but even then it is beyond the resources of that organization to generate designs covering all the requirements of the operating industry. The most important thing is to concentrate efforts on those projects which are really important. A major concern in preparing an R&D program is therefore to make the right make or buy decisions.

In 1969 Northern Electric's performed R&D amounted to approx. $41.3 million while the value of information purchased from Western Electric was $2.9 million. The corresponding figures for Bell Canada were: Performed R&D $2.6 million, purchased R&D (From A.T.&T. $5.9 million). The R&D budget of Northern Electric has been increasing at a rate of $5 million annually for some years now and should continue to do so over the next five-year period unless the current shortage of funds continues and forces a stop to this expansion.

Nor should it be forgotten in discussion of R&D being performed by the R&D Laboratories that some very worthwhile R&D is also being undertaken directly by Bell Canada. Such telecommunications carrier R&D is normally concerned with special assembly work to engineer a system to suit a specific function but some larger efforts such as the SWAP system development, which is a radio paging system for wide area use, have been undertaken by Bell engineering staff. A considerable amount of development work is also being done in the operating industry in the area of improved technology for burying cables, improved maintenance practices, etc. Bell Canada is also actively engaged in research in the demographic and social science field, in cooperation with the University of Toronto and the University of Montreal.

Source: Trans-Canada Telephone System.

Appendix I

Industrial Research Institute Programs

In 1965, the University of Windsor approached the Department of Industry, with a preliminary proposal, endorsed by the Windsor Chamber of Commerce for the establishment at the University of a research institute to serve local industry. During 1967, grants were approved to assist in the establishment and maintenance of Industrial Research Institutes at Nova Scotia Technical College, McMaster University, the University of Waterloo, and the University of Windsor.

Objectives

All are non-profit organizations to provide scientific services to industrial firms and other institutions, which are unable to maintain research facilities and personnel of their own. The objectives were to help alleviate the shortage of scientific and technical resources, to foster a closer relationship between universities and industry, to improve the universities' understanding of the problems of industry, to help industry become acquainted with the latest pertinent scientific and technical development. This is done through negotiation of grants or contracts between industry and universities to cover particular problems or problem areas.

Program Expenditures and Results

The Departmental expenditures are expected to be $168,000 for the year 1968-1969. In the previous year they totalled $84,206. By January 31, 1968, grants totaling $500,157 had been authorized.

Assistance under the program takes the form of grants to cover the costs of establishing and administering Industrial Research Institutes, including the salaries and wages of managerial and administrative staff, office rentals and supplies, and similar administrative expenses, normally for an initial period of three years.

Staffs have been acquired by these institutions and ongoing contracts have been established with industry and local governments; a number of contracts have been completed and active research is under way for others. The sizes of the research contracts have been generally small but have totalled $800,000 of which $300,000 was from governments. There is some element of specialization in the work, oriented towards local environment. The volume of contract research is growing at a rate that is considered satisfactory for this stage of the program. The

Institutes also provide educational services for industry in the form of specialist training, refresher courses and seminars.

There have been proposals from a number of other universities to establish industrial research institutes.

Appendix J

The R&D Committee
of the
Electronic Industries Association of Canada

This committee was formed several years ago to deal with R&D matters of concern to the electronic and telecommunications manufacturing companies in Canada. It is made up of representatives from member companies of the Electronics division, who produce professional or capital equipment, and who carry out most of the R&D activity. Their interests range from radio and television broadcast and cable systems, microwave and radar, land, air and maritime mobile equipment, navigational systems, to electronic test and industrial equipment, telecommunication switching and apparatus systems, computer and peripheral equipment.

Several briefs have been prepared by this committee for submission to the government, including those presented to the Senate Committee on Science Policy, and to the Department of Industry, Trade & Commerce. It has actively studied various R&D assistance programs with particular emphasis on IRDIA. It continues to look for ways and means of providing an effective liaison with government departments, especially where consultation before legislation is drafted is appropiate. Because it is specifically oriented towards electronics and telecommunications, it represents the best presently organized interface with this segment of the Canadian manufacturing industry on R&D affairs.

Source: Electronic Industries Association of Canada

Appendix K

The R&D Committee

of the

Canadian Manufacturers' Association

This committee was formed in 1961 to consider matters of common interest to CMA members in the R&D area. It was inactive for several years but was resuscitated during 1969 because of the need for better communications between the manufacturing industry and the government on R&D matters. Because the CMA membership comprises over 7,000 industrial companies, the Committee represents an extremely broad base of manufacturing interests and viewpoints. Its member companies are large and small, Canadian or foreign owned or controlled.

During the last eight months, this committee has devoted itself to work in the following categories:

(a) Statistics -- working with the Dominion Bureau of Statistics.

(b) Definitions -- what is meant by R&D and innovation?

(c) Government R&D Assistance Programs: -- IRDIA, PAIT, DIR, IRAP, IDAP, IMDE, DIP, NRC, Fellowship Programs.

(d) R&D problems of small manufacturers.

(e) Technical Manpower.

(f) Business spin-offs.

(g) Relation between inventors and investment sources.

(h) R&D and profits.

(i) Government Reports O.E.C.D., Lamontagne Committee, etc.

The committee has 46 members, mainly directors of research or engineering, or other senior company officials interested in R&D matters. It has already held several meetings to which senior government officials have been invited, and much useful and informative discussion has resulted. It is available at any time for round-table discussions of either general or specialized subjects in large or small groups.

The industry believes this committee can perform a very important role for the promotion or R&D in Canada and thus promote the economy. It can act as a sounding board for the government for all R&D matters of general interest to industry. Since its members represent most, if not all, of the industrial R&D organizations in Canada, it can prepare briefs to the Government which are widely representative of industrial thinking.

Appendix L

The Canadian Research Management Association

History, Constitution and Purpose:

The Canadian Research Management Association was formed in 1962 for the prime purpose of improving personal contacts across the country between individuals responsible for the management, as distinct from the execution, of research in government, industry, university and institutional organizations. Membership is by invitation and now totals approximately 124, of which the percentage in government, research councils, and institutes, universities and industries are approximately 4 1/2, 6 1/2, 19 and 70 respectively.

The common interest among members is in improvement of techniques of research management. The Association operates on a small budget, with no paid officers, and meets once a year for presentation of papers, discussions and informal seminars, and appraisal of research activities in the region. Meetings have been held in Montreal, Ottawa, Toronto, Vancouver, Edmonton, Sarnia and Halifax. In 1970 the Annual Meeting will be in Montreal, and in 1971 in Saskatoon.

Because of its broad representation, the Association does not seek a consensus, or expression of views in public, or the drafting of policy statements concerning the conduct of research in Canada. Rather it provides a means for expressing, evolving and analyzing ideas, leaving each member free to act later in the interests of the organization to which he belongs.

Appendix M

SCITEC

SCITEC is the "Association of the Scientific, Engineering and Technological Community of Canada", officially organized in January 1970. Its founding resolution states its objective: "To marshal the scientific, engineering and technological community to provide leadership, to communicate, co-operate and work within itself, with government and the public in the national interest, in those areas in which it can make a competent contribution."

The provisional SCITEC constitution provides for both society (or association) and individual memberships. Members may be affiliated with either a French-speaking "Assemblee" (ACFAS) or an English-speaking "Congress", which in turn are represented by a 29-man council. This provisional council includes members of the Chemical Institute of Canada, the Canadian Association of Physicists, the Agricultural Institute of Canada, the Biological Council of Canada, the Canadian Federation of Biological Societies, the Canadian Medical Association, the Canadian Dental Association, and the Engineering Institute of Canada, all representing English-speaking Canada. The French-speaking scientific community will have seven representatives drawn from l'ACFAS. Three social scientists, a University of Toronto graduate student, an under-graduate from the University of Alberta, and a University of Montreal student round out representation on the present council. The executive held its first formal meeting in Montreal on February 18th, 1970.

SCITEC sees communications within the community it represents, with the government, and with the general public as its most important function.

Appendix N

Technology, Innovation & R & D

Improvements in applied technology are basic to a nation's economic growth for the traditional economic inputs of labour and capital are no longer, by themselves, enough. What is critical is the application of these resources to productive purpose by means of modern technology. The effecient utilization of technology is the source of growth and vitality for individual enterprises, industry sectors, and entire nations. Studies indicate that some 90% of all productivity increases and 70% of measured economic growth in the United States, over the preceding 35-50 years, could be attributed to technological change. New technology has created new products and new industries, and there is a universal expectation of a continuous flow of new products and a continuous change in the quality of life. Certain industries, including communications, may be defined as technology-intensive with high dependence on a continuous innovative activity.

Innovation is a man-created activity and will not generally occur in industry except under one of the following circumstances:

> A general incentive or pressure for a firm to innovate; this may stem, for example, from the anticipation of increased profit margins, turnover, or growth, or a solution of its labour problems.
>
> The pressure of competition; acceptance of the need of innovation, once other firms have done so in order to survive.
>
> Ability to identify technical and connected opportunities for innovation, available for in-house capabilities, or purchasable externally.
>
> Disposal of adequate managerial, organizational, technical, and financial resources.

In the Canadian environment, the speed and effectiveness of technical innovation depends primarily on the competence and initiative of private firms. Government actions and policies, while aimed at encouraging innovation, rely primarily on initiative from industry.

The importance of science and technology in shaping a nation's future has been recognized and emphasized in recent years. Policies have accordingly been formulated and implemented, one of which is the promotion as both the source of innovation and the means of adjusting to it. This is reflected in the growth of resources devoted to R & D by developed countries, and the growing range of national objectives for which R & D is supported by government. The rapid growth in R & D is fairly recent; commitment to the support of R & D on a grand scale arose in large part from specific defence requirements, and was accelerated during the 1950's. But it is only in the past ten years that R & D and national science policies have come to reflect a broad-based public interest in accelerating the rate of technological change and economic growth. This has forged close links between industry, universities, and governments.

However, it must be emphasized that, because of international technology flows, it is not necessary for countries or companies to generate all their technological knowledge internally. Multinational companies are dominant in transferring industrial technologies and exchanging large quantities of technical goods and services between affilliated companies in various countries. Other institutions such as joint technical ventures, co-operative R & D programs, and cross-licensed enterprises are the other means of acquiring R & D. In Canada a large contribution to innovation is made by foreign companies which impose their technological, competitive, and management standards on their Canadian subsidiaries.

The corporate view of the R & D process is one of continuous operation with an object of providing a a steady flow of new and improved products and processes, including the mangement process. R & D has come to be accepted as part of the production process, subject to planning and budgeting, control and optimization. The activity is worthwhile when the monies expended for R & D are less than the resulting savings through improved production or managerial processes, or through additional revenues that may accrue from production innovation in terms of new products or improvements.

Three elements can be distinguished in the introduction of a new or improved process or product-

- establishing the technical feasibility of a new or improved product or process;

- introducing a new or improved product or process into the economy for the first time;

- innovation by imitation, when a firm introduces products or processes already introduced elsewhere.

Research and Development undertaken by a corporation may result in:

- technical success.

- product or process change or improvement.

- new product or process.

Success in any of these enables a corporation to reduce costs, as for example through savings in labour or material and economies of scale, and thereby to increase profits, to increase sales and exports, to rely less on on borrowed technology, to increase revenues through sales of technology, or to improve competitiveness.

R & D need not always be undertaken solely to create or improve specific products but may also be undertaken to gain experience and knowledge of a kind which makes possible the adoption of a technology, past or future.

The decision to commit corporate funds to R & D expense is tending to become systematized. Both quantitative and subjective measures are used to evaluate project proposals and their feasibility. They include availability of technical skills, corporate objectives, and technical, manufacturing, marketing and other economic implications.

Studies indicate that about four out of every five hours are devoted by scientists and engineers to projects that do not reach commercial success. Data on the percentage of projects that result in new products or processes show an average of 30%. According to the studies by Booz, Allen and Hamilton, based on surveys among major companies in the same industry, the efficiency range varies from less than 6% to 84%. Efficiency was defined as the percentage of the companies' R & D expenses devoted to successful products. On an average across all companies reporting data, only 45% of the terminated projects result in increased profitability.

The sales-volume/profit-pattern and the timing of the product life-cycle varies by product and industry. The result is that systematic evaluation of R & D results is most perplexing. The concept of efficiency requires a determination of but leaves open the decision of what cost elements should be taken into account. A determination of efficiency has no meaning without reference to effectiveness in achieving specific objectives at particular times, and cost may not be the only or the most relevant consideration.

The effectiveness of R & D can be determined by associating the quantitative measure of its cost with subjective notions of research achievement, which may relate to various objectives, some directly rated to profit, others to different corporate ends (i.e., manpower training).

In general a systematic methodology for evaluating R & D in these terms is lacking. Economics, sociology, politics and other disciplines are involved. It is also difficult to justify R & D by cost benefit analysis. Therefore the argument for support must be based to some extent on faith in intangible values.

A general impression prevails that innovation and R & D are the same phenomenon - that, if you have more R & D you get more innovation. Innovation is better described as a total venture, not just R & D. In most projects R & D is only 5-10% of the total process. For innovation, it is not true that the only available incentive is that of underwriting research and development. In fact, concurrently with the underwriting of R & D expenditures, measures also have to be undertaken to stimulate a high rate of investment in the industry and in the economy, so that new technical knowledge can be rapidly incorporated in the production process.

Few companies think of themselves as designed deliberately to foster innovation. In certain sectors where there is a need for a breakthrough,as communications, new collective needs of the community may not be satisfied through R & D activity alone. Only a small percentage of R & D activity in corporate laboratories, even when directed to product development involves breakthroughs; it is mostly application of known skills and procedures.

In the general innovative process, industry and government seldom concentrate on radical technological changes that may sweep aside existing practices and open new opportunities. R & D establishments usually lack a systematic methodology for evaluating such changes in which economics, sociology, politics, and even ecology are involved and affect its diffusion.

In telecommunications, innovation is required if output is to grow and the share of the market has to be cultivated. It is a large-equipment sector where innovation will have an important effect on total environment and performance. The sector is of strategic importance with regard to the employment of scientists and engineers. Few other countries are as advanced; therefore the problem is not to rely mainly on foreign technology or to make an effort to catch up with other countries.

Having identified the need for development in telecommunications it would be necessary to develop the necessary unified program of research and application, after having defined the technological and economic environment. A <u>laissez-faire</u>

concept does not lead to optimum allocation of R & D resources for the common good and future growth. Future growth is not to be viewed in only the economic sense but in the sense of possibilities and potentialities of a given society.

A present handicap is the absence of leverage, through procurement contracts, to influence the level of R & D in the industry. In the absence of a national strategy for industrial development, it would be necessary to develop a framework for the telecommunications industry if R & D endeavour is to increase and give results.

An example is the new world of opportunity that is being created in the field of information science. It should be possible to provide a totally new information and entertainment service for the individual user. Despite the enthusiasm for such a network at all levels, neither the industry not the government has yet produced the grand design needed to tie together the multilinks of different information and entertainment network schemes.

In the absence of such planning, the companies would have to maintain a costly program of R & D on a continuous basis, aimed essentially at product improvements and updating. There is no need for external stimulus for the encouragement of such R & D. Competition would require companies to improve products and to reduce cost in order to survive, and it is not the R & D programs but the heavy expenditures on equipment, marketing, and forced obsolescence which would continuously affect their capital resources and profits.

Source: J. Moorjani, Department of Industry, Trade and Commerce.

Appendix O

Why Canadian Companies Engage in Communications R and D

The purpose of industry is to produce and market manufactured goods or services. To achieve the primary purpose it also aims at providing employment for professional people and for a diversity of skilled, semi-skilled and unskilled workers. It organizes the efforts of this total work force, coupled with the utilization of raw materials and capital equipment, to achieve this primary purpose.

The basic reasons for carrying out R & D programs in industry vary from company to company, depending on size, ownership and product or service interest. In one way or another, however, the following generalizations apply to most science-based or technologically oriented companies.

All the complex and diverse operations of industry must be conducted efficiently in order to provide a satisfactory return on the capital invested in the enterprise. This can be utilized either for expansion of the business, when market circumstances make this desirable, or to pay a dividend to the stockholders, or both. The achievement of this 'return on invested capital' is a major objective of busines which, unfortunately, is often misunderstood or misrepresented by some modern critics of the industrial scene. From the point of view of the stockholder, it is to some extent comparable to the interest paid by the chartered banks for deposits in savings accounts. From the viewpoint of the company it is also analogous to a management fee earned by virtue of good management in the conduct of the business operations. Finally, it is on the basis of these 'profits' derived from business operations that corporation income taxes are paid and therefore, if the return on invested capital declines, so also will government revenues derived from industry.

Despite some of the failings attributed to industrial operations, which are receiving increasing publicity at the present time, it is fair to say that, on balance, in the pursuit of its objectives industry has contributed not only to national economic growth but also to the quality of life. It does this directly through the products or services it makes available to the public, and indirectly by generating government tax revenue. Together, these represent a very large proportion of government income and, to the extent that such revenues are used to improve the quality of life in a country, industry is making a very substantial contribution. Finally, less tangibly but no less importantly, industry contributes to the quality of life by virtue of its social links with the community and the kind of total environment which it establishes for its working force.

From the customer's point of view the products of competitive industry must be reasonably priced. This is also an industrial objective, since a much wider market is usually open to a lower priced product. The customer also expects quality in the products he buys, and no industry will survive long if its goods are shoddy. The customer has also come to expect improvements and advances from year to year in the products available. This is especially true now, when technology is advancing rapidly. Improvements in performance, quality, or price are all attractive to a customer or prospective customer. All the interests of the customer are protected under a free-enterprise system in which competition is strong. For each company to retain an acceptable portion of the market it must continually strive to remain efficient in all its operations, lowering its costs so that its products or services are offered at competitive prices, still leaving a satisfactory return on the capital invested in the company. The competitive environment also forces all companies to maintain the quality of their products and their performance characteristics, and to look to the future, engaging in product improvement and the marketing of new and advanced models, keeping fully abreast of the state of the art. The attainment of all these objectives is dependent on the R and D undertaken by industry.

Some service industries are virtual monopolies, where prices to the customers are regulated by government. Since this procedure limits income, such industries are under particularly heavy pressure to be efficient in order to make returns on investment which will attract new capital required to meet the demand for increased services. This pressure is passed on to the manufacturing companies supplying monopolistic service industries, and it is imperative that they sell competitive products at the lowest prices consistent with making reasonable returns on their own investment. To accomplish these objectives supplying companies must undertake well organized programs to reduce costs and increase efficiency. If they are to maintain inventories of modern equipment suitable for sale in both domestic and foreign markets, they have no option but to undertake comprehensive R & D programs.

If an industry is engaged in manufacturing and marketing a product, from time to time production problems will arise which call for engineering assistance in their solution. This engineering assistance will often necessitate research before it can be effective, and this research will usually be of an "applied" rather than a "basic" nature. In general, the more technically advanced the product, the more sophisticated the production engineering support will have to be, and the more highly qualified the engineering personnel.

Again, to keep such an engineering team on its toes and abreast of advancing technology, it is essential that they devote part of their time to research programs of direct relevance to the field of technology with which the company is generally concerned. Such research programs would most likely be aimed towards the development and ultimate production and marketing either of improved hardware, or of completely new models with such qualities and characteristics as will make them much more attractive to customers and potential customers than either the older products or the products offered by the competition. Here again, as in all cases, it is the needs of the customer which really determine what a company must offer in order to be successful in the market. The successful entrepreneur needs all the skills, knowledge, and past experience available to him in correctly assessing what the customer needs.

In the course of providing production-engineering support, engineers and scientists will recognize the possibility for improvements in products, based on some redesign to incorporate recent advances in technology. Here again development programs are essential. Much more radical product changes may appear possible if research programs are undertaken to explore completely different technological approaches. Decisions must be made at the management level, and it is evident that the degree of risk is proportional to the extent that the new products depart radically from the old. Thus the evolutionary process within a company originates most frequently from the engineering team engaged in product support. The pressure to develop new products may derive from commercial intelligence about what the competition is doing or may be going to do, or what the customer is beginning to demand, or what it is thought that he will be demanding in the near future. In such cases, the sales and marketing departments, or the senior corporation management itself, may identify and promote or initiate the required R&D programs. Since it is accepted that all products have a limited life-span and will, sooner or later, be replaced, companies must themselves be engaged in advancing the technology, to an extent that enables them to lead rather than follow in the development cycle.

Since market demands may give rise to fluctuations in business activity (and this is very true for defence requirements), most companies attempt to stabilize their business by diversification of products and development of broad markets. This is often difficult and calls for conscious and deliberate management decisions to initiate R&D programs leading to products quite different from those being currently produced, although usually based on the same or closely associated technologies. It is not common for companies to be able to achieve success in diversifying their activities into fields employing technologies radically different from those to which they are accustomed, other than through acquisitions or mergers.

In the complex world of today the technology utilized by industry for innovative purposes comes from a variety of sources. Some is self-generated, some is imported from parent or associated companies, and much is derived from current publications or past contributions to the existing total pool of knowledge.

Industrial companies, especially in Canada, do much more applied R&D than basic research. To some extent basic research is a cultural activity which adds to our fundamental scientific knowledge but cannot usually be economically justified on a large scale within industry. Because of its association with the production of new scientific knowledge and the learning process, it is an activity best suited to the university environment. To some extent basic research in certain areas is appropriate within government laboratories where, as in the universities, the generation of short-term results leading to the production of new goods and services is not required. Modern research tends to be highly sophisticated, involving specialized and expensive facilities and test equipment which can be provided only through large expenditures by or in government, or by special grants or endowments to universities.

Between 50% and 80% of the products of most technology-based industries did not exist ten years ago. These products are the result of applied R&D either performed in Canada, or based on imported technology developed from foreign programs. Canadian companies will have to import much of their technology for many years to come, and that the transfer and application of this technology requires a trained staff competent to make technical decisions. Such competence, and the ability to make decisions which will best utilize a company's resources, cannot usually exist without an in-house capability in applied R&D.

Diversification and the development of a broad product line can be achieved by importing technology, but market requirements in Canada are often sufficiently different to necessitate special design requiring additional applied R&D. The exploitation of export markets generally demands designs somewhat different from those used domestically, and here again applied R&D is required in Canadian companies. It is becoming increasingly apparent that only those companies which maintain a dynamic and progressive applied R&D capability will be able to meet the challenge from foreign competition in both their internal and overseas markets. Nonetheless, industry is now recognizing that some of the basic research necessary to ensure the continuity of business must be done in industry, where it can be product-or mission-oriented. The amount of basic research in Canadian industry can be expected to increase in future but, even if product or service development is vastly increased, Canada will continue to rely heavily on the results of foreign research.

Hitherto, a significant factor in coordinating R&D activities has been the pivotal effect of the government grant or aid programs. An EIAC representative pointed out that the Department of Industry, Trade & Commerce makes a very real effort to coordinate industrial applications. In making grants it has attempted to establish whether companies have the resources for any determined research project; it also encourages work under way in the laboratories, and assists in marketing the results of that research. As previously noted, the NRC university research grant program is a focal point in obtaining information on research activities in universities. However, it was ageed that there is really no central clearing-house affording a total picture of R&D activity in the communications sector, and singularly missing is some form of active information exchange between research projects in differing but allied fields of activity. The industry representatives on the Project Team noted particularly the difficulty of receiving and maintaining an accurate flow of information on research activities undertaken by government departments in their own laboratories.

The exchange of information on research activities is inhibited by the problems of proprietary information in industry and, in some instances, of security in government. As excuses, both are often chimeric. There is no doubt that the lack of information, particularly between one research manager to another, contributes to the inefficient utilization of resources, and deflects the coordination of research activities with specific goals.

The coordination function of government grant programs is really one of its secondary objectives in promoting a higher degree of effectiveness in R&D activity. The main thrust of the IRDIA and PAIT programs has been to develop a higher degree of technology and R&D capability in Canadian industry; to get, as the current phrase goes, 'more bang for the buck'. In discussing the effectiveness of present research and development policies, the EIAC representative made the following comment on government grant and aid programs:

> "The generally low level of profits in the telecommunications manufacturing industry makes it impossible for most companies to fund their own R&D programs. Many companies are now unable to afford their share of jointly funded programs, though this situation has recently been improved by the change in the

regulations of the PAIT program whereby companies no longer have to pay back the government share of successful programs. The Trans-Canada Telephone System is a notable exception to this state of affairs as it can afford to sponsor some R&D in fields of direct interest, though this is due to the volume of its business rather than to the percentage profit it makes, since its rates are subject to Parliamentary regulation. The universities also need considerable government assistance to augment their own very limited resources and one benefit from this could be to encourage them to do more applied and less basic research. The government must share the overheads as well as the direct costs of research programs and a review should be made of the support afforded graduate students and of the salaries paid to junior faculty or senior research associates. If this is not done the drain will accelerate.

The initiative in all these programs comes from the company or the university concerned whose task is to convince the responsible government department of the need for the proposed research and development of funds and of its ability with available personnel and resources (sometimes augmented by capital grants) to carry the work to a successful conclusion within the time frame and financial aid requested.

This is fine, except that it does not go far enough. Certainly neither the universities nor industry would accept complete government direction of their R&D activities, but there are very few direct government R&D contracts in either of the non-government sectors.

Government must have strong in-house R&D to keep it up to date with technological progress so that it can assess trends, decide priorities, and coordinate national R&D efforts, but there should be a greater willingness to make use of expertise, regardless of where it exists, in the country. It is therefore necessary in Canada to have major fully funded government programs extending over periods of three to five years to enable industry and the universities to establish and maintain research and development at an adequate level."

Considering the present spread and organization of R&D activities, it seems desirable that coordination for the purpose of monitoring the level of activity, exchanging information, and analyzing the results so that they can be related to national goals should be the prime responsibility of the government. As previously stated, government-supported aid programs now contribute greatly to coordination at the information level, although there has been little leadership from the government in establishing goals for research and development in the communications sector. The difference between coordination and planning was noted in discussion, and it was suggested that there was little likelihood that R&D activities could be so tightly coordinated as to produce a single end result, or indeed that this degree of coordination should be sought for. In the long run the objective should be that each research centre - whether in government, industry, or a university - would establish its own objectives, paying due regard (if only through enlightened self-interest) to the contribution to be made in meeting national goals.

Source: Electronic Industries Association of Canada

Appendix P

Reasons for Conducting Research and Development in Universities

By a series of historical accidents, universities have acquired several functions, the most obvious of which are, teaching and professional training, the difference being primarily one of attitude. Other functions are the additions to the accumulated store of man's knowledge through research and similar activities, and the ability to speak authoritativly in academic matters by testing for professional certification.

At present it is generally agreed that the best performance in any of these activities cannot be achieved by concentrating on that activity alone -- the best teachers, from the university point of view, are those who are up to date in their subject, and who maintain contact with the latest developments through research. In many subjects it is necessary to maintain a close contact with the outside world by, for example, private practice in the professions, or by consulting in the sciences. These activities produce many internal conflicts of interest.

However, if there is one consideration which overrides all others in a university of repute, it is the constant striving for excellence. The path to advancement in the university hierarchy is by demonstrated personal excellence in all the functions listed above. This is an individual performance, and it has the consequence of ensuring that the research activity of each academic is a part-time effort, although often much more than a half-time effort, and that the judgment of an individual academic staff member in research is based on his ability to conceive a new research project and to carry it out.

There is a tradition, embodied in the slogan "academic freedom", that universities shall not dictate the nature of the intellectual activities of individual faculty members, and this is consistent with the practise in the assessment of performance, that it is the individual's judgment in these matters which is being assessed, and that the individual must have complete freedom to choose what line of research he should pursue.

University administrations cannot tell an individual faculty member what kind of research he should do. The only ways in which research interest in the university can be directed by the administration are by hiring as faculty members people with common interests, and by providing facilities in a certain field (although this may not be as effective as may often have been thought). Of course, a faculty member may change his interests, and almost nothing can be done to stop him since he is usually protected by "tenure". This is of course one aspect of the concept of academic freedom.

In addition to his advancement in the university hierarchy, an individual faculty member usually takes great interest in his reputation in his wider professional community, and his reputation outside the university is almost always taken into account by the university in assessing his total performance.

Universities are not places where a concentrated effort can be mounted using a large team of scientists and technicians on any particular problem. Since the same research activities are used to train graduate students and are part of the teaching function of the university, such projects cannot be carried on with the same efficiency as in an institute devoted entirely to research.

Source: Dr. J.M. Daniels, University of Toronto.

Appendix Q

The Role of Systems Engineering in Telephone Communications

The term "Systems Engineering" has a variety of meanings attached to it. In different places and different circumstances many of these meanings are equally useful. It is now recognized that systems engineering is an essential activity in most parts of the communications industry, but this discussion will be confined to systems engineering as it applies to the telephone network. The scope and complexity of the telephone communications network undoubtedly influenced the early introduction of systems-engineering techniques and philosophies.

Historically the telephone network has been considered to comprise four major classes of communications equipment.

(1) Station Apparatus - comprising a wide variety of input - output devices, including the telephone set located on the user's premises.

(2) Outside Plant - comprising a variety of wires and cables, with their associated mounting hardware and supporting structures, used to interconnect separate points in the network.

(3) Transmission Equipment - used to amplify and/or multiplex a large number of circuits onto a wire, guided wave, or radio facility; included are equipments for amplifying or regenerating the transmitted signal on the facility.

(4) Switching Equipment - used to select an available path through the network under the control of the user, to permit connection of the calling party to the called party.

These somewhat arbitrary definitions have served their purpose well for many years, but as technology advances the differences between these four kinds of plant are becoming increasingly difficult to distinguish.

One of the principal activities of systems engineering is to optimize the economic and technical design of the overall network, taking into account both initial capital requirements and ongoing operating and maintenance expenses. This involves the introduction of changes to permit existing services to be handled more economically, the introduction of new services to increase usage of the existing network, and anticipation of the changes required for future service requirements that would exceed either the capacity or the capability of the existing network design.

On account of the size of the capital investment embedded in the existing network, and of the universal nature of network service requirements, it is seldom possible to design an entirely new network. All future changes must be considered in the context of what already exists. The future must be made compatible with the past.

In the introduction of new technology into any one of the four major kinds of plant indicated above, the existing characteristics of the other three place restrictions on what can be done with the one under consideration. Therefore it is generally necessary to consider advancements in all four classes simultaneously; the establishment of trade-offs, and the definition of interface characteristics and functions to be performed by each is a major objective of systems engineering.

While systems engineering is a relatively small group accounting for only about 5% of the total R & D effort, it represents the tip of the R & D iceberg--it guides and directs the rest of R & D in determining what should be done, why it should be done, and when it should be done. It assures that the efforts of individual development groups are co-ordinated towards the establishment of an efficient economic overall system or network of communications.

Perhaps Peter Drucker was thinking of the importance of systems engineering when he said:

> "Success is more dependent on doing the right things than it is on doing things right."

The fundamental role of systems engineering is to determine, from the millieu of development opportunities, the limited number of projects that <u>should</u> and <u>can</u> be undertaken, and in this way to provide guidance in establishment the scope and content of R & D programs.

Since the systems engineer forms a sort of bridge between the user and the developer, he must be capable of interpreting the state of the art and the development capabilities to the user; telling the user what can and cannot be done at this time and why. He must also protect the user's interests and interpreting their requirements to the development engineer. It is therefore essential that system engineer's relationships with both groups be maintained on the highest possible level.

The process of project selection is complex, and there are no easy rules by which the value of one specific project versus another can be determined. There is, however, a variety of criteria which must be considered in each case, and the trick is to determine what weighting should be applied to each factor in each case.

Some of these criteria are as follows:

--- Corporate objectives
--- The Need
--- The Market
--- The State of the Art
--- Competition
--- Resources
--- Technical Feasibility
--- Economic Feasibility
--- Timing

--- What?
--- Why?
--- Why Now?
--- Why This Way?
--- How Much?

The systems engineer is charged with the responsibility of protecting the integrity of the existing communications network in terms of its quality and its ability to continue to provide communication services now and in the future.

Source: Northern Electric Company Limited.

Appendix R

The Economics of Research & Development

Synopsis

This paper presents a brief discussion of the economics of Research and Development in the Communications Industry, in a limited sense. It does not concern itself with the importance of R & D in the national economic context, but is confined to the questions of a) costs of R & D related to new products and b) the economics of decision-making in R & D programs.

Relationship of R & D Costs to Total Costs of Innovation

In order to discuss the aspect of R & D economics, some definitions are necessary. For our purposes, the following will be used:

R & D Costs: The costs incurred in the innovation process up to the point of creating and producing a feasibility prototype of the product, with all performance characteristics substantiated, and manufacturing drawings available. Innovation Costs: The total costs of creating a marketable product. These include the costs of R & D, and the costs of engineering for production, tooling, manufacturing set-up, and initial marketing planning. There is no simple rule-of-thumb relating costs of R & D to total costs of innovation. The kind of manufacturing system (production line or job shop), peculiarly suited to the product has a heavy bearing on such a ratio and is perhaps the most important single variable.

(a) Products which are amenable to (and justify) the establishment of a production-line manufacturing system, have a heavy proportion of innovation costs in the non-R & D phases. That is, the costs associated with tooling and manufacturing set-up tend to be high compared to the basic design costs. Further, by their nature, such products are generally directed to a diverse market, and market introduction costs are thus significant. For these reasons, basic R & D, defined as above, may represent as little as 15% of total start-up cost.

(b) Other products, generally of greater complexity, involving more assembly operations, and often being made to order, have a different cost build-up. They are often made in facilities adapted to a variety of products which meet different needs of the communications industry, but which have many manufacturing features (e.g. printed circuit boards in shelves on bays) in common. R & D for these products may be 50% of total start-up costs.

Cost of R & D as a Function of Sales

(a) Here again, there are no generally applicable rules. Production-line techniques are justifiable only for high volume sales, and it follows then, from the discussion above, that the costs of R & D will be low in relation to sales volume. In practice, as little as 1% of sales may be adequate.

(b) Job shop type products generally are aimed at a less diverse market, often being designed for a community of communications users rather than for individuals. This tends to limit their potential sales and raise the amount of R & D compared to sales. R & D costs may, for these products, be as high as 8% of sales.

Economics as a Factor in R & D Decisions

The decision to produce or not to produce a given item is based on a complex array of factors. The decision to manufacture a major product line, and the decisions governing the selection of individual products within that line, require judgement on economic factors as well as on purely technical ones.

The "technical" parometers, for system or sub-systems, are generally amenable to precise measurement and specification. Economic factors are quantifiable but often not to the same degree of accuracy. In spite of this, a great deal of attention has been devoted in recent years towards generating systematic decision making where subjective judgments are assigned a fixed commercial value. Procedures have been developed in which estimates of innovation costs, manufacturing costs and overhead, and marketing expense, are considered along with estimated revenues to arrive at a return-on-investment figure. These accounting tools are also applicable to the measurement of R & D progress.

Summary

In the Communications Industry,

(i) R & D costs range from 15% to 50% of total innovation (start-up) costs for new products.

(ii) a) R & D costs range 1% to 8% of probable sales of new products. b) Total Innovation costs range from 5% to 20% of the sales of new products.

(iii) The decision to undertake or not to undertake a new product venture is based, in an increasing number of cases, on a methodology which ascribe values to the cost of R & D and the possible or potential pay-off from incurred R & D expense.

Source: Dr. R.R. Jackson, Northern Electric Company Limited.

Appendix S

How Companies carry out R & D programs in Canada

A description of how industrial R&D Programs in the communications field are organized and carried out in Canada must take into account that the procedures may vary depending on size of company and ownership. Chart 1 gives a generalized view of the most likely responsibilities for the main functions associated with any R&D programs or project. There are, of course, large companies both Canadian and foreign owned, which do little or no research and development, since they depend almost entirely on imported technology to provide the design and manufacturing information for their manufactured products. On the other hand, there are large foreign-owned companies which carry out in Canada all the R&D and manufacture associated with certain lines of product for their whole company and for which they have access to world markets.

Origin of Ideas:

The main elements of any new program are origin of ideas, planning, approving and execution. In large companies, the flow of ideas, proposals, and plans is generally upward through the organization, whereas in a small company it is usually downward from the senior officers. In large companies the motivation to establish new programs comes from middle management which is sufficiently senior to appreciate the significance of ideas generated elsewhere because it is close to the technical aspects of the business. In small Canadian owned companies, the president or one of his senior officers is generally the prime innovator and motivator. Small foreign-owned companies generally do not have R&D programs, since most, if not all, of their design information is imported.

The industrial innovative cycle, leading to the introduction of new products or services, begins when an idea occurs for a mission-oriented basic or applied research program, or a carefully aimed development program. Such ideas originate from many sources, including customers, management or marketing departments, or from individual inventors either within or without the organization. Generally speaking, however, most ideas for products, services or programs originate, in large companies, in scientific or engineering departments where highly developed technological awareness of the state-of-the-art exists. At one time it was thought that innovation followed an orderly progression from research, through development to manufacture, ending in the sale of products or services. This sequence is true in many cases, but it is becoming increasingly evident that a more common starting point in industry is the recognition of a customer need. Since industry is customer oriented, R&D programs are generally undertaken in areas where definite needs, however tenuous, have been identified.

Program Plan:

The next step is a program plan in which technical, economic, human and physical factors are considered collectively. Where the products or services are complex, it may first be necessary to institute an exploratory program to determine technical feasibility before a full development program is undertaken. Before development begins the program plan must have considered the chances of success or the risk of failure. This involves determination of the estimated total cost of the engineering development, the estimated market for the goods or services, an assessment of the capital expenditures required for tooling, testing, other manufacturing costs, cost of production prototypes and field trials and costs of market introduction. The estimated price and quantity of the product to be sold gives the estimated income which is then compared to the total of all costs up to the "ready for manufacture" point, to determine the return on the investment. Only after this is done can the risk be weighed and a decision made whether or not to proceed with the development. Decisions to carry out small developments are often made intuitively by experienced managers, but large developments where the risks are very high, are demanding more and more careful study before authorization and approval.

The program plan must take into account technical, management, marketing, financial and manufacturing aspects of the proposed program. The technical plan sets the technical objectives to be attained as a result of the development; the estimated time, staff and cost on the basis of arriving at certain milestones in order to accomplish the final objectives. Estimating some development plans is equivalent to planning invention, where success requires the solution of problems for which there is no ready solution. The tendency is to underestimate the length of time required to obtain these solutions. Experience in development work is essential in estimating realistic schedules. The management plan usually shows the organization required to perform the various tasks, including staffing, scheduling, flow or PERT diagrams. Marketing plans describe the potential markets and quantities for the successful product, including customer data, timing, sales and distribution methods, sales promotion and advertising. They may also include installation planning maintenance and servicing methods and routines. Financial Planning will depend on the size of the company. In large companies, even major programs may be fitted into the overall R&D budget. Small companies may have to borrow through normal channels, sell bonds or stocks or otherwise find financial backers. Many companies rely heavily on government incentive programs to fully or partially fund R&D

expenditure. Companies expanding their R&D operations (increasing expenditures) are usually eligible for IRDIA grants allowing them to undertake programs which otherwise could not be afforded. Manufacturing plans must take into account capital expenditure for tools, test equipment and other plan facilities which would be necessary to carry out manufacture if the product is successfully developed. These plans may also include staffing requirements, the provision of special skills, training programs, and shop loading for planned delivery scheduling.

Financial Approval:

Most industrial companies have an overall R&D budget which is approved on an annual basis by the president and board of directors. This budget blocks out the general nature of the work to be performed and the funds and staff required. During the year each major project will be studied and planned as outlined earlier and will require separate approval (within the overall budget) at different management levels up to and including the president and in some cases the Board of Directors. Smaller projects are carried out under blanket approvals in the overall budget and are individually approved at lower levels in the company.

Some foreign owned companies in Canada operate in an autonomous manner with full control of approval of their R&D programs. However, most subsidiaries refer their R&D , manufacturing and sales budgets to their parent company for approval. Major R&D projects may require corporate headquarters approval, based on a complete cost assessment by the local organization. In programs involving a high degree of uncertainty and financial risk, the usual procedure is to plan and approve only the initial expenditure, which may cover exploratory research or development or system engineering studies. When this portion has been completed, the company should have a much clearer view of the whole program and at this time decide whether or not it is worth proceeding.

The Innovation Process:

Once approval has been obtained for the entire program, research or development begins according to the technical plan. As work progresses, and designs or methods evolve, a continuous procedure of feedback and checks must be made to ensure that the desired specifications are being met. Flexibility must also be maintained so that changes in state of the available technology or customer requirements, or design changes to reduce cost or permit ease of munufacture, may be readily and smoothly introduced from time to time. This flexibility does not always exist and its absence can significantly affect the profitability of the program.

The technical feasibility phase may be considered complete when a working prototype (or breadboard) successfully meets all design criteria. However, at this stage the development is far from complete because final production models must be produced from sets of manufacturing drawings. Before this can be done, tool design and manufacture is often required in order to produce tool made samples or prototypes representative of the product to be manufactured in quantity. The cost of this portion of the development, up to the "ready to manufacture" point which includes preparation of final manufacturing drawings and related information, is generally much more expensive than the original technical development. If market studies and introduction costs are included, the total cost of the entire innovative cycle may be anywhere from two to six times the cost of the basic R&D, where R&D refers to all costs up to and including provision of manufacturing drawings.

Exploratory Work:

Before technical feasibility can be demonstrated, exploratory development or even basic research may be required. If neither of these activities is involved, the project would be simply a matter of engineering design based on known techniques or principles. Design programs should in no way be downgraded, since they are a primary source of innovation and contribute heavily to the promotion of new business. New R&D is not always necessary to create innovative programs, since a vast store of knowledge derived from past R&D activities now exists and can be used for many years to come.

Development:

During the development of a product or the evolution of a product design, feedback to the designer from company departments which will later be affected is one of the most important procedures required to attain success. Tool and test-set design and manufacturing departments have essential information concerning the effect of design details on production costs; marketing may contribute information which will effect the acceptability of the product. Installation departments can often offer suggestions to the designer which will lower installation and maintenance costs. Where the development effort is spread over several years, it is also important to keep in close touch with the potential market because requirements may change from year to year. Many development programs have been less than fully successful because this reevaluation mechanism either did not exist or was ignored.

In many instances this feedback process exists throughout the life of a product and adds considerably to the cost of maintaining the product in production. Sometimes maintenance is referred to as "product,improvement and evolution". The cost of maintaining a product with long life is really part of the development cost and is the cost of postponing the obsolescence of the product. It is seldom included in the original estimates of R&D costs because the future of any product is difficult to foresee over an extended period of time.

Development is a process whereby a product design is created:

(a) directly by the designer's knowledge and experience,
(b) by mathematical calculation as a direct or indirect method of arriving at decisions affecting the size, shape, function, materials, etc. to meet design requirements.
(c) by systematic cut and try methods.

The process usually requires the solution of one succeeding problem after another, trade-offs between performance and cost and between one criteria and another until all essential problems can be resolved, this means that all designs (certainly in the communication field) should be optimizations of performance characteristics and cost.

In addition to skill and knowledge, development work demands certain human characteristics and temperment. People who are easily discouraged, who lack tenacity and drive seldom make good developers. Ability to absorb, mould and use the results of work done by others is essential. The developer should be co-operative by nature. He needs to have courage, imagination and stamina, especially on programs extending over many years.

Manufacturing Design:

When a prototype which can demonstrate the feasibility of meeting all design requirements has been designed and built, the work of producing a manufacturable design begins. The cost of this part of the process, up to a complete set of manufacturing drawings and full manufacturing information (including manufacturing specifications, tool design, making and prove-in , provision of capital equipment, floor layouts, process design and implementation, etc.) is at least equal to, and usually much greater than the cost of the basic design for proving feasibility. It is generally necessary to produce tool-made samples of the product to prove-in tooling and shop processes and methods. Depending on the nature of the product, field trial models may be necessary to check the design under actual field operating conditions and also to test customer acceptance. During production of such models and the field trial period, customer feeback to the designer is essential so that mandatory changes may be made to the original design or manufacturing methods.

Assessment of the final results of the field trials by the original designers or planners must take place before final approval is given to proceed with production.

Appendix T

The Generation and Control of Ideas in Research and Development

The title suggests a paradox, and Webster defines a paradox as "an assertion seemingly contradictory, or opposed to common sense, but that yet may be true in fact".

The complexity of any organizational structure is a function of its size, and a large Corporation engaged in Research and Development is faced with two major problems:

(1) How to ensure the continued generation of new ideas within a framework of sound economic control.

(2) How to communicate rapidly and accurately between the many segments of the organization which have had diverse backgrounds of experience and as result of which have different expectations of what constitutes success.

In a nutshell the problem is how to ensure that the various arms of the Marketing, R&D, Engineering and Manufacturing departments will all be enthusiastic about the same project at the same time, and that the project will turn out to be an economic success.

The answer appears to involve the creation of an informal atmosphere of inter-departmental team effort at all levels throughout the organization, working within a well conceived formal organizational structure, with well defined areas of responsibility and well recognized methods of communication.

Within the Bell Canada Ltd/Northern Electric Co Ltd. organization, various tools are employed in an attempt to reach both those objectives.

Due to the rapid pace of technological change and due to the rapidly changing external environment, much time and effort is devoted to the determination and understanding of a set of <u>dynamic corporate objectives</u>.

All R&D activity is logically divided into three broad time frames:

(1) Planning
(2) Feasibility testing

(3) Development.

Planning

R&D systems engineering is responsible for network definition within the territory served by Bell Canada. This involves the identifications of new products required to permit handling existing services more economically, the introduction of new services to increase usage of the existing network, and anticipation of the change required to be able to cope with future service requirements that could exceed either the capacity or the capability of the existing network design.

During the planning phase systems engineering works in close cooperation with the Bell H.Q. Planning and Design divisions in order to determine the future market and operating and maintenance requirements of the operating company and with the Marketing departments or the various manufacturing product divisions in order to determine and influence the business plans of those divisions.

The output of the planning phase is called a Prospectus, a document which delineates what should be done and why it should be done.

The factors considered in the preparation of a Prospectus include:

(1) Corporate Objectives.
(2) The Need -- The need is basically established by the users of telephone service, not by the company providing the service, and certainly not by the manufacturer of the products required to provide the service.
(3) The Market -- The extent of the need is determined through the preparation of short and long term market surveys.
(4) The State-of-the-Art -- The State-of-the-Art proposed to be used in a new development versus the general State-of-the-Art has significant impact on the anticipated life of any new product.
(5) The Competitive Situation -- The contemplated availability of competitive offerings has significant impact on the availability of a short term market.
(6) Availability of Resources -- The availability of resources to develop, to manufacture, and to sell has an important bearing on the advisability and timing of introduction of each new product.
(7) Economic Feasibility -- Various ratios of Development and Start-up cost to anticipated sales dollars, anticipated cost price ratios and discounted cash flow

studies are used to evaluate the relative economics of various projects.

(8) Technical Feasibility -- The degree of confidence in being able to meet the requirements of the need must be estimated.

(9) Timing -- Each of the above factors is time sensitive and so the overall timing must be worked out on the basis of an optimum compromise.

Feasibility Testing

Assuming that the recommendations contained in the prospectus are agreed to by Bell, by the Manufacturing Product Division, and by the appropriate development group in R&D an exploratory development program is initiated to test the technical and economic feasibility of the recommendations contained in the prospectus. At the same time the Product Division Marketing department undertakes a detailed market analysis to establish realistic price and sales objectives.

During the exploratory development phase systems engineering works in close cooperation with the development group to refine the product definition.

The output of the feasibility testing phase consists of a definition of system requirements from the Systems Engineering group, an estimate of costs and a plan from the development group, a set of market objectives from the Product Division Marketing group and an estimate of startup cost and manufacturing costs from the Manufacturing Division.

All this information is analysed by a Product Planning Committee consisting of representation from Systems Engineering, Development, Marketing and Manufacturing and a recommendation in the form of a Product Development Authorization is forwarded for approval by the Vice President of the Product Division or by an administration committee consisting of the Vice-President R&D, Vice-President Engineering of Bell and the Vice President H.Q. Planning of Northern Electric.

Source: Northern Electric Company Limited.

Appendix U

Notes - re Need for Research in Fields other than Pure Technology

The future is becoming more important to the present than it has ever been: we have entered an era where the pace of change is accelerating so rapidly that man has difficulty in reacting with appropriate speed and responses. At the same time the scale of impending change is increasing. Therefore, the risks and opportunities that confront us justify expanded efforts to lead the course of events rather than be led by them.

Long-term planning, which is the art of optimising the consequences of future probabilities when deciding what to do to-day, is used to various extents in conventional public and private institutions. Too often such planning is in no way geared to this task. Even more unfortunately, the effort is all too frequently highly-oriented to future technological possibilities without regard for society's real needs and emerging patterns of living.

The challenge to policy-makers and planners in public and private enterprises is to develop a true understanding of the underlying causes and needs behind society's propensity to generate forces of change. Such study is needed to give proper direction to any technological developments. Now , almost anything can be invented and developed. The question is what does society really need?

An illustrative example of the range of problems is reflected in the telecommunications industry. Historically, this industry has been involved in long-term planning because its very existence depends on providing service on demand, where and when customers want that service. Providing service requires much fixed capital investment. Hence, planning must correctly anticipate what man needs and where he is likely to want it.

Within recent years, Bell Canada, has augmented its long-term planning effort with an environment-study process. This was introduced in' the belief than many forces exist, are developing, or are waning, all of which make the future look a lot different from a mere statistical extension of past and present trends.

The guiding philosophy of the environment-study process is that man is the key to what happens in the environment. He, alone among living creatures, not only accommodates to the limits of his environment but simultaneously attacks and seeks to overcome these limits, motivated by his capacity and desire to picture and fashion an improved condition of life. His environment influences him, but he in turn influences it.

Man's development and his destiny become a continuing process of action and reaction. These forces interact through economic, political, social, philosophical and technological aspects of the environment. The results of these interactions are man's constructions (urban landscape) and institutions. Therefore, for a better understanding of the future landscape and institutions it becomes necessary to analyse man himself, and how he has reflected his desires in his present constructions. These constructions are of particular concern to the telecommunications industry since its service is provided by 'overlaying' what man builds. On the other hand, well planned communications systems designed to meet new and emerging needs can in turn influence how man may wish to shape his physical, social and economic environment. For instance, to be able to go to the office by staying home is becoming an increasingly viable option.

Many organizations have a very large stake in understanding such problems. Governments are concerned, so that they may enact laws which would control potentially undesirable situations. Industry is or should be vitally concerned with these problems. All organizations that must distribute services to the population are concerned with how and when cities will grow. Manufacturers are concerned with how markets will shift geographically, how tastes will change, and what new responsibilities they must share with society. Similarly, universities, over and beyond concern for how changing environmental factors will affect them, are increasing their study of the various aspects of the environment. For example, the University of Toronto has a centre for Urban and Community Studies, and the University of Waterloo has initiated a Department of Man-Environment Studies. In addition, CMHC. is offering 125 fellowships for graduate research in the urban environment and related topics. All these examples and many others indicate a large concern for the problems of man and his environment.

As these concerns grow, research by individual organizations will increase. This could result in a gross misuse of resources, since much of the research would possibly be duplicated and all available data and views would not be available in any one place. Moreover, certain companies may have data bases available that would be of immense value to the country in general.

At the present time TCTS, through Bell Canada, is attempting to overcome some of these problems by organizing studies between industry and universities. For the past three years Bell Canada has worked with the University of Toronto on studies concerned with such subjects as central city, urban-rural trends, urbanization, transportation, housing, to name a few. These studies have proven to be very profitable to both organizations. In 1969 studies between Bell Canada and the University of Montreal were initiated to pursue topics such as Cellular Design of Living and Working Spaces, Urban Accessibility, Changes in the Nature and Functions of Centre-City, Residential Trends and Shopping trends. These industry-university studies consist primarily of papers on the various subjects and will provide the bases for several seminars in the near future. So far, within Bell Canada, exploratory thinking on changing social, economic, and philosophical patterns is largely in the hands of a few people who rely on conferences, reading, and academic contacts for mutual stimulation and direction.

While other examples of work on component subject areas are presently being performed in many institutions, a sufficiently concentrated and interdisciplinary integrated activity with the necessary skills, scope, and freedom does not exist in Canada to-day. The time seems ripe to consider the setting up of a group, possibly a national cooperative foundation, which could undertake fundamental studies and examine long-term consequences of decision contemplated to-day that would affect all aspects of environmental problems - urban, regional and national. Indeed the complexity of inter-relationships among the various sectors of modern society makes inter-disciplinary analysis a necessary precondition to the effective function of such an organization. Such a foundation would provide an effective way for industry, government and educators to pool resources and effectively tackle problems facing Canada, as well as providing planners with the information to suggest means of creating a better way of life.

Source: Bell Canada Limited.

Appendix V

A New Research Relationship

The Environment Study is attempting to improve our Company's planning ability at two levels: one is the long range work to the year 2000, with an emphasis on trends rather than numbers; the other level concentrates on the next ten to fifteen years. It is hoped that we can achieve an understanding of present inter-relationships and trends which will contribute to a predictive model for the two time periods. It is anticipated that for the longer term it will be necessary to combine mathematically oriented forecasting methods with intuitive speculation.

A unique research relationship between Bell Canada and the University of Toronto has resulted in a significant contribution to our Company's planning potential. As a link between theoretical and pragmatic research, this liaison is providing significant input to the Environment Study.

During 1966 and 1967 the basic concepts of the Environment Study evolved, and a fundamental framework was presented to the University of Toronto. This framework formed the guidelines according to which the University has operated ever since.

For the first year, 1967-68, it was mutually agreed that the University would undertake several main areas of research, including study of urban patterns and trends, comparison of US and Canadian city structures and rural land use changes. By the end of 1968 we had received nine reports and four seminar papers.

During the second year, 1968-69, the urban and rural studies were continued, and several new areas were opened up. Exploration began into (1) the characteristics of the rural-urban "fringe" known as the urban field; (2) transportation and its impact on land use; (3) the role of migration and interaction in creating urban patterns; and (4) various forecasting methods. To date (December 1969) we have received eleven reports and we are expecting another five before January 1970.

The proposal for the third (and current) year, 1969-70, extends the foregoing studies, with the exception of forecasting methods, which will be expanded only in 1971-72 when data from the other studies can be collated and used as input for a predictive model.

The concept of the Environment Study evolved gradually over a period of years until in 1967 its main precepts could be put onto paper. Similarly, Toronto's contribution is evolving and developing as the researchers benefit by new insights into the whole problem of the changing environment.

1967 - 1968 Studies
University of Toronto

Report No.	Title	Author	Date Received
1	Urban Development, Ontario and Quebec: Outline and Overview	L.S. Bourne & A.M. Baker	Sept. 1968
2	Behaviour of the Ontario-Quebec Urban System: City - Size Regularities	J.B. Davies & L.S. Bourne	Sept. 1968
3	Structural Characteristics of the Ontario-Quebec Urban System	T. Bunting & A.M. Baker	Sept. 1968
4	Growth Characteristics of the Ontario-Quebec Urban Systems	S. Golant & L.S. Bourne	Sept. 1968
5	Trends in Urban Redevelopment	L.S. Bourne	Sept. 1968
	Appendix - List of Cities and Urban Development Variables		
6	Flows in an Urban Area: A Synthesis	J.W. Simmons	Nov. 1968
7	Farm Numbers in Ontario and Quebec Analyses and Preliminary Forecasts	E.B. MacDougall	Sept. 1968
8	Trend Surface Analysis of Farm Size Patterns in Ontario and Quebec 1951-1961	G.T. McDonald	Sept. 1968
9	Comparisons of Structure and Growth of Urban Areas in Canada and the USA	Gerald Hodge	Mar. 1969

Seminar Papers - Urban Field (Sept. 1968)

1	The Urban Field of Toronto: An Examination of a Sector	Heather Heaps	
2	New Parameters in Rural Land Subdivision	M.E. Kusner	

3	The Distribution and Impact of Cottagers in Toronto's Urban Field	A.P. Hammer	
4	Travel Patters	R.J. Gravel	

Report

10	Land Use Structure and City Size An Ontario Example	C.A. Mather & L.S. Bourne	Feb. 1969
11	Cartographic Summary of the Growth and Structure of Cities in Central Canada	G. Gad & A. Baker	Mar. 1969
12	Univariate Spatial Forecasting	L. Curry	Sept. 1969
13	Dynamic Programming and Geographical Systems	R. MacKinnon	Aug. 1969
14	Forecasting Land Occupancy Changes Through Markovian Probability Matrices: A Central City Example	L.S. Bourne	Aug. 1969
15	Models of Spatial Behavior in Urban Areas	A. Baker	Sept. 1969
16	Urban - Rural Relationships	R. VanderLinde	Nov. 1969
17	Structure & Process in Small Urban Areas	G. Barber &	Oct. 1969
18	Highway System of S.Ontario & Quebec: Network Generation Problems	R. Mackonnon	
19	A Highway Link Addition Model for S. Ontario	J. Hodgson	Nov. 1969
20	Space as a Variable in Seriological Enquiry	W. Michelson	Nov. 1969
21	Analytic Sampling for Design Information.	W. Michelson	Nov. 1969

The research relationship which has existed since 1967 with the University of Toronto and was extended to include the University of Montreal in 1969.

Discussions through 1968 and the first half of 1969 formed the basis of a mutual agreement in September 1969 whereby Professor Chevalier is responsible for a program of research on our behalf. The Faculte d'Amenagement, for which he is in charge of graduate studies, includes architecture, urbanism, and industrial design which together form the Faculty.

The proposal which we agreed upon outlines five main areas of interest:

(a) Cellular design of living and work space
(b) Design for urban accessibility
(c) Changes in the nature and functions of centre city
(d) Residential trends; and
(e) Shopping trends

Of these work is actively progressing in part (b) - urban accessibility: as a study of the need for school space in centre city and the concomitant inefficient use of space in the central city.

The Study on cellular design is already underway under other auspices.

The work that the University of Montreal is undertaking is different in scope than that of the University of Toronto. It is much more problem oriented, due in part to the influence of Michel Chevalier, and less concerned with exploring casual relationships as is Toronto.

It follows that our involvement with them has also differed from our relationship with the University of Toronto. We are being asked for much greater participation not only for ideas, but also as consultants to them as to communications possibilities.

Source: Bell Canada Limited.