Science Council of Canada

August 1971
Report No.13

A Trans-Canada Computer Communications Network

Major Program on Computers

Phase I

A Trans-Canada Computer Communications Network

Phase I of a Major Program on Computers

Available by mail from Information Canada, Ottawa, and at the following Information Canada bookshops:
Halifax
1735 Barrington Street
Montreal
1182 St. Catherine Street West
Ottawa
171 Slater Street
Toronto
221 Yonge Street
Winnipeg
499 Portage Avenue
Vancouver
657 Granville Street
or through your bookseller

Price $0.75
Catalogue No. SS22-1971/13
Price subject to change without notice

Information Canada
Ottawa, 1971

Design: Gottschalk+Ash Ltd.
The computer typesetting was produced by Alphatext Systems Limited.

March 11, 1971.

The Right Hon. Pierre Elliott Trudeau,
P.C., M.P.,
Prime Minister of Canada,
House of Commons,
Ottawa 4, Ontario.

Dear Mr. Prime Minister,
In accordance with sections eleven and thirteen of the Science Council Act, I take pleasure in forwarding to you the views and recommendations of the Council as they concern policies for a Trans-Canada Computer Communications Network, in the form of a report entitled "Science Council Report No. 13-A Trans-Canada Computer Communications Network: Phase I of a Major Program on Computers".

Yours sincerely,

O.M. Solandt,
Chairman,
Science Council of Canada.

Summary

General

1. A Major Program of national scope is essential to the healthy development of Computer Applications and Technology in Canada. Moreover, Computer Applications and Technology meets all of the criteria of a national Major Program.

2. In the sector of service to users, there is one Major Project which would dramatically improve the quality and quantity of computer services available to all Canadians and would greatly assist Canadian industry. It is the organization of a nationwide system of computer communications networks.

3. To achieve this goal a positive, vigorous Canadian policy is urgently needed. A "laissez-faire" attitude will eventually result in the supply of most computing and information services via spur lines from U.S. computer communications networks. Such an outcome is completely unacceptable on economic and social grounds. (In this respect the situation is analogous to the state of air travel in Canada before the creation of Trans-Canada Airlines, and a concerted national effort is again required.)

4. The system of networks should not be allowed to practise "cream-skimming" by concentrating exclusively on the densely populated, highly profitable regions of Canada. It must link all important centres in Canada in order to bring computing and information services to the greatest possible number of Canadians.

5. Orderly growth of the network system is essential. It must take into account the entire existing complex of telecommunications equipment, facilities and circuits, the realities imposed by this plant, and Canadian geography and economics. By building on these, it must evolve into a rationally designed system serving the greatest possible number of Canadians. A major planning effort will be required to develop strategies for this evolution, and the government must intervene if necessary to ensure their satisfactory implementation.

Policy

1. Due to our federal political system and widely different regional needs, we feel that the imposition of a single network of uniform design would be inadvisable. The development of interconnected subnetworks, each tailored to its own environment but able to communicate with the others, is a better approach. However, this approach requires:

a) a National Spine, or trunk computer communications network, to link the subnetworks (certain services could also be offered directly via the National Spine);

b) provision of regulatory and operating functions, to ensure the technical compatibility of subnetworks with the National Spine and to own and operate the National Spine.

2. The National Spine is well suited to ownership by a single Network Organization. This organization should itself be entirely Canadian-owned. Moreover, the federal government must ensure that it serves the best interests of Canada. This could be done by federal regulation of a private organization or by the holding by the federal government of a controlling interest in a mixed public-private venture.

3. The attached service complexes (computers) should be multiply-owned. Any organization, public or private, should be permitted to attach and own a service complex, subject only to meeting technical standards for compatibility with the network. This will stimulate vigorous competition in computer services, which will serve the public interest.

4. Any organization which participates in ownership of the National Spine should not be permitted to market or sell services via either the Spine or the regional networks. However, this does not preclude a network owner from attaching service complexes to the network for his own exclusive use.

Technical and Economic

1. Digital transmission of data, including computer data, voice and television signals and facsimile, is technically feasible and economically attractive. It is also more flexible than the current analogue methods and can be made much more reliable. (The Trans-Canada Telephone System is slowly converting its voice network to digital transmission for these reasons.) The major barrier to an all-digital computer communications network system is the capital invested in present analogue plant.

2. The privacy and security of data entrusted to the network system will be a major issue of concern. There is no point in developing safeguards for service complexes if the interconnecting network is open to theft of data.

3. The Canadian computer service industry is vulnerable to the dumping of surplus computer capacity from abroad, and to the high costs of current data communications services.

4. The great majority of network users will initially be found within organizations, specifically industry, government and educational institutions. However, we foresee eventual growth of computing and information services within private homes. As this trend develops, a shared use of home distribution facilities by the Trans-Canada Computer Communications Network, the telephone network and Community Antenna Television (Cable TV) will be logical. Specifically, any local distribution facility could be allowed to carry data to and from homes, although voice traffic should be restricted to the existing telephone facilities.

5. Successful prototype networks are now in operation, but none of these was designed with Canadian conditions and needs in mind. Therefore, a major research and development effort is needed to plan a network system suitable for Canadian needs. This need, plus the forecast growth in demand for data communications, means that an immediate start on network research and development is essential. Improved digital multiplexers, switchers and microwave radios must be developed. Design studies based on Canada's unique geography, on transmission economics and on anticipated types and volumes of traffic must be undertaken. Exploration of the twin approaches of circuit switching and packet switching must be performed. Research into the new software techniques needed to use computers attached to a network system is needed.* An agency to issue and monitor R & D contracts covering these and other items will be required.

6. It will be necessary to ensure that the network is responsive to the national interest, and is not allowed to drift aimlessly at the mercy of local and continental market forces.

7. The success of the network system will ultimately depend on its offering cheap enough service – substantially cheaper than the services offered in Canada today. U.S. services are cheaper today, and the American Telephone and Telegraph Company (AT&T) expects to cut its costs by nearly one-half by exploiting the economies of digital transmission.

*It should be stressed that the existing networks (see Chapter III) are experimental systems, and that they have not provided full or adequate solutions to these research and development problems.

Table of Contents

Chapter I

The Computer Industry: Economic and Technical Prospects

The Science Council's involvement with Computer Applications and Technology began with Report No. 4.[1] There it was noted that "the electronic computer may well be the basis in the 1970s of the world's third largest industry, after petroleum and automobiles, and just as these existing industrial complexes have wrought innumerable changes in contemporary society, so the computer industry will play a major role in shaping the society of tomorrow".

There can be little doubt that the computer industry* is the world's fastest growing industry. Worldwide revenue for the computer industry has grown from $975 million (U.S.) in 1960 to about $10 000 million in 1969. A value of $24 000 million has been projected for 1974.[2,3,4]

With regard to specific nations, one study of the British market has predicted that the total U.K. expenditure on computing will approach 4 per cent of GNP by 1980.[5] In France, the computer industry is expected to overtake the automobile industry in dollar volume by 1976.[6]

In Canada, about 0.48 per cent of GNP was spent on computing in 1968, and the industry enjoyed a total revenue of $500 million in 1969.[7] About $400 million of this was spent for computer *equipment*, and the rest was spent on the production and purchase of computer *programs* - the detailed sequences of commands which cause a computer to do a specific job - and on the purchase of computing services. (Computer equipment is known in the industry as *hardware*, and the computer programs are known as *software*.) One recent study[7] suggested that Canada may experience growth rates of 25-30 per cent per year in hardware expenditures and 40-50 per cent per year in software expenditures over the next ten years. These rates of growth imply expenditures in 1975 of $1.3 billion and $0.67 billion, for hardware and software respectively.

Another study[8] took a different approach to the problem of estimating industry growth, but yielded similar results. It estimated that the total value of the industry in 1979 - including spending for telecommunications - will be between $3.4 billion and $8 billion, with a "most probable" value of $4.8 billion. If we assume that Canada's 1979 GNP will be $145 billion, this means that computing (hardware, software and services) may account for 2 per cent to 5 per cent of our GNP. By way of comparison, we spent 4 per cent of our GNP on new cars in 1968.

One fact clearly emerges from this array of numbers and projections: the computer industry has immense economic vitality and growth potential. On economic grounds alone, it therefore appears to be a prime candidate for a concerted national effort.

Technological progress in the computer industry has also been impressive. New generations of computers, each involving major new technologies, have appeared every five or ten years. These technologies have been able to reduce the size of central processors by a factor of 200 in fifteen years, while operating speeds have risen by a factor of 200 and the costs of computing have dropped by a factor of about 300 in the same period. These rates of improvement will persist for several more years, and the *quantitative* changes they express will lead to far-reaching *qualitative* change. Greatly increased accuracy in the mathematical modelling and forecasting of the weather, of the dynamics of cities, of national economies - all of these are becoming feasible projects. Conse-

*This report uses the phrase "computer industry" to include the design, manufacture and sale of hardware (the hardware industry), the design, manufacture and sale of software (the software industry), and the sale of computer services (the computer service industry). Firms specializing in the latter are called service bureaux.

quently Computer Applications and Technology is a fertile field, ripe for technological exploitation.

The qualitative changes mentioned above are creating great social change in ways which are only partly understood. Personal privacy is being threatened by the development of data banks; many individuals may be able to do a day's work via computer terminals without leaving their homes; and education and health care may become personalized, cheaper and more plentiful.

Computer Applications and Technology is therefore of prime interest on economic, technical and social grounds, and this raises an urgent question for Canadians. What part should we play in this vital new industry?

The major resource needed for a computer industry is human brainpower and skill – the industry is fundamentally a "knowledge industry". The manufacture of hardware items (which requires the largest material support) is less capital-intensive than many other industrial activities, and the software industry is even less so. Indeed, the plant required for a software industry consists of office space, paper and pencils, access to computers, and perhaps a plentiful supply of coffee! Software requires little supporting industrial infrastructure, and a major element of infrastructure required for hardware manufacture is an integrated-circuit production facility such as Microsystems International Limited. Educational standards in Canada are among the world's best, and we are training large numbers of mathematicians, engineers, programmers and other potential computer professionals. Hence there is *no fundamental factor* preventing us from winning a share of certain intelligently chosen parts of the computer industry. In fact, many less well-endowed countries, such as Holland, Sweden and Israel, are already participating actively in the computer industry.

However, the present trends displayed by the Canadian industry are discouraging. The Canadian industry began with a program of original design and development in the 1950s, sustained largely by defence programs which have since disappeared. This initial effort has been replaced by branch plant manufacturing sustained by tariff barriers and industrial incentive funds. Canadian participation in the broad range of opportunities for hardware development and manufacture has been extremely small, and the software and computer service industries are generally weak and shaky. Most of our computer service bureaux are reporting annual losses and several have been taken over by U.S. firms. (The lion's share of the revenues cited earlier is enjoyed by foreign-owned computer firms.) In short, the Technology of Technologies is sick in Canada, despite the fact that there are no *fundamental* factors barring the road to a successful Canadian industry.

The causes of this malaise are well known, for they have plagued many other high-technology industries in Canada. They include small and scattered markets, the effects of Canadian geography, exposure to powerful competition from foreign firms growing in a more hospitable climate, high costs, and industrial fragmentation. A detailed discussion of these problems must await the completion of the Council's Study on Industrial Research and Innovation; however, it should be said here that the problems do not appear insoluble. Indeed there are still many promising opportunities open to Canada in the computer industry, but time is running out. The opportunities will be lost, and Canada will become a mere importer of hardware technology, software technology and services if a coherent policy is not adopted in the next few years. (Indeed, a serious trade imbalance in electronic data processing equipment is clearly visible.*) The Council feels that branch plant status for the Canadian computer industry is just not good enough. Leaving aside questions of exports, excessive dependence on foreign suppliers and lack of worthwhile jobs for highly educated Canadians, we are above all faced with the urgent need to exercise control over the shape and thrust of the industry, so that its development may be harmonized with our social priorities.

The concept of Major Programs, as set out in the Council's Report No. 4, can make a contribution towards the objective of a healthy, socially responsive Canadian computer industry. This report discusses the first of a set of Major Projects, which will collectively form a proposed Major Program. However, the adoption by government of strong and positive policies, designed to foster a healthy computer industry, will be essential to the success of this Major Program.

*This trade imbalance has grown from $35 million in 1964 to $148 million in 1970, although exports expressed as a percentage of imports have risen from 16 to 27 per cent over the same period. (Dominion Bureau of Statistics, Cat. 65-004 and 65-007. These figures cover electronic computers and parts plus card punching, sorting and tabulating machines.)

Chapter II

Three Phases of Study

The issues outlined in Chapter I certainly called for further study. Consequently a Committee of the Science Council was formed in January 1970 to conduct a detailed study of Computer Applications and Technology in Canada. The Committee's mandate was very broad, so much so that it was hard to tackle as a single entity. The study was therefore split into three separate but inter-related phases. The major questions posed in each phase are as follows:

Phase I: Satisfaction of the Needs of Computer Users
What action or actions could provide a dramatic jump in the quantity and quality of computing services available to Canadians, and strengthen the Canadian computer service industry?

Phase II: Development of a Canadian Hardware and Software Industry
What can be done to build a strong Canadian industry in hardware (computing equipment per se) or software (the design and production of computer programs)? In what areas should the industry specialize, and what are the potential costs and benefits? What policies are required to encourage this industry?

Phase III: Deployment of R & D Funds
What are the best mechanisms to support the large amounts of R & D which successful programs in Phases I and II will require? It is clear that our existing methods of R & D funding are inadequate. National Research Council grants to academics, although numerous, tend to be too small to support significant work in applied computer science. The software industry, despite the fact that it may generate four times as much revenue as that from hardware by 1980, has not been supported in the past by the Department of Industry, Trade and Commerce's PAIT program. Large industrial firms or consortia are conspicuously absent. How can this situation best be improved?

This report deals with Phase I of the study – the satisfaction of the needs of computer users.

Chapter III

The Needs of Computer Users

Our goal is to supply the best possible computing and information services to the largest possible numbers of Canadians at the lowest possible cost. The achievement of this goal is also expected to improve markedly the business climate of the Canadian computer service industry.

At present, most of the users belong to organizations - industries, governments and educational institutions - and they are heavily concentrated in urban areas. In the future, they may be joined by private citizens, both urban and rural.

The bulk of today's computing services is supplied to users at the computer site. In the future, many services will be supplied to physically remote users via telecommunications links. Even now, services such as batch processing and conversational processing, and access to data banks such as airline reservations data, stock market data and industrial product information, are all supplied via telecommunications. (At least 150 data banks exist in the public sectors of the OECD nations alone.[9]) Under active development in Canada are nationwide teller transaction systems for banking, medical record systems for doctors, and distribution systems for Scientific and Technical Information. In the future, financial utilities* and computerized shopping systems are foreseen, to name only two of a host of radically new services.

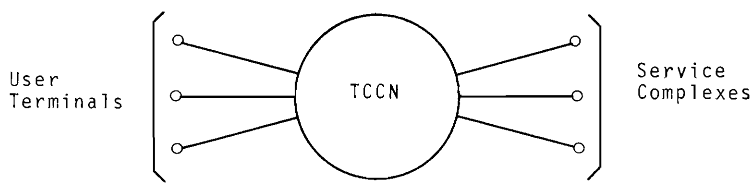
Most of these services are supplied from a limited number of sources, and a user anywhere in Canada must be electronically connected to one of the sources in order to use the service. Air Canada reservations, for example, are held in one central computer. In principle, any user may at some time demand access to any service, just as any telephone user may at some time demand to be connected to any other telephone.

There is a great need, therefore, for a computer communications network able to selectively connect any user to any service, quickly, reliably and cheaply. We have called such a network the Trans-Canada Computer Communications Network, or TCCN.

The broad outline of a Trans-Canada Computer Communications Network is shown in Figure III.1.

*Financial utilities, as envisaged by a number of authors, are computer-based systems which could automate most financial transactions, and thus could eventually lead to the disappearance of cheques and the near-disappearance of cash as media of exchange. Significant first steps in this direction are being taken by a number of financial institutions, for example the Bank of Montreal (see Chapter IV).

Figure III.1 - Structure of a TCCN



Physically, a computer communications network such as a TCCN is an integrated system of telecommunications links and data switching centres. It would permit nationwide access to computer services from computer terminals*, as well as connecting terminals to terminals (as a partial substitute for the Royal Mail) and computers to computers (to permit machines to work co-operatively). A TCCN would allow a design engineer in Regina, for example, to draw on

a) a conversational computing service in Saskatoon for rapid design calculations using pre-stored procedures;

b) a data bank in Vancouver for design data and specifications; and

c) an "electronic catalogue" in Toronto for the latest prices of materials;

all in the course of a morning's work. The effect on the engineer's productivity, and on his firm's ability to generate rapidly and efficiently new or modified bids for projects, would be most significant. This improved "reaction time" could in turn have a marked effect on the ability of Canadian firms to compete internationally.

As another example, hospital personnel in North Bay could call on

a) an analysis service for electrocardiograms in Montreal;

b) catalogues of drug prices and characteristics in Toronto; and

c) a central file of patient histories, for example in connection with an accident victim whose home was far away, whose medical history was otherwise unknown, and whose condition was critical;

whenever these services were needed. This kind of capability could make a real difference in the level of health care available to Canadians. (Notice that both of these applications involve the connection of terminals to computers. We expect that this kind of connection would be prevalent, at least during the initial period of network operation.)

These examples can be multiplied endlessly, and a number of computer communications networks are being built with these benefits in ultimate view. At present, for example, we know of:

a) the U.S. Advanced Research Projects Agency (ARPA) network[10]†, which links 14 computers at universities and laboratories from California to Massachusetts. It is basically a research project, but will allow these institutions to use each other's specialized computing facilities and data files.

b) the British National Physical Laboratory's (NPL) "local exchange"[11,12,13,14]† which links normally incompatible terminals and peripheral devices in a large laboratory.

c) the MERIT network, which will allow Michigan universities to use each other's specialized facilities and data files.

d) the Purposely Limited Network, which will link computers at the Carnegie-Mellon University.

e) the Bristol network[15], which will allow four universities in the West of England to share computing loads between their computers, thereby making better use of the excess capacity and specialized equipment of their machines.

Thus it is clear that the potential advantages offered by computer communications networks are stimulating considerable research and development. Some of the economic issues motivating this research and development are discussed next in Chapter IV.

*A computer service is any service supplied by mating a hardware system (computer equipment) with appropriate software and data bases. A computer terminal is any device which consumes computer services. Devices such as teletypewriters and cathode-ray tube displays are computer terminals, and the push-button telephone can also be used as a computer terminal.

†Brief technical descriptions of the ARPA and NPL networks are given in Appendix A.

Chapter IV

Economic Forces and Responses

There are many indications that Canada and other industrialized nations will experience startling growth in volumes of computer communications. The most carefully developed prediction known to the Council is that of the U.S. DATRAN Company, which has predicted a volume of some 8 000 computer communications "calls", or transactions *per second*, in the United States by 1980. An article in *Fortune* magazine[16] has predicted that 50 per cent of U.S. computers will be connected to telecommunications links by 1974, and in Chapter VI of this report, it is argued that the present telephone network is not well suited to carrying these "calls". These dual trends of explosive demand and inadequate supply of computer communications services have led to petitions to the U.S. Federal Communications Commission by Microwave Communications Incorporated, by Western Union, and by the DATRAN Company. Each of these firms wishes to build a specialized computer communications network.[17,24,25,26,27]

In its petition, the DATRAN Company[18] has estimated that the number of data terminals will increase from 0.18 to 2.5 millions by 1980, owing to expected growth rates of 45 per cent per year to 1974 and 21 per cent per year thereafter. They forecast traffic volume of 8 000 transactions per second by 1980, this being a growth of 1 650 per cent over today's figure. These forecasts appear reasonable and they obviously are relevant to the situation in Canada, given the many parallels which exist between our two nations. A similar trend is visible in Great Britain, where the Post Office reports that there are now 14 000 data terminals, and that forecasts of 50 000 terminals by 1973 and one-half million by 1983 have been adopted for planning purposes.[19] No forecasts of comparable depth and detail are as yet available for Canada; however the reader is referred to Telecommission Studies 4 and 5* for general information. Also, the Department of Communications Task Force on Computer Communications is working on a detailed market survey and forecast for Canada, which should fill this need well.

In addition to the traffic volumes outlined above, there are certain other economic forces which encourage the growth of computer communications networks:

a) A TCCN will offer the Canadian computer service industry greatly expanded access to Canadian markets, and a host of new computing and information services will become feasible. These effects will in turn help to overcome the industrial impediments to the Canadian service industry (small and scattered markets, geographical distances and exposure to strong foreign competition) which were mentioned in Chapter I.

b) Economics of shared resources will become possible. First, copies of certain information files are currently kept permanently in many computers. When these computers can communicate via a network, it will be possible to do away with many of the copies and use remote access to shared copies with a saving in cost. Second, there is considerable surplus computer capacity in Canada today. Where there is compatability between machines, a TCCN could allow a restricted form of load sharing (analogous to load sharing on electric power grids), thus permitting fuller use of our computer capacity.

c) Economy of specialization will be encouraged. Specialized computer designs which do certain kinds of work with greatly improved efficiency are being developed. By permitting wider access to computers, the network will allow work to be directed to the most suitable machine, thereby encouraging the use of these specialized and more efficient designs.

d) Economies of scale will be encour-

*Produced by the Telecommission of the Canadian Department of Communications.

aged. Within certain limits, it appears that doubling the cost of a computer roughly quadruples its capacity (Grosch's Law*). Again, access by computers to wider circles of users will permit this technical fact to be exploited more fully.

e) Regional economic expansion will be aided to some extent. The availability of cheap and varied computing services is one factor influencing the choice of location by some kinds of businesses and industries. By evening out the nationwide supply of these services, a TCCN will encourage a more even development of the regions of Canada. This effect will be strengthened if network services are priced according to quantity of information moved (flat-rate charging) rather than time-and-distance charging as practised by the telephone network today.†

These economic forces are operating today, and as one might expect, responses to them can already be seen. The drive to establish networks in the United States and in Great Britain has been noted, and analogous responses are visible in Canada. CN/CP Telecommunications have planned to offer integrated computing and communications services.[20] The Newfoundland Government has created a provincial Crown Corporation for computing‡, and the Saskatchewan Government has made similar plans. In Ontario, the Committee of Presidents of the Universities has studied the possibility of setting up networks to serve their institutions[21], and plans for a network to serve educational institutions have been laid in Quebec.[22] Finally, the Bank of Montreal is building a specialized network to connect all of its branches in Canada to a central computer.[23]

Hence the options available do not include the choice as to whether or not computer communications networks will be created; economic forces have made that choice for us. What can be done, if Canadians move promptly, is to influence the shape and form of Canadian networks and the goals which they serve. Thus we can ensure that Canadians control the development and applications of networks for the benefit of Canadian society. After a brief look at social issues (Chapter V) and technical issues (Chapter VI), we examine the options fully in Chapter VII of this report.

*Dr. Herbert R.J. Grosch, until recently Director of the Center for Computer Sciences and Technology, National Bureau of Standards, Washington, D.C.

†The two issues here are social utility and real costs. Flat-rate charging is highly desirable from the viewpoint of social utility. For example, the ability to send a short transaction anywhere in Canada for a small, fixed charge would greatly encourage the growth of nationwide information services of all kinds. East-west flows of information would be encouraged and the Canadian computer service industry would be greatly strengthened through access to nationwide markets.

In principle, it is possible to impose any kind of rate structure on any kind of network, as long as total revenue is adequate. However, fairness and practical considerations dictate that the charges to users reflect real costs of providing service. It is explained in Chapter VI that the present telephone network uses a mode of operation (called *circuit switching*) in which real costs depend strongly on the time taken and distance spanned by a call. Thus the use of time-and-distance charging by the telephone network. However an alternate mode of network operation (called *packet switching*), which offers advantages for certain kinds of computer communications, is also described in Chapter VI. It appears that the real costs of operating a packet-switched system depend primarily on the quantity of information moved rather than time or distance. Thus the technique of packet switching fortunately seems to favour a socially desirable objective.

‡Newfoundland and Labrador Computer Services Company Limited came into being as a provincial Crown Corporation in September 1969.

Chapter V

Some Social Issues

Colin Cherry, the eminent British engineer, has said that a society is a group of people in communication.[28] Hence the kinds and quantities of communications available to a society strongly influence its nature. The ability to transmit unprecedented masses of information across Canada, coupled with the ability to store, manipulate and process this information, is therefore of some social significance.

We could define *information* as data which is relatively difficult for a given person to access and use. Conversely, data which has been absorbed into a person's inner mental world could be called *knowledge* possessed by that person. Thus the contents of an unread book on your bookshelf is information available to you, but those contents become part of your stock of knowledge after you have read, studied and inwardly digested the book.

In the light of this distinction, computerized data banks assume new significance. Data which has been stored in a carefully structured way in a computer, and for which effective retrieval programs have been written, occupies a middle ground between information and knowledge. It is certainly not as accessible or "personal" as knowledge (computer science has yet to develop sufficiently good man-machine interfaces!), but it can be far more accessible and usable than data stored in a book. If we make such data available to large numbers of Canadians by a computer communications network, we will make a radical change in the mental resources of our society.

These concepts are somewhat abstract, but it is difficult for laymen to make more concrete observations. The examples given in this report – the design engineer in Regina working up a project bid, the medical personnel in North Bay drawing on a nationwide array of services – are examples of these themes. Privacy and security of information must rank as the most important specific issues of a social nature, and indeed are topics of concern even today. However, the effects of networks on such things as the concentration of people in urban areas, the sense of loneliness or community felt by individuals, and even the political process – these are all unanswered questions. We urge competent bodies to seek answers to these questions, as their answers will determine much of our common future.

Finally, because of the pervasive influence of computers on social and cultural affairs, on national unity and on our sense of national identity, we feel that Canadians *must* be able to control fully the development of computer communications networks in Canada.

Chapter VI

Technical Issues

We do in fact have a "data communications" network today – the switched voice (telephone) network is being used to connect terminals to computers. However, the Trans-Canada Telephone System's switched voice network was not designed to do this job, and so:

a) Error rates are too high (according to one Canadian company, one error occurs for every 10^5 bits of data sent, but a rate of one error for every 10^9 bits sent is needed[29]*).

b) The service is expensive compared with the service offered to U.S. competitors of Canadian firms.[30,32] Worse yet, the American Telephone and Telegraph Company (AT&T) has announced a new network devoted to computer communications which will span some 60 U.S. cities by 1974 and offer costs one-half the current U.S. ones. The cost reduction is made possible by digital transmission, according to AT&T.[31,32]

c) The service is inflexible (a much wider range of data rates is urgently needed, as well as more modern and inexpensive interfacing equipment[29,33]).

d) The service is fundamentally unsuited to short-message traffic which invokes fast responses, such as data bank inquiries and conversational programming (calls take too long to place, by a factor of 10-100).

e) The use of the voice network for this additional service will eventually harm voice service, as data transmission violates key assumptions under which the voice network was designed and built. Specifically, the design of the voice network assumes that calls last for an average time of about three minutes, and that the average usage of telephones is very low. However, telephones used to transmit data are often in use forty hours per week and the calls placed may last several hours.

However, the switched voice network exists, it represents a very large investment, and many parts of it are usable for computer communications. Therefore we must learn how to integrate it with new hardware and technologies, in order to create a TCCN in an orderly, rational manner.

*The user can be provided with low error rates in either of two ways. High-quality or "gold-plated" lines can be installed, at great cost and inconvenience. Alternately, we can provide some means for detecting errors and correcting them without the user's knowledge. The switchers of the ARPA network, for example, store each message as it is received. When complete, the message is checked and if errors are detected the switcher asks for retransmission. This process continues, unknown to the customers, until the message is correctly received. This technique has allowed the ARPA network to use relatively noisy, low-quality lines and yet provide nearly error-free service.

Some Necessary Technical Innovations

a) Digital Transmission

– Almost all of today's telecommunication facilities transmit analogue signals rather than streams of digital pulses, in part because the human voice is a "naturally" analogue signal, and in part because digital facilities were impractical in the past.

– Digital transmission† is now feasible, and offers economy, flexibility (a wide range of data rates and flexible interfacing are possible), the ability to send computer data – which is of course digital in nature – without transformation (encoding), vastly improved control of errors, and the ability to send voice, video and facsimile signals after encoding.

– Digital transmission hardware is available *now* for microwave radio links and wire-pairs, and will be available in a few years for coaxial cable links.

– The Trans-Canada Telephone System is slowly converting the voice network to all-digital transmission for these reasons, but this task is not expected to be completed for many years.

†Also known in the jargon of telecommunications as "end-to-end regenerative pulse transmission", because of the use of pulse regenerators at regular intervals. These are used to create a perfect, noise-free pulse for transmission onwards from a misshapen, noise-ridden pulse received by the regenerator.

b) Packet switching

Packet switching is an alternative basic principle to circuit switching.

Circuit switching is the basic principle of the voice network. When A calls B, a "pair of wires" or circuit is set up between them and is dedicated to the call until it is finished. Circuit switching is a good principle for the transmission of voices, video and possibly of large data files.

However, much of today's computer communications traffic consists of short messages invoking rapid responses. These are called transactions. Circuit switching, based on today's relatively slow circuit-switching machines, is quite inadequate for this important kind of traffic – a better principle is packet switching.

Under *packet switching*, A simply makes up a short message or "packet" of information, attaches a note saying "send this to B" and sends it off. The network reads the note and forwards the packet by the best possible route. As no dedicated circuit is set up, equipment may be utilized more fully and the transmission delay is greatly reduced. The user may send packets at any convenient rate up to the limits imposed by switchers and telecommunications links, and a link failure can be smoothly handled by simply choosing a new route. Also, operating costs are dominated by the quantity of information sent rather than by time or distance. None of these advantages is offered by a circuit-switched service. Because of these technical facts of life, the British Post Office's planned computer communications network will probably offer both types of service. The ARPA network uses packet switching exclusively.

Things to be Done

We have seen that industries using computer communications facilities are growing explosively; that the existing voice network is inadequate and expensive for this service and will become relatively more so; and that the new technology needed for a TCCN is available. Hence immediate action is required. However, "immediate action" does *not* mean "start building a TCCN", because although computer communications networks have been built, they may not be well-suited to Canadian needs. Thus the following steps should be undertaken:

a) Forecast the types and volumes of network traffic for Canada.

b) Explore the trade-offs between circuit-switched and packet-switched services.

c) Using the results of steps a) and b) plus constraints dictated by our geography, existing telecommunications facilities, transmission economics, privacy and security needs, and available and forecast technology, produce trial network designs.

d) Evaluate these designs extensively, with the help of computer simulations. Particular attention should be paid to a very careful and thorough evaluation of economic and financial costs and long-range benefits. Identify "gaps in technology".

e) Issue development contracts aimed at closing the gaps.

f) Freeze the design for a prototype network.

g) Build and evaluate the prototype network, again paying special attention to economic and financial costs and benefits.

h) Start construction of TCCN.

To meet the expected demands, this program should be completed within five years. An agency will be needed to manage the program and fund the contracts.

Chapter VII

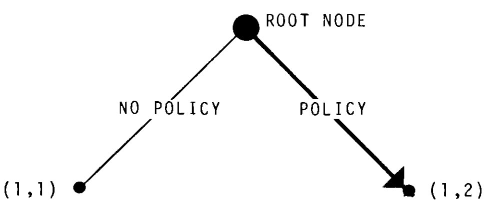
Policy Options for the Computer Utility

In this chapter our view is widened to include both computer communications networks and the attached service complexes* – the total computer utility. Our purpose is to examine the policy options for ownership and organization of the entire computer utility.

A Policy Tree

We have examined the options with the aid of a mathematical entity called a *tree*. Beginning at the tree's *root node* (Figure VII.1), either a policy of some sort is needed or it is not.

Figure VII.1



Hence we get two new nodes which are labelled (1,1) and (1,2). We feel that a National Policy is essential – our arguments are given in Chapter VIII – so we go to node (1,2), as shown by the arrow. (Unlike the garden-variety or botanical tree, a policy tree grows downward from its root node!)

Next, we consider the ownership of the entire utility – should it be single or divided? Our view is that a single organization which owned the computer communications network and all of the attached service complexes (including data banks and processing facilities) would be too powerful – it might eventually come to control government and not vice versa. Hence we develop the tree as shown in Figure VII.2 and go to node (2,2).†

Given a divided form of organization for the computer utility, we may choose

a) a single, nationwide computer communications network of uniform design; or

b) a system of many interconnected subnetworks, each tailored to its environment but able to communicate with the others.

This choice is represented in Figure VII.3.

Due to our federal political system and our widely different regional needs, we feel that a single, monolithic network of uniform design would be impractical. Hence to node (3,2). However, this choice makes desirable:

a) a national spinal computer communications network to tie the subnetworks together; and

b) provision of regulatory and operating functions to operate the national spine, and to ensure technical compatability of the subnetworks with the National Spine and with each other.

This is illustrated in Figure VII.4.

We now deal with questions of ownership of the National Spine and of the attached service complexes. Competition is highly desirable in any business enterprise, but for the National Spine:

a) Nationwide coverage and compatability are vital.

b) The cost of entry into the "network business" is very high.

c) Unit costs decrease with size, due to the economics of trunking and switching.

Hence the National Spine is well suited to ownership by a single organization. Many bodies could participate in this organization. However, in order to

*A *service complex* is the thing which we attach to a network in order to offer a computer service (see page 14). It consists of hardware, software and data files, the whole being carefully tailored to supply an efficient computer service.

†Note that the branches of the tree are not being developed uniformly. Those that represent undesirable options are abandoned or "pruned". Also note that the policy decisions represented by a given node can be read off by following the path from the root to that node.

Figure VII.2

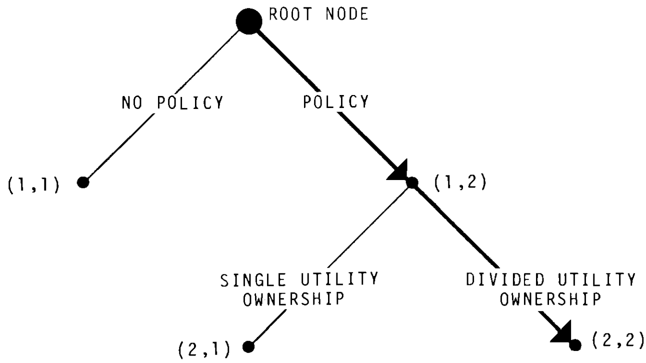


Figure VII.3

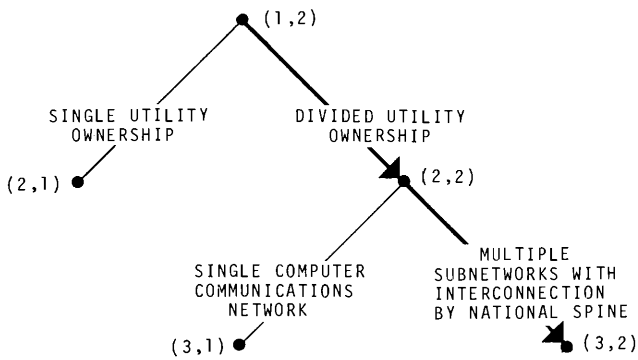


Figure VII.4A - The Single Computer Network Option

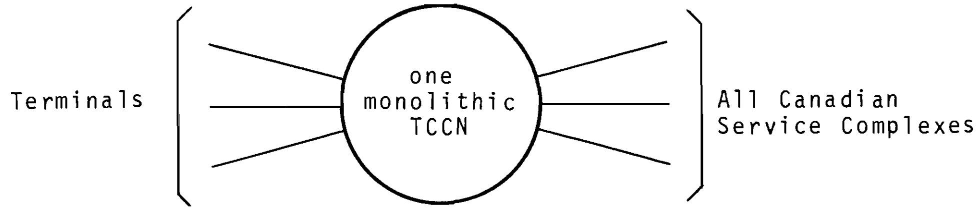
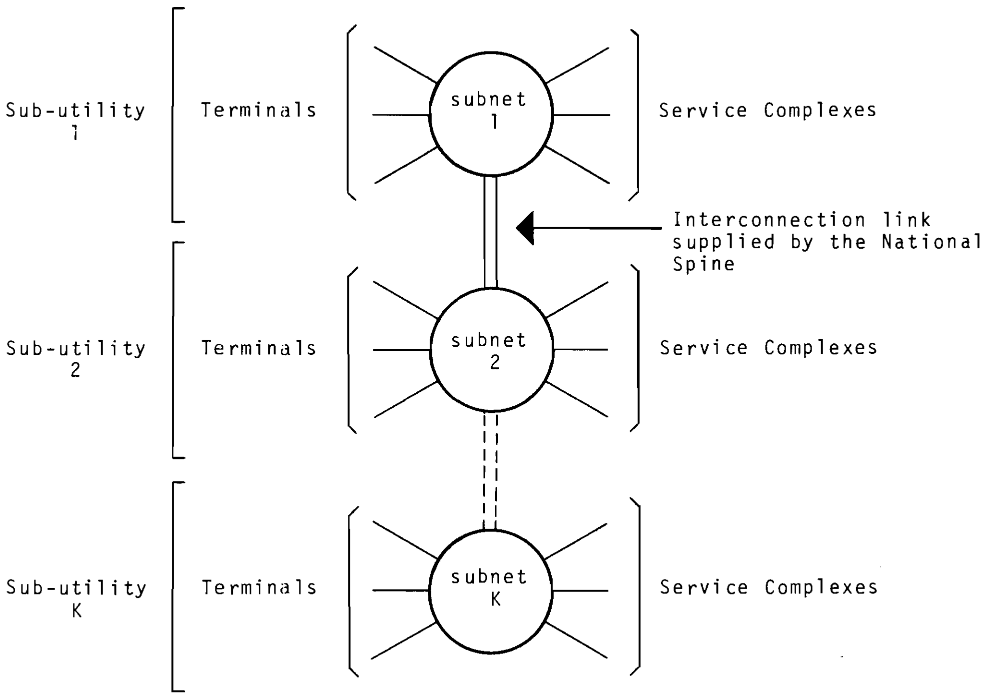


Figure VII.4B - Option of Multiple Subnetworks, hence Multiple Subutilities



achieve maximum benefit to the people of Canada, it will be necessary to restrict the free play of market forces. For example, it may be necessary for the federal government to hold a majority interest in this owning organization, or otherwise influence its operations and planning. This approach, whereby a single Network Organization owns the National Spine but many groups are allowed to participate in the control of the owning organization, is referred to as *integrated ownership.*

For the attached service complexes:

a) Nationwide access is assured if a complex is attached to the network system.

b) The cost of entry into the computer service business is relatively small.

c) Owing to the continuous flow of new technology, competition is vital for the computer service industry. Hence the attached service complexes are well suited to multiple ownership. We therefore hold that any organization, public or private, should be permitted to own service complexes and attach them to the computer communications network.

However, one proviso must be added. Consider an organization which is a part-owner of the Network Organization. If such an organization also owned a subsidiary which sold services via the network, then the subsidiary could receive:

a) early notice of new network facilities;

b) preferred treatment in gaining access to the network system (earlier delivery of lines, multiplexers and so forth);

c) better co-operation in clearing up network faults and the other problems which bedevil any computing facility using telecommunications; and

d) favoured treatment through subtle biases in network design which favoured the subsidiary's equipment and service offerings.

All of these unfair practices would be extremely difficult to detect or prove. Hence we suggest separate ownership of the network system and of those attached service complexes which sell services via the network. However, this decision would not prohibit a network owner from attaching service complexes, whose services were not sold but were for his own exclusive use. These policy decisions are expressed in Figure VII.5, where we choose nodes (4,2), (5,1) and (6,1).

Other Policy Options

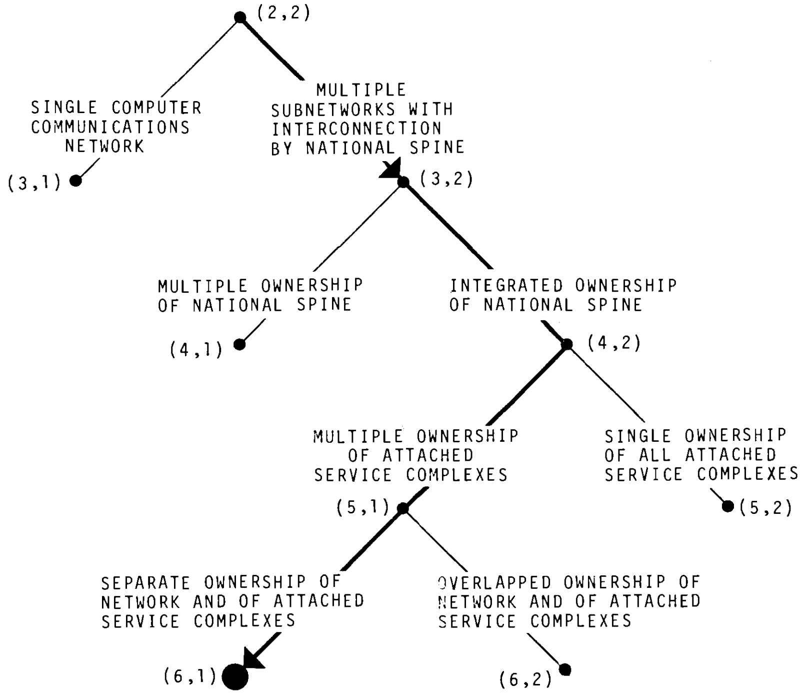
Here we discuss some items which do not fit the tree format well. The first option has to do with customs tariffs, whose present patchwork structure is irrational from the point of view of the computer service industry. Moreover, tariffs on computer hardware invariably place the Canadian computer service industry at a disadvantage with respect to the U.S. computer service industry.[34,35,36] The tariff structure should therefore be re-examined with a view to encouraging the Canadian computer service industry. At the same time, the need to foster the development of a Canadian hardware and software industry must be kept firmly in mind. (The Council hopes to identify promising areas of specialization for a Canadian hardware and software industry in Phase II of its Computer Study.)

A related issue is the question of dumping. Canadian service bureaux are vulnerable to the dumping of excess computer capacity from abroad. Hence anti-dumping measures are needed.*

Finally, we wish to comment on the current costs of data communications in Canada. Briefly, they are much too high. They are high when compared with U.S. charges for similar facilities[37,38,39], and this trend will be accentuated when U.S.

*An example of a potential dumping situation appears in an announcement of the extension of Control Data Corporation's U.S. Cybernet Computer Services network to Calgary, and of plans for eventual extension across Canada. The following statement was made: "A point which will be of interest to users is the question of line costs when Cybernet Calgary is linked to Palo Alto, California. A user in Calgary, though, is in the same position as if he were in Palo Alto. He receives the same billing rate for total costs."[40]

Figure VII.5



(2,2)
SINGLE COMPUTER COMMUNICATIONS NETWORK
MULTIPLE SUBNETWORKS WITH INTERCONNECTION BY NATIONAL SPINE
(3,1)
(3,2)
MULTIPLE OWNERSHIP OF NATIONAL SPINE
INTEGRATED OWNERSHIP OF NATIONAL SPINE
(4,1)
(4,2)
MULTIPLE OWNERSHIP OF ATTACHED SERVICE COMPLEXES
SINGLE OWNERSHIP OF ALL ATTACHED SERVICE COMPLEXES
(5,1)
(5,2)
SEPARATE OWNERSHIP OF NETWORK AND OF ATTACHED SERVICE COMPLEXES
OVERLAPPED OWNERSHIP OF NETWORK AND OF ATTACHED SERVICE COMPLEXES
(6,1)
(6,2)

digital networks for computer communications begin operation.* They are also too high when the economic feasibility of many exciting and useful new services is studied. Indeed, the ultimate success of the Trans-Canada Computer Communications Network will depend on its offering sufficiently low rates. New technology will help to cut these rates, but government regulation and subsidy may also be required.

*Specifically, the networks planned or proposed by AT&T, Western Union, the DATRAN Company, and Microwave Communications, Inc.

Chapter VIII

The Need for a National Policy

In Chapter VII we studied several policy options with the aid of a mathematical entity called a tree. The first decision taken there was that a National Policy is in fact needed. Here we seek to justify that decision by suggesting some probable results of a lack of policy.

The Canadian telecommunications carriers are pursuing some of the technical studies suggested in Chapter VI. Digital transmission by cable and radio, digital switching machines and forecasts of future needs are all being explored in Canada. However, there are some gaps, for example in the development of packet switching, and more overall co-ordination is needed.

More seriously, no long-range commitments to build a Trans-Canada Computer Communications Network, of a scale comparable to the commitments made in the United States (by the DATRAN Company, for example), have been announced by Canadian organizations. Thus, in the absence of governmental initiatives, it seems likely that Canadian computer communications facilities will remain in essentially their present state for some time to come.

In the short term, this will lead to a drastic loss of effectiveness in the computing community. The health of our computer service bureaux will be severely impaired* and the public will be denied the benefits of new and useful services.

In the long term, U.S. interests will provide modern facilities for us, even as they provide automobiles, academics, capital, entertainment and school books. Thus predominantly north-south patterns of computer communications will become dominant, just as north-south patterns of airline transport became dominant prior to the creation of Trans-Canada Airlines.[41] For example, computer communications between Winnipeg and Toronto may tend to flow via Minneapolis and Chicago. This trend will imply:

a) a continual outflow of funds for network charges, of a magnitude and growth rate largely beyond our control;

b) little control by Canadians of privacy and security standards;

c) little opportunity for Canadian bodies to even verify that advertised standards of privacy and security are in fact being met;

d) the possibility, once trans-Canada links have been established via the United States, of supplying cheaper services direct from U.S. points rather than "going back up" into Canada.† Hence a further severe blow to the Canadian computer service industry;

e) the further possibility that the creation of source material for services, such as information banks and computer-assisted learning, would migrate to the points of supply of these services. Thus much of the information and many of the ideas and values which underpin our society could eventually become largely alien.

The Science Council, as a group of concerned and informed Canadians, considers these trends to be unacceptable. They can be avoided if Canadians generally share this view. To do so, money and manpower must be allocated to build Canadian computer communications facilities. However, such a diversion of resources can properly be regarded as a financial investment as well as a social investment. For, although public service must be the primary goal of the Trans-Canada Computer Com-

*The president of one Canadian bureau has said that there may be substantially *no* Canadian computer service industry five years hence, if the operating climate of these companies is not greatly improved. (Personal communication from Dr. J. Kates, President, SETAK Ltd.)

†According to the *Financial Post*[42], the Canadian life insurance companies have collectively developed files containing confidential medical and other personal information about policy applicants. These files, called the Life Card Library, have been kept in Canada until recently. Now, however, they are being moved to the United States in order to take advantage of lower costs.

munications Network, an eventual reasonable return on invested capital is a feasible *secondary* goal for the network. Indeed, the program of studies suggested in Chapter VI ("Things to be Done") called for a continual and careful examination of the economic and financial feasibility of network designs and services.* Finally, this report has noted that many parts of the existing telecommunications networks can be used by the TCCN as well. This means in effect that a large part of the total capital outlay needed to create a TCCN from scratch has already been invested.

In summary, we have a long tradition of creating nationwide links for national survival and unity. In the past we have created the Canadian Pacific Railway, the Canadian Broadcasting Corporation, and Air Canada. Some of these links carry goods, others carry information, ideas and values. Each required a sustained national effort and substantial leadership by the Government of Canada, often in the form of a Crown Corporation. Each has been a major factor in building national unity and in balancing the north-south pulls of continentalism with a healthy concern for national goals, and at the same time has built up a strong and valuable Canadian industry. The Trans-Canada Computer Communications Network is in fact the newest potential member of this family of national links.

*"Economic feasibility" refers to a broad analysis of economic and social benefits versus economic and social costs, and this report suggests that the network system can be an economically feasible proposition. "Financial feasibility" is a narrower term, and refers to a strict analysis of dollar revenues versus dollar investment. This report suggests that the network system may indeed be ultimately feasible in the financial sense as well, but that government subsidy may be required for a considerable period of time.

Chapter IX

Recommendations

General

1. The Science Council believes that a strong Canadian computer industry, active both in computer services and in certain areas of development and manufacture of hardware, software, and peripheral devices, is essential to supply Canada's needs in this field and for Canada's future social and economic health.

To supply the needs of Canadian computer users, the development and construction of a system of interconnected computer communications networks should be planned and subsequently undertaken as a national Major Project. As a matter of policy, the system should span all populated regions of Canada, and should be entirely Canadian-owned.

2. Planning responsibility for the orderly growth of the network system should be assigned to the Department of Communications Task Force on Computer Communications or to its successor. The objectives of this planning should include the development of a wholly digital National Spine integrated with existing telecommunications plant where feasible, and the encouragement of east-west flows of information. The Task Force is ideally organized to do a comprehensive analysis of alternatives, followed by the formulation of recommendations and the setting of priorities. (Because of the limitations on time and manpower available to the Task Force, the bulk of detailed planning might best be left to a successor agency.)

Policy

1. A national trunk or spinal network should be established. It should serve all of Canada, it should employ digital transmission throughout*, and it could be built on surplus capacity† of the existing trans-Canada microwave systems. The Network Organization (discussed in Chapter VII) should function as owner-operator of the National Spine.

2. The development of standards, to ensure compatibility of subnetworks with each other and with the National Spine, should flow from research, development and network planning conducted by the Canadian electronics industry and the universities. The definition and administration of these interconnection standards should be performed by the Network Organization. The Organization should ensure that equipment attached to the network system remains compatible by certifying that adequate maintenance contracts are in force for all such equipment where necessary.

3. Any organization, public or private, should be permitted to attach service complexes (computers, plus system software, plus applications software) or terminals to the network, subject only to meeting the interconnection standards. However, no organization which participates in ownership of the network system should be allowed to sell computing services *via* either the National Spine or the regional networks.

Technical and Economic

1. The network system should employ digital transmission throughout at the earliest possible date. Because of the cost required to convert local distribution facilities, this goal will not be completely attainable *ab initio*. However, the National Spine should be en-

*At least one "set of boxes" to accomplish this is now available on the Canadian market – Canadian Marconi Limited's MCS 6900. It offers digital transmission in the sense that the phrase is used throughout this report: end-to-end regenerative transmission of discrete signals.

†The existing microwave systems have surplus capacity in the following sense. The towers and equipment rooms are respectively able to accommodate additional antennas and repeaters, and frequency assignments for additional channels have been established. Hence additional channels are potentially available at very little additional cost, as the great majority of costs for a microwave system lie in the towers, buildings, access roads, hydro feeds, rights-of-way and so forth.

tirely digital from the beginning, and the subnetworks should employ digital technology to the fullest possible extent. To this end, the Network Organization could collaborate with CN/CP Telecommunications and the Trans-Canada Telephone System in activating some of the surplus capacity of their trans-Canada microwave systems to create a digital trunk, providing transmission facilities for the National Spine. In addition, the planned installation of T-4 and T-1 digital links by the Trans-Canada Telephone System could, respectively, provide alternative and supplementary sources of supply.

2. In all probability, the network system will have to offer both packet-switching service (to cope with the immense forecast volume of short-message traffic requiring very fast switching), and circuit-switching service (to handle lengthy messages generated by the transmission of large computer files, digitized video and so forth). It may well be possible to provide the circuit-switching service by upgrading present circuit-switching services such as MULTICOM and Broadband Exchange. The packet-switching service will require extensive new facilities, in addition to facilities shared with the circuit-switching service.

3. It will be necessary to develop effective standards for the privacy and security of data passing through the network system. Moreover, it will be necessary that these standards be both enforced and seen *by the public* to be enforced. Reassurance of the public that the privacy and security of data are not being violated should be a prime aspect of the regulatory function for the network system. Regulation should, of course, be done by Government. However, as in the past, it should be done, not by a government department, but by a semi-judicial body holding public hearings.

4. Measures should be adopted to prevent the dumping of excess computer capacity from abroad in Canada.

5. A Design Authority should be designated for the network system. It should be given broad responsibility for systems definition activities, and for the award and monitoring of contracts covering feasibility studies, network planning, specific research and development tasks, development of prototypes and subsystem manufacturing. First preference for all contract awards should be given to the Canadian computing, telecommunications and electronics industries, in order to encourage the transfer of technology needed for manufacturing. Second preference should be given to the universities, and only if both of these alternatives are absolutely unworkable should a contract be awarded to government laboratories or agencies. In order to attract and retain a group of technically competent systems specialists able to carry out these supervisory and monitoring functions, the Design Authority should perform a limited amount of in-house research and development.* However, this research should be focussed on system problems rather than "nuts and bolts" development of specific devices. Moreover, the in-house component of research and development should not be permitted to exceed 10 per cent of the total performed, whether measured in terms of dollars or man-hours.

6. We have noted that the success of the network ultimately depends on its offering sufficiently low rates. This places the following responsibility on Government. If the exploitation of scale and technology does not yield large enough cost reductions quickly, Government should be prepared to subsidize the operation of the network for a limited period of time. Ultimately, the network should be expected to become self-supporting in the same manner as Air

*The Council holds that highly competent technical specialists are vital to intelligent systems definition and contract monitoring activities. A certain amount of in-house research and development is essential to attract, develop and retain such specialists.

Canada. However, public service must be the first priority, with eventual profitability as a secondary priority. In the same vein, Government may have to provide a large share of the capital investment needed to develop and build the network system, or develop suitable inducements for the supply of private capital.

Finally, owing to the urgency of the situation, interim measures to reduce the prices of existing data transmission services should be adopted without delay.

References

[1]Science Council of Canada. Towards a national science policy for Canada. Report No. 4. Ottawa, Queen's Printer, 1968. p. 42.

[2]Smith, William D. Computer industry to be world's largest business by year 2000. Globe and Mail from New York Times. 2 June 1970.

[3]Computer industry to-morrow - a prophet speaks. New Scientist. 24 September 1970.

[4]Babson, David L., and David T. Wendell. Computer industry seen top three within a decade. Financial Post. 9 May 1970.

[5]Hoskyns Group Limited. UK computer industry trends, 1970-80. October 1969. p. 10.

[6]Le Marché de l'Informatique. L'Expansion, Paris. No. 21, July/August 1969. pp. 96-105.

[7]Brodie, David J. The Canadian computer industry. Report for Alfred Bunting and Company Limited, October 1969. Revised May 1970. p. 4.

[8]Richardson, Lyman. A forecast of developments within the information processing industry in Canada. Report for Department of Communications, March 1970.

[9]Organization for Economic Cooperation and Development. Inventory of data banks in the public sector. Document DAS/SPR/70.2 of the Directorate for Scientific Affairs of the OECD, Paris. 11 February 1970.

[10]Roberts, Lawrence G., and Barry D. Wessler. Advanced Research Projects Agency. Computer network development to achieve resource sharing. AFIPS Conference Proceedings, Vol. 36, 1970 Spring Joint Computer Conference. pp. 543-549.

[11]Davies, D.W. The principles of a data communication network for computers. IFIP Congress Proceedings 1968. pp. D11-D15.

[12]Wilkinson, P.T., and R.A. Scantlebury. The control functions in a local data network. *Ibid.* pp. D16-D20.

[13]Bartlett, K.A. Transmission control in a local data network. *Ibid.* pp. D21-D25.

[14]Scantlebury, R.A., P.T. Wilkinson, and K.A. Bartlett. The design of a message switching centre for a digital communication network. *Ibid.* pp. D26-D30.

[15]Personal communications from members of the Department of Computer Science, University of Bristol, to Eric G. Manning.

[16]Cordtz, Dan. The coming shake-up in telecommunications. Fortune. April, 1970.

[17]U.S. Federal Communications Commission. In the matter of regulatory and policy problems presented by the interdependence of computer and communications services and facilities. Docket no. 16979. 1 April 1970.

[18]Data Transmission Company. Comments to the Federal Communications Commission, Washington. Re docket no. 18920. 10 October 1970.

[19]United Kingdom, Post Office, Telecommunications Development Department. Studies within the U.K. on a proposed public switched data network - an interim statement. April 1970. Issue 2. May 1970.

[20]Canada, Department of Communications. Participation of telecommunications carriers in public data processing. Introduction p. 5. 1970.

[21]Getting computers together. Fourth Annual review 1969-70. Committee of Presidents of Universities of Ontario. pp. 31-34.

[22]L'Université du Québec et les communications. Demande de subventions auprès du Conseil National de la Recherche, Université du Québec. 2 July 1970.

[23]Robert A. McDougal, Vice President, Bank of Montreal. Technological evolution and its control. Seminar on the wired city, University of Ottawa. June 1970.

[24]How Commissioner Johnson bugs Ma Bell. Business Week. 14 November 1970.

[25]Data transmitters deluge the FCC. *Ibid.*

[26]WU to offer digital data in 1972. Datamation. 1 December 1970.

[27]Nolan, Herbert. Moving business data. Business Automation. 1 December 1970.

[28]Cherry, Colin. The nature of human communication. Proceedings, Royal Society of Arts. February 1966. p. 160.

[29]Letter from president of an electronic data processing company. Toronto. 25 November 1970.

[30]Letter from president of a time-sharing service bureau. Toronto. 24 July 1970.

[31]William Ellinghaus, Vice President, American Telephone and Telegraph Company, at a conference on "The revolution in transmission of business information", New York. Datamation. 15 November 1970. pp. 113-115.

[32]Nolan. Moving business data.

[33]Letter from manager of a computer services bureau. Toronto. 23 October 1970.

[34]Letter from D.R. Newman, Assistant Comptroller, Bell Canada, Montreal. 9 September 1970.

[35]Letter from J.C. Paradi, Vice President, Dataline Systems Limited, Toronto. 20 May 1970.

[36]Letter from G.W. McNiece, Vice President and General Manager, Sperry Rand Canada Limited, Univac Division, Toronto. 18 December 1969.

[37]Letter from the president of a time-sharing service bureau, Toronto. 24 July 1970.

[38]Letter from the vice president of a computer services bureau, Toronto. 20 May 1970.

[39]Letter from the manager of a computer services bureau, Toronto. 23 October 1970.

[40]Full-page advertisement by Control Data Canada Limited, *The Albertan*. 12 January 1971.

[41]Currie, A.W. Economics of Canadian transportation. University of Toronto Press. 1954. pp. 539-540.

[42]Mulligan, Isabel. Insurers move personal data files to U.S. Financial. Post. 29 August 1970.

Appendix A

Two Computer Communications Networks

This Appendix gives a brief technical description of two networks. They are the network proposed by Davies and his colleagues at the British National Physical Laboratory (NPL), and the U.S. Advanced Research Projects Agency's (ARPA) Network. They were chosen from the list of networks in Chapter III because they embody promising approaches to future needs, and because they have actually been built wholly (ARPA) or partially (NPL), and found to work well. In addition, these two networks, although developed largely independently, resemble one another to a striking degree. In fact, we will see later that the NPL network consists of two parts. One part has been built and is operational in Britain; the other part is nearly identical with the ARPA network which is operational in the United States.

The NPL network is intended to service a wide variety of customers' equipment: typewriter consoles, line printers, multi-access computers, file storage systems and so forth. The design of the network will allow any of these equipments to send information to any other.

Two goals were paramount in the design of the NPL network. The first was the need to supply a very wide range of transmission speeds, ranging from a few characters per second to a million or more. The second was the need to reduce the delay encountered by a message (from the time it leaves the sender until it arrives at the receiver) to much less than a second. (The switched voice network may require as much as 10 or 20 seconds to complete a trunk call). These considerations led Davies and his co-workers to the following approach. Since one party to most "conversations" is a computer which is able to store data, the basic unit of data is taken to be a short message called a *packet*.

Packets are handled by the technique of *packet switching,* as was described in Chapter IV. That is, each packet carries a "label" which bears the name of the intended recipient. A packet is sent from its originator to a switcher, which in fact is a specialized computer. The switcher *stores* packets in its memory, and then inspects the labels. Using the address information, it decides on the best way to *forward* each packet and does so. As was mentioned in Chapter IV, this process is quite different from the process used by the telephone network, where a "pair of wires" or the equivalent is specifically set up for each conversation and is dedicated to that conversation.

The NPL network does not use a single large switcher to switch packets. Rather, there is a collection of geographically dispersed small switchers, tied together by telecommunication lines. Davies calls these switchers *node computers,* and the collection of node computers plus telecommunications links is called the high-level network. (See Figure A. 1.)

All information processed by the high-level network is in the form of packets, which are at most 128 characters long and have address labels. The network users, however, do not have to break their messages into packets – this is done by machines called *interface computers.* An interface computer handles a mixed collection of customers within a small geographic area. Thus one might have an interface computer for a high-rise office building, a small industrial park or perhaps eventually a residential neighbourhood. All customer equipments transmit to the interface computer one character at a time, whether they are teletypes, graphic displays or service complexes. Characters are collected into packets, labelled and sent to the high-level network by the interface computer, which also allows customer equipments to communicate directly (local calls), and provides various control and acknowledgement signals which they require.

An interface computer plus all equipment attached to it is called a *local area network,* as shown in Figure A. 1. (A national system would therefore consist of one high-level network and many local area networks.) Two types of "customers" are catered to by the local area network:

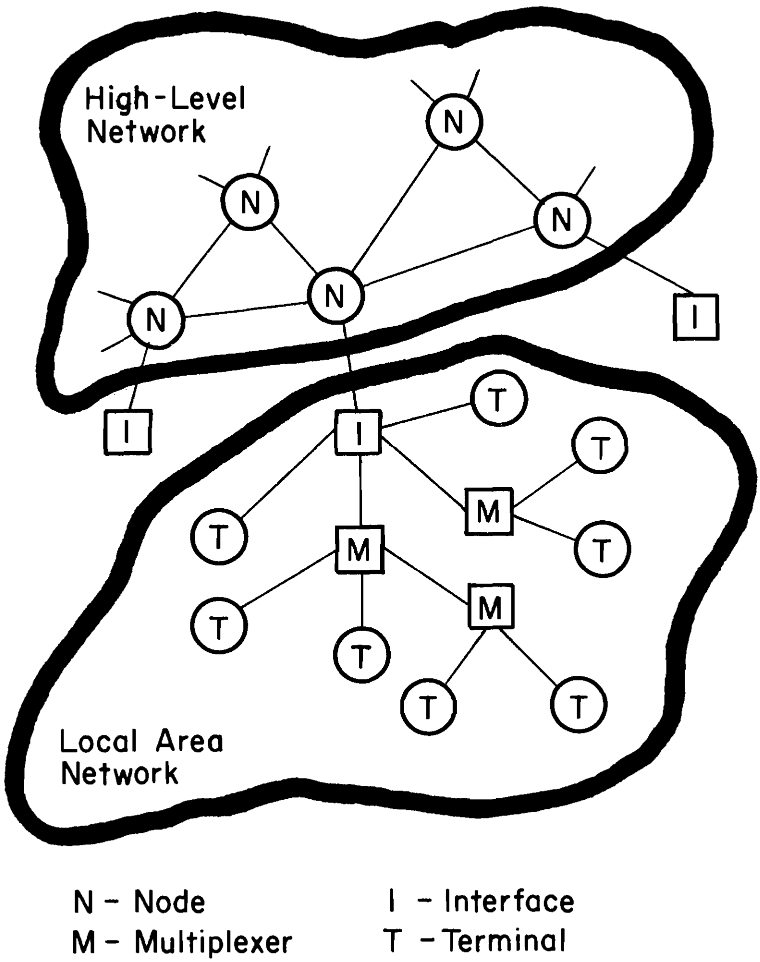
1. Devices such as service complexes, which possess "intelligence" and can move data at high rates. These connect directly to the interface computer.
2. Slow, "stupid" devices, such as typewriter terminals, which are connected via multiplexers.

For the latter group, short response time to the interface machine, very simple out-lying gear on the customer's premises (to reduce costs), and the ability to cope with all data codes and control procedures are important. These goals have been largely met by the proposed design. Davies' NPL group has built a local area network, including the interface machine.

To conclude, the design for the NPL network offers the following features:

1. Control procedures to suit the customer's devices are provided by the network. This minimizes the cost of gear on the customer's premises.
2. Bit rates to suit the customers are provided. The costs vary primarily with the amount of data (number of messages) sent. They do not depend strongly on customer connection time or distance.
3. Data could be translated automatically if desired, allowing dissimilar computers and terminals to communicate more easily.
4. Data routing is done automatically.
5. The network can grow gracefully. For example, the maximum size of messages can be varied, and the speeds of nodes and links can be upgraded piecemeal. (This is due to the store-and-forward or packet-switched mode of design.)
6. Each local area network must have only the translation and control facilities needed by its particular set of cus-

Figure A.1


High-Level Network
N
N
N
N
N
I
I
I
T
T
T
T
T
T
T
T
M
M
M
Local Area Network
N - Node
M - Multiplexer
I - Interface
T - Terminal

tomers. A new type of customer can be added relatively easily.

The other network discussed here is the ARPA network, funded by the Advanced Research Projects Agency of the United States Department of Defense. The ARPA network is a "high-level" network in Davies' terminology; it links together service complexes rather than terminals. At present, it interconnects some 14 service complexes (computers) scattered between Massachusetts* and California.† Machines at the Universities of Illinois and Utah are also on the network, and the ILLIAC IV array processor will be on after it becomes operational.

The ARPA network was designed to allow *resource sharing* between the service complexes attached to it. The resources to be shared include hardware, software and data files. Thus, any program running on an attached service complex would be able to freely access data stored in other service complexes, and it could also get the other service complexes to perform computations for it. This kind of pooling could greatly improve the utilization of hardware and software resources, and would also allow rapid retrieval, comparison and merging of data from files scattered across the United States. Finally, a user would not have to acquire several different terminals in order to use several different service complexes – a single terminal connected to any service complex of the network would suffice.

The ARPA team, led by Dr. L.G. Roberts, began work with a modest trial project. They interconnected two large time-sharing systems so that each would act as a user terminal of the other. This experiment helped to define the major project goal – a completely new computer communications facility able to pass short messages quickly, reliably and cheaply. More specifically, the goals of the new communications facility were to include:

1. Reliability greatly in excess of that provided by the common carriers;

2. An end-to-end delay or connection time of less than half a second (in contrast to the connection times of 5-20 seconds offered by the voice network);

3. Capacity sufficient to serve 20 or so attached service complexes;

4. Costs sufficiently low to ensure that the communications costs borne by a network user would always be less than 25 per cent of his computing costs.

The system which was developed to meet these rather ambitious specifications is the ARPA network. Technically, it is a distributed, over-connected, packet-switched network, which means that it uses many physically dispersed small switchers rather than one large one; that there are always at least two paths from any point in the network to any other point; and that the switching discipline employed is packet switching rather than circuit switching (see Chapter VI for definitions of these terms).

The switchers of the ARPA network are called Interface Message Processors or IMPs. They are actually small computers, so-called mini-computers, and they correspond to the node computers of the NPL network. They are connected by high-speed (50 kilobits per second) private lines leased from AT&T. In addition, IMPs serve as the attachment points to connect service complexes to the network, as shown in Figure A.2. Notice that a given IMP is usually connected to two or three other IMPs, that at least two possible routes exist between any pair of IMPs (for reliability reasons), and that a packet may have to pass through several IMPs to reach its destination.

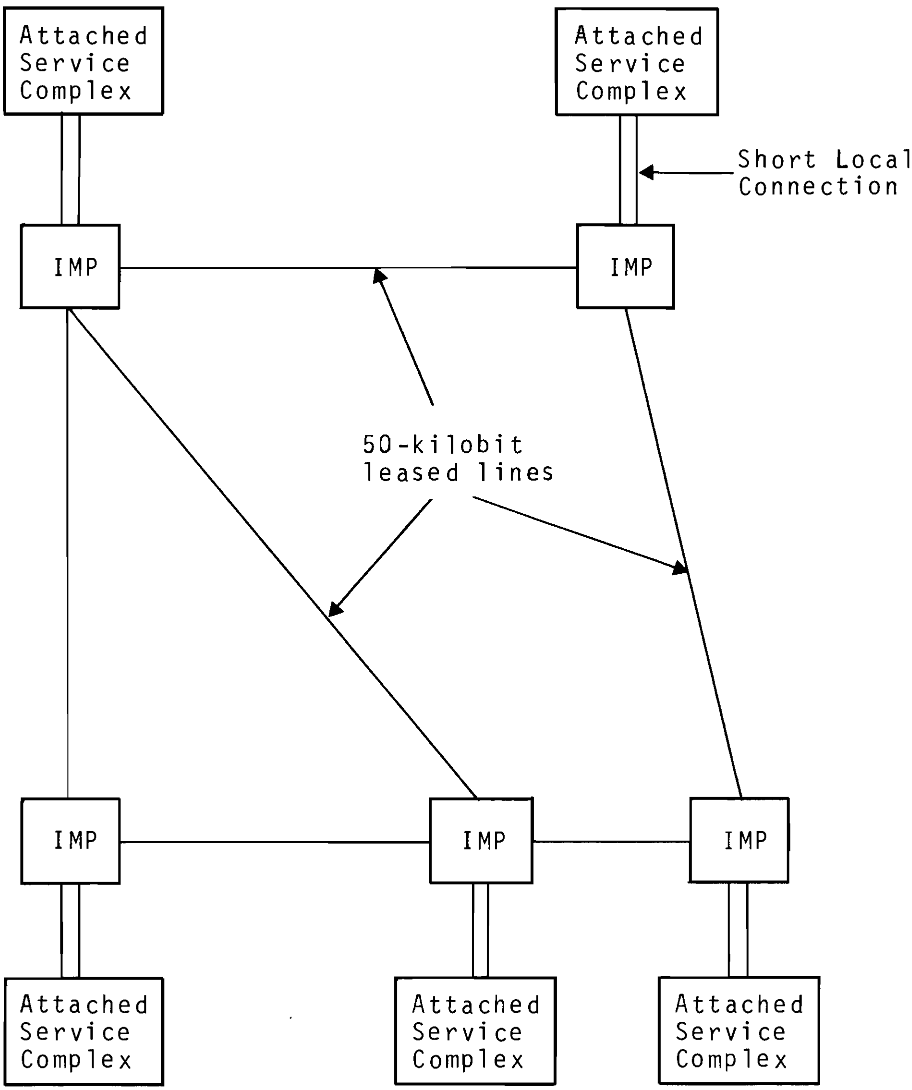
Thus an IMP has several functions to perform. It accepts messages of variable lengths from its attached service complex, breaks them up into packets, attaches a label bearing the name of the addressee service complex plus control

*Computers at Harvard, MIT, the MITRE Corporation and Bolt, Beranek and Newman Inc.

†Computers at the Santa Barbara and Los Angeles campuses of the University of California, at Stanford University, Stanford Research Institute and the Rand Corporation.

information, and forwards the packets to other IMPs for delivery. It accepts packets from other IMPs and checks each for transmission errors until the packet is received correctly. If errors are detected, it asks for retransmission of the erroneous packet. It then examines the label. If a packet is addressed to the local service complex, it stores it in memory, pending the arrival of the other packets of the message. When these are all available it sorts them into correct order, strips off extraneous information and delivers the message to its local service complex. If, on the other hand, a received packet is not addressed to the local service complex, it is held briefly while the IMP determines the best route and is then forwarded via that route. Finally, an IMP is able to avoid lines which are out of service or overly busy, and it is also able to cope with its own internal troubles by requesting assistance from neighbouring IMPs.

Figure A. 2



The performance achieved by the ARPA network is remarkable. Fourteen service complexes of several different types are attached to it, and each is able to send messages to any of the others. The IMPS are able to receive, store, identify and forward a packet in about one-third of a millisecond, and each IMP can handle traffic at a peak rate of about 100 000 characters per second. The error recovery procedures discussed above have yielded excellent transmission reliability, and the network is able to survive at reduced capacity in the face of severe hardware breakdowns. Finally, because of the naturally complementary nature of the local area network at the U.K. National Physical Laboratory and the ARPA network, plans are afoot to connect them via some sort of trans-Atlantic link.

In summary, the ARPA network is a very promising medium for intercomputer communications. The major unsolved problem probably lies not in the network itself, but in the attached service complexes. For it is necessary that each service complex "understand" how to interpret and respond to messages delivered to it by the network. In most cases, this will involve basic research on the problems of getting computers to work co-operatively with one another in an efficient way, followed by extensive modifications to the machines' operating software to implement the new techniques. The difficulty of this problem should not be under-estimated; in fact it is probably largely responsible for the fact that the volume of traffic carried by the ARPA network is still relatively light.

Appendix B

Members of the Science Council Committee on Computer Applications and Technology

Chairman
Dr. L. Katz
Director
Accelerator Laboratory
Department of Physics
University of Saskatchewan
Saskatoon, Saskatchewan

Members
Dr. L.J. L'Heureux
Chairman
Defence Research Board
125 Elgin Street
Ottawa 4, Ontario

Mr. J.D. Houlding
President
R.C.A. Limited
Ste. Anne de Bellevue, Quebec

Mr. A.E. Pallister
Vice President
Kenting Limited
700 Sixth Avenue S.W.
Calgary 1, Alberta

Dr. G.N. Patterson
Director
Institute for Aerospace Studies
University of Toronto
Toronto 5, Ontario

Secretary
Mr. J. Mullin
Secretary
Science Council of Canada

Project Officer
Dr. Eric G. Manning
Science Adviser
Science Council of Canada

Project Associate
Dr. S.N. Silverman
Science Adviser
Science Council of Canada

Executive Assistant
Mr. A.F. Pickard
Science Council of Canada

Publications of the Science Council of Canada

Annual Reports

First Annual Report, *1966-67* (SS1-1967)

Second Annual Report, *1967-68* (SS1-1968)

Third Annual Report, *1968-69* (SS1-1969)

Annual Report, *1969-70* (SS1-1970)

Annual Report, *1970-71* (SS1-1971)

Reports

Report No. 1, **A Space Program for Canada** (SS22-1967/1, $0.75)

Report No. 2, **The Proposal for an Intense Neutron Generator: Initial Assessment and Recommendations** (SS22-1967/2, $0.25)

Report No. 3, **A Major Program of Water Resources Research in Canada** (SS22-1968/3, $0.75)

Report No. 4, **Towards a National Science Policy for Canada** (SS22-1968/4, $0.75)

Report No. 5, **University Research and the Federal Government** (SS22-1969/5, $0.75)

Report No. 6, **A Policy for Scientific and Technical Information Dissemination** (SS22-1969/6, $0.75)

Report No. 7, **Earth Sciences Serving the Nation–Recommendations** (SS22-1970/7, $0.75)

Report No. 8, **Seeing the Forest and the Trees** (SS22-1970/8, $0.75)

Report No. 9, **This Land is Their Land...** (SS22-1970/9, $0.75)

Report No. 10, **Canada, Science and the Oceans** (SS22-1970/10, $0.75)

Report No. 11, **A Canadian STOL Air Transport System–A Major Program** (SS22-1970/11 $0.75)

Report No. 12, **Two Blades of Grass: The Challenge Facing Agriculture** (SS22-1970/12, $0.75)

Special Studies

The first five of the series were published under the auspices of the Science Secretariat.

Special Study No. 1, **Upper Atmosphere and Space Programs in Canada**, by J.H. Chapman, P.A. Forsyth, P.A. Lapp, G.N. Patterson (SS21-1/1, $2.50)

Special Study No. 2, **Physics in Canada: Survey and Outlook**, by a Study Group of the Canadian Association of Physicists headed by D.C. Rose (SS21-1/2, $2.50)

Special Study No. 3, **Psychology in Canada**, by M.H. Appley and Jean Rickwood, Canadian Psychological Association (SS21-1/3, $2.50)

Special Study No. 4, **The Proposal for an Intense Neutron Generator: Scientific and Economic Evaluation**, by a Committee of the Science Council of Canada (SS21-1/4, $2.00)

Special Study No. 5, **Water Resources Research in Canada**, by J.P. Bruce and D.E.L. Maasland (SS21-1/5, $2.50)

Special Study No. 6, **Background Studies in Science Policy: Projections of R & D Manpower and Expenditure**, by R.W. Jackson, D.W. Henderson and B. Leung (SS21-1/6, $1.25)

Special Study No. 7, **The Role of the Federal Government in Support of Research in Canadian Universities**, by John B. Macdonald, L.P. Dugal, J.S. Dupré, J.B. Marshall, J.G. Parr, E. Sirluck, E. Vogt (SS21-1/7, $3.00)

Special Study No. 8, **Scientific and Technical Information in Canada**, *Part I,* by J.P.I. Tyas (SS21-1/8, $1.00)

Part II, Chdpter 1, Government Departments and Agencies (SS21-1/8-2-1, $1.75)

Part II, Chapter 2, Industry (SS21-1/8-2-2, $1.25)

Part II, Chapter 3, Universities (SS21-1/8-2-3, $1.75)

Part II, Chapter 4, International Organizations and Foreign Countries (SS21-1/8-2-4, $1.00)

Part II, Chapter 5, Techniques and Sources (SS21-1/8-2-5, $1.25)

Part II, Chapter 6, Libraries (SS21-1/8-2-6, $1.00)

Part II, Chapter 7, Economics (SS21-1/8-2-7, $1.00)

Special Study No. 9, **Chemistry and Chemical Engineering: A Survey of Research and Development in Canada**, by a Study Group of the Chemical Institute of Canada (SS21-1/9, $2.50)

Special Study No. 10, **Agricultural Science in Canada**, by B.N. Smallman, D.A. Chant, D.M. Connor, J.C. Gilson, A.E. Hannah, D.N. Huntley, E. Mercier, M. Shaw (SS21-1/10, $2.00)

Special Study No. 11, **Background to Invention**, by Andrew H. Wilson (SS21-1/11, $1.50)

Special Study No. 12, **Aeronautics – Highway to the Future**, by J.J. Green (SS21-1/12, $2.50)

Special Study No. 13, **Earth Sciences Serving the Nation**, by Roger A. Blais, Charles H. Smith, J.E. Blanchard, J.T. Cawley, D.R. Derry, Y.O. Fortier, G.G.L. Henderson, J.R. Mackay, J.S. Scott, H.O. Seigel, R.B. Toombs, H.D.B. Wilson (SS21-1/13, $4.50)

Special Study No. 14, **Forest Resources Research in Canada**, by J. Harry G. Smith and G. Lessard (SS21-1/14, $3.50)

Special Study No. 15, **Scientific Activities in Fisheries and Wildlife Resources**, by D.H. Pimlott, C.J. Kerswill and J.R. Bider (SS21-1/15, $3.50)

Special Study No. 16, **Ad Mare: Canada Looks to the Sea**, by R.W. Stewart and L.M. Dickie (SS21-1/16, $2.50)

Special Study No. 17, **A Survey of Canadian Activity in Transportation R & D**, by C.B. Lewis (SS21-1/17, $0.75)

Special Study No. 18, **From Formalin to Fortran: Basic Biology in Canada**, by P.A. Larkin and W.J.D. Stephen (SS21-1/18, $2.50)

Special Study No. 19, **Research Councils in the Provinces: A Canadian Resource**, by Andrew H. Wilson (SS21-1/19, $1.50)

Special Study No. 20, **Prospects for Scientists and Engineers in Canada**, by Frank Kelly (SS21-1/20, $1.00)