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AN APPROACH FOR THE ESTABLISHMENT OF PRIORITIES IN S&T

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AN APPROACH FOR THE ESTABLISHMENT OF PRIORITIES IN S&T

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INTRODUCTION

The framework for determining S&T priorities

All governments have grappled with defining priorities in science and technology. Although this is a political question, ultimately it is a matter of social choice. It involves the rational management of human and financial resources within an economic and industrial strategy however elaborate that strategy may be. Finally, of course, it is determined by the state of knowledge itself.

Once priorities have been established, research projects may be selected. A framework for allocating public funds among the economic, political, social and scientific components must first be set up. Furthermore, government priorities in general and the limited priorities within the field of S&T must be clearly deliniated. The distinction is not as obvious as it would first appear. For example, energy self-sufficiency may be both a general government priority and a priority in the area of S&T. If it is considered a general priority, the decision-makers must choose between different means (or, at least, between the relative weight) to be assigned to each means of achieving it. Methods may include increasing the research effort, improving production techniques, establishing export quotas, regulating prices, etc. Thus, the government R&D effort would be merely one way of achieving a political and economic objective. If self-sufficiency is considered

important in the area of S&T, the kinds of research programs[1] must first be determined and then the different projects they would include can be decided.

In principle, defining priorities is central to the decision-making process. This exercise assumes that government reflects a consensus of national objectives and that defining these priorities is a prerequisite to the rational pursuit of these objectives. Theoretically, defining priorities in any field is part of sound management. In practice, however, the frequent absence of clearly identified national objectives or changes in these objectives, together with the precarious nature of determining the nature of social consensus, make such definition more difficult than it appears.

First, any framework for establishing priorities must be flexible. Defining priorities in order to identify research programs assumes that these programs have been assessed on the basis of certain criteria. These criteria are very likely to change in response to changes in national objectives and circumstances. Certain criteria may become irrelevant and disappear completely, while others may be added to the list. In addition, the relative importance of each criterion may change. Hence, any framework for establishing priorities will require monitoring and revision.

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1 By research program, we mean a general research proposal which could consist of a very large number of research projects. For example, a proposal dealing with the climate or water-resource management is a research program, whereas improvement of the salmonids on the Pacific Coast is a research project.

Thus mechanisms for re-evaluation must be provided. Any such framework must be flexible because circumstances are evolving and improvements may be possible.

Any framework for establishing priorities in S&T is an administrative tool and not a system for project selection. Too many factors and their attendant interactions are based on speculation or, quite simply, on lack of foreknowledge (for example, the long-term impact of basic research programs). At the same time, the question of S&T priorities arises from divergent viewpoints and at different levels and thus various criteria and qualifications must be considered. In fact, the criteria and qualifications can range on a spectrum from the technical to the political and they are necessarily normative: in short, they represent an evaluation scale which reflects society's demand for goods and services.

In this document, the literature dealing with the determination of S&T priorities will be reviewed. A number of evaluation criteria which could be selected for use in determining the priority of research proposals will be proposed. These evaluation criteria will include general objectives and more specific selection criteria that apply to very well-defined projects. A method for determining the relative weight of each of these objectives and criteria will be proposed. Finally, the usefullness of these objectives and criteria in evaluating the priority nature

of research proposals which are submitted to MOSST will be described. One of the appendices contains a classification of technological research fields. The weighting of the objectives selected for this report are contained in an abridged version of this classification. The classification, weighted in this way, can be used as an assessment grid for an initial evaluation of research proposals which are submitted to MOSST. This grid is rather general; it shows the priority nature of broad fields of research. The managers of funds designated for R&D work will be able to refer to the detailed classification in order to locate the research proposal being examined in the weighted grid and use the existing weights for the objectives and criteria.

It should be pointed out that although this classification includes the field of industrial R&D, it was developed first and foremost on the basis of the R&D activities carried out or supported by the federal government.

Chapter 1

The Issues

For many years the literature on S&T priorities concentrated on basic research. In fact, the first investigations of scientific policy and science economics concluded that the previously sacrosanct principles of the market economy led to a smaller investment in R&D than might be socially optimal.[2] Essentially, past investigations sought to justify government intervention in the area of R&D to compensate for the limitations inherent in the mechanisms of the market. However, deciding the optimal social level proved difficult because it was impossible to analyse the relationships between the various levels of research investment and the resulting social benefits. In 1971, the American National Institute of Health financed a study of norms to determine the appropriate level of public funding of research and how to allocate this funding.[3] One of the study's conclusions is as follows:

> "Even within a utilitarian context, the problem of translating a social objective into a given level of financial support through research has remained insoluble, and almost all attempts have been effected within narrow systems of economic values".[4]

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2. Arrow (1962), Nelson (1959)
3. OECD. CPST. document SPT (81), p. 4
4. ibid, p. 5 (translation)

Studies have examined the well-documented inability of market mechanisms to determine whether research will be financed on the basis of anticipated results. Other studies have sought a rational method of allocating public funds for research to maximize the return on the investment at the social level and, more importantly, to identify and measure this return. All these studies have merely confirmed that this is the most difficult problem facing science policy.

Because of the inability of the market mechanisms to serve as a guide to allocate funds for research, the principles of cultural value and general costs were advanced to justify government intervention in supporting basic research. But the search for arguments to justify such support failed to answer the crucial problem of "how" to distribute public funds among various fields and types of research. In order words, the question of criteria was avoided. In 1968, Edward Shils, editor-in-chief of MINERVA, collected a series of articles published between 1962 and 1966 in that journal. These articles addressed the question of how the allocation of research[5] funds was determined. The most influential of these articles is certainly Alvin Weinberg's on the criteria for scientific choice.[6] Weinberg stands in between the proponents of the laisser-faire approach to the financing basic research, (a principle which leaves the scientific

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5. Shils (1968)

6. Weinberg (1968)

community solely responsible for determining the orientations of research), and the proponents of bureaucratic planning in such research. Weinberg was the first to deal explicity with the question of selection criteria, underscoring the importance of determining their respective values and recognizing that certain aspects of such decisions fall to scientists while other aspects belong to society as represented by their governments.

Weinberg proposes two major categories of criteria - internal and external. The internal criteria are clearly based on scientific authority. Weinberg has identified two of these criteria: the maturity of the field and the qualified human resources within this field of research. The external criteria cannot be divided as easily between the scientific and political authorities. There are three of these criteria: technological interest, scientific interest and social interest. The technological interest for Weinberg is a relatively simple criterion. It involves society's decision as to whether it desires certain technical ends. The political authority is therefore responsible for deciding on this criterion. The social interest also falls within the jurisdiction of society in general -- in other words, the political authorities -- and is related to the determination of social objectives which these political authorities are expected to articulate. The other external criterion which Weinberg identifies, the scientific interest, is difficult to distinguish from the

internal criteria. Weinberg assumes the scientific criterion is related to its relative scientific significance, that is, the scientific significance of a field of research to other fields or subfields. Based obviously on scientific authority, this criterion is determined by the structure of a field of research and not by its social or economic impact or by its possible technical repercussions.

Weinberg's criteria have had a major impact on the study of scientific policy and on decision-making as well. In terms of the study of scientific policy, Weinberg's article, by recognizing the double-edged nature of choices in S&T, sounded the death knell for the laissez-faire approach. At the decision-making level, the criteria defined by Weinberg have been used by the National Science Foundation (NSF) and the National Institute of Health (NIH), for example, although they do not appear to have proven particularly functional. Two limitations to the effectiveness of Weinberg's criteria are their overly general nature and the absence of weighting. It would have been preferable first to identify the various components, or the principal components, of the proposed criteria by using subgroups of criteria. As will be demonstrated later, subsequent attempts were made to deal with this problem but not on the basis of Weinberg's criteria. A weighting of the various

criteria is essential, if choices are to made (1) between research programs and, even more important, (2) between the research projects within research programs. A fitting conclusion to this debate on research priorities and on how to justify the allocation of public funds for basic research was offered by Harvey Brooks several years later.[7] Brooks noted the difficulty of determining which fields of research were to be encouraged. The political usefullness or economic value of some fields of research are not evident. In addition, certain fields lack "intellectual appeal", either because of the scientific "mode" (which is related to both the cognitive and social structure of the scientific community) or because of the low (or lower) level of theoretical difficulty presented by certain fields of research.[8] For these reasons, certain problems of a scientific or technical nature may become relatively acute without ever receiving attention.[9]

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Concurrent with the discussion on S&T priorities and on how to justify the allocation of public funds for basic research, another discussion was taking place, this time against the background

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7 Brooks (1972)

8 For example, the appeal of theoretical physics as compared to analytical chemistry in the late 1950s.

9 The same example of theoretical physics as compared to analytical chemistry may explain the problems posed today by the identification, impact evaluation and elimination of toxic substances.

of the debate between the incrementalists and the rationalists[10] on the decision-making approach.

Critics of incrementalism say it merely describes how decision-makers work, recognizes only existing or similar to existing policies and offers only a few options and choices. Incrementalism suggests that the most realistic method of visualizing the decision-making process is to proceed by marginal increments. Thus the decision-making process becomes a process of adjustments, adaptations and compromises.

Rationalist criticism of incrementalism stresses that this decision-making approach is based on ultra-conservatism and status quo and is thus necessarily anti-innovative.[11] Rationalism as a decision-making approach stresses the precise definition of the aims and objectives of a policy, program or project and assesses all possible options and their consequences, and emphasizes cost-benefit analyses. It may use strictly economic models, based almost exclusively on cost-benefit analyses, or operations research models, which place the emphasis on the development of different scenarios based on prospective analysis.

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10 Charles E Lindblom (1959) and (1968) is the principal spokesman for the incrementalist school.

11 Dror (1964)

While incrementalism may be justifiably criticized for being inherently ultra-conservative, this charge may be equally levelled against rationalism. Because the rationalist decision-making approach seeks to ensure exhaustive analysis and maximum quantification, the decision-making process may be prolonged ad infinitum. Incrementalists maintain that even the rationalists must make some arbitrary decisions to attain a degree of realism.

An examination of the criticisms and justifications of these respective approaches reveal certain elements which allow a more moderate approach to the decision-making process.

For example, the incrementalists raise an interesting point when they maintain that technically or economically optimal solutions or policies may prove socially impractical or politically unacceptable.[12] Similarly, it is possible to proceed by marginal increments when optimal conditions are met, that is,

1) when existing policies offer satisfactory results;
2) when there is a high level of continuity in the nature of the problems;
3) when there is a high level of continuity in the means used to deal with the problems, a condition which, like the second condition, assumes a degree of high social stability.[13]

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12 Silverman (1981)

13 Dror (1964)

Similarly, the rationalists must be believed when they maintain that if these conditions are not met or, again, when no policies exist within a given field, incrementalism is inapplicable. It is possible, then, to improve on incrementalism, through the use of models based on the rationalist approach.

The models based on this approach can be classified in three major categories:

1) the economic approach;

2) operations analysis;

3) the decision-making approach, using scoring methods.

Strictly speaking, the economic approach is limited to the examination of economic variables within the decision-making process in general and in the determination of priorities in particular. The inputs are thus essentially quantitative in nature and the exercise of analysis is aimed essentially at evaluating programs or projects on the basis of the cost-benefit ratio, solely in economic terms.[14] As we have seen above, whatever the rational merits of such an approach, applied to S&T, it is impractical because many of the factors are unrelated to what is economically rational.

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14 In other words, it excludes costs for social, political, cultural or other benefits.

Operations analysis, developed primarily within military or industrial research organizations, combines quantitative techniques, the construction of predictive models (or scenarios) and simulations. This approach uses proven methods from logistics (including the use of sequential decision trees) and planning and is based, in the final analysis, on methods of evaluating the risks associated with each of the possible decisions.

Operations analysis requires such a high level of sophistication and so many scenarios that it is difficult to apply on a macro scale. In addition, to be functional, it must have access to a range of technical expertise rarely available to central planning and co-ordinating agencies, which are responsible for extensive and diversified fields of intervention. In other words, operations analysis may be useful within organizations which have a limited and specific role to play. Such organizations would have a choice of well-documented research strategies which would be easy to assess.

Operations analysis is only useful within limited boundaries. For example, it would be employed in laboratories with clearly defined roles, or research programs involving little or no basic research and projects involving short-term research. Operations analysis works within an institutional context which permits cost, prediction, needs and results for each scenario[15], as for example in

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15 Nutt (1965)

industrial and government laboratories fulfilling specific functions.

The decision-making approach, using scoring methods, may come closest to the moderate approach mentioned earlier. It attempts to maximize the rational nature of decisions and choices. At the same time it recognizes the need for realism and the role of the arbitrary and the normative in the decision-making process and the determination of priorities.

Essentially, scoring methods use semi-quantitative techniques to permit a systematic comparison of different research proposals.[16] They attribute "values" to project selection criteria,[17] or to objectives (objectives in terms of programs, activities, sub-activities, projects - if we use a significance tree[18]), or to the projects themselves. The attributed values may be very simple, that is, they may be expressed solely in terms of a positive, negative or neutral evaluation, or they may be distributed on a weighting scale. A weighting scale may have as few as 3 or 5 "values" or it may have as many as 100.[19] The scoring techniques may use a simple linear scale or a double-entry matrix (for instance, the objectives may be placed on one axis and the S&T activities on the other, thus establishing relations of significance).[20]

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16 Arnon (1975)

17 ibid

18 Marshall (1972)

19 ibid

20 Unesco (1977)

Scoring methods, in their different versions, are the most widely used in determining S&T priorities. When applied to research fields in general or to broad areas of research[21], they are frequently the only method used, whereas, when they are applied to more limited fields, they may be combined with other types of analysis. An example of such combination is the Project Appraisal Methodology - PAM.[22] This methodology was developed jointly by the US Department of Energy and the Energy Research and Development Administration (ERDA) of the Department of the Navy.[23] PAM is essentially a combination of a scoring model and an economic analysis model. A committee of experts might use the former to assess projects in relation to certain given criteria. The economic analysis model might be used to assess projects on the basis of given variables and economic scenarios. For example, various levels of financing might be assessed as minimum, current or maximum).

PAM has been used within the limited environments of a NAS committee and the Gas Research Institute.[24] Here, the selected criteria were able to achieve a high level of precision and refinement and the economic variables were identifiable and circumscribed. The users reached the same conclusions. This is a logical and

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21 Agriculture, for example. See Arnon (1975)

22 Project Appraisal Methodology

23 Burnett and Monetta (1978)

24 Monetta (1979)

reproducible but non-mechanical instrument, a tool which can be used on a sectoral basis, and one which does not prevent the decision-makers (and experts) from applying normative criteria.

Whatever the approach to determining S&T priorities, the final decision will always be subjective. Although certain R&D management tools are available, decision-makers will unlikely to find an infallible system for the determination of priorities.

Chapter 2

National objectives and selection criteria

Criteria for determining R&D priorities and research programs are closely linked to overall national objectives. These criteria are developed and adopted on the basis of national objectives which are those conditions desired by society. Generally, there are three classifications of objectives: economic, social and political. For the purposes of this study scientific and technological objectives will also be considered.

In determining criteria, it is important to decide whether to produce a list of mutually exclusive and comprehensive elements. The objectives, however, can be neither mutually exclusive nor comprehensive. Thus, a decision on the national objectives will only indicate the aims of society as perceived at a given moment. The determination of national objectives will necessarily reflect the imperatives governing the exercise. In this case, these objectives will be related to the S&T field, among others.

From the start, we had attributed to these national objectives the status of priority-determination criteria in connection with research fields and/or proposals. In other words - and it is important to make this semantic distinction clear from the outset - not only the national objectives which are proposed below but also the research-project selection criteria will play a role in determining

the priority nature of research programs and specific research projects. For research programs, the national objectives alone will be used, whereas for research projects, both the national objectives and the selection criteria will be employed.

As we shall see, the national objectives are, by definition, of a very general nature. Because these objectives are so general, their use is ncessarily limited to relatively broad fields of research. Moreover, the external and internal criteria that we shall discuss can, because of their specific nature, only be applied to particular projects for which the parameters are well defined. Consequently, we shall identify two levels of evaluation, which are defined by the degree of generality of the research proposals being evaluated. In the first case, namely, that of general proposals, the national objectives will serve as criteria for determining the priority or non-priority nature of the proposals and in the second case, that of research projects, the external and internal selection criteria together with the national objectives will serve the same purpose. We felt that a two-level evaluation of research programs would better reflect the procedures and operation of the decision-making process.

This identification exercise also assumes a number of value judgments. In this regard a process of conciliation and harmonization of interest, and not one of confrontation, is taken for granted. Moreover, objectives were proposed which,

while not addressed to specifically identified groups or interests, would nevertheless not be too general (that is, they would not include objectives such as peace throughout the world or the elimination of hunger).

As a first step, we drew up a list of political, economic social and scientific and technical objectives. We submitted this list, for comments, to MOSST officers and to officers in a number of departments and central agencies[25] - the same people we invited to participate in an exercise dealing with the weighting of the selected criteria and objectives.[26] The objectives which are listed here reflect the consensus which was established concerning the relevance of their use.

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25 In this case, the Department of Finance, the Treasury Board Secretariat and the Ministry of State for Economic and Regional Development.

26 cf. infra Chapter 3

1. Seven possible political objectives:

- political visibility and public support;
- reduction of regional disparities;
- improved and increased federal-provincial co-operation;
- improved and increased intersectoral co-operation (government - industry - universities);
- international prestige and visibility
  a) cultural, scientific and technical;
  b) economic;
- improved and increased international co-operation;
- aid to developing countries.

2. Eight principal economic objectives

- increased industrial growth;
- improved product quality;
- increased productivity;
- expansion of domestic market;
- increased exports and improved commercial trade balance;
- Canadianization of industry ownership;
- increased availability of resources;
- regional economic balance.

3. Social objectives

Social objectives, which here have been deliberately limited to two, could be extended considerably.

- environmental protection;
- improved quality of life, in terms of

a) physical environment

b) working conditions

c) leisure time

d) increased purchasing power

e) increased participation in culture and education.

4. Scientific and technical objectives

- theoretical developments;
- training of highly qualified manpower;
- development of advanced technologies:
  a) responding to national needs
  b) reinforcing the economic and cultural impact on the international scene.

This study concludes that the national objectives should be weighted on the basis of a scoring method and that research programs should be assessed in terms of these objectives. Within these research programs, the projects can be evaluated on the basis of both the national objectives and a number of more specific selection criteria immediately applicable to specific research projects. This distinction seems necessary because of the nature of the proposals submitted to the decision-makers. These proposals frequently involve research programs and their general nature makes it impossible to apply specific criteria. A two-tiered assessment of research activities[27] will reflect more clearly the intentions of the decision-making process.

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27 See chapter 3

Alvin Weinberg's distinction between internal and external criteria will be used here. However, the concept of internal criteria will be associated with the concept of scientific and technological interest and the concept of external criteria will be associated with the concept of economic interest.

1. Internal criteria

Evaluation of the scientific technological interest of a research project or related scientific activities may be based on the following criteria:

- state of the art:
  a) level of theoretical difficulty;
  b) probability of success;
- availability of qualified researchers;
- the existence of adequate research facilities (namely, laboratory equipment requirements and requirements related to laboratory conversions);
- theoretical spin-offs for other fields of research;
- possibility to foresee:
  a) performance time-space;
  b) application time-space;
  c) costs;
- projects' life expectancy;
- scope of application of results;
- nature of application of results (relevance vs prestige).

2. External criteria

Because of the framework should be flexible, the criteria are selected so that they will be neither comprehensive nor mutually exclusive. Sometimes external criteria are merely another aspect of internal criteria. However, all criteria will be included because their weightings may differ depending on whether they are viewed from the internal development of a field of research or on the basis of their significance. Excluding political and

social objectives, which may become selection criteria, we have chosen five:

- urgency to develop the field;
- strategic importance of affected industrial sectors;
- availability of funds, according to different funders;
- forecasted needs in human resources.

Chapter 3

Weighting of national objectives and selection criteria

A scoring method is the preferred method here to determine R&D priorities within the very broad context which considers all research fields. Such is the case with MOSST. Rigid mathematical models and prospective scenarios which establish a weighting system for major research fields, objectives, criteria, and R&D priorities, have been discarded. A Delphi-type method will be used instead.

The Delphi method, originally developed by the Rand Corporation in response to requests from the American air force was first used to predict military strategies. Adapted to other fields of application, it is flexible and streamlined. Essentially, a group of specialists are presented with a series of questionnaires which will identify any consensus within the group. The fields of application may vary considerably and hence this method can readily be used to assign weightings to various objectives and criteria.

In the case of R&D priorities, the scoring system will determine the relative importance of national objectives and selection criteria.

We obtained a weighting of the objectives and criteria, by means of a Delphi exercise,[28] in the following manner: using the four major classes of objectives and the two major classes of criteria presented in chapter 2, we asked the participants to assign a value to each objective and each criterion, for a total of 100 points per class. The results appear, as averages, in appendix II.

As given, however, this weighting is not enough to enable us to compare the value of objectives and criteria from different classes. There are two possible solutions to this problem: we can either decide that the value to be assigned to each class is entirely the responsibility of the political authority and hence use objectives and criteria weighted solely within their own class and evaluate research proposals by group; or assume that the various classes of objectives and criteria are of equal value and index the objectives and criteria from all classes on the basis of the value assigned to them by experts of the Delphi group.[29] For the purpose of this proposal, we have chosen the second possibility, and the indexed weighting of the objectives and criteria is presented in appendix III.

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28 Our group of experts was composed of 10 individuals, representing government branch (3), industry branch (1), and university branch (3) from MOSST, from Treasury Board Secretariat, MSERD and Department of Finance.

29 In order to obtain an indexed weighting of the objectives and criteria, we reduced each item to a common denominator, based on the number of items per class. The total of the weighted indices for each class thus corresponds to the sum of the items for each class.

We can make the following comments on the Delphi exercise and the results that were obtained: a consensus emerged concerning the relative importance of national objectives and selection criteria. In each of the two cases, when the participants were asked to assign a number of points to each item (with a total of 100 points for each class), there were only slight variations in the classifications of objectives and criteria by order of importance. Moreover, the variations which did occur in the assigned weights were hardly significant. Consequently, insofar as it is possible to speak of a consensus emerging on a relatively modest scale (recall that our group of experts consisted of only ten persons), we can without any hesitation conclude that a consensus did emerge.

As we have mentionned earlier, we invited the participants to comment on the significance of the objectives and criteria proposed and to offer suggestions as to any possible additions. Judging from their comments, the list of objectives and criteria is a functional one.

On the basis of this experiment, the evaluation of research programs and projects in this manner appears to be a reasonable management tool.

It is important to point out here that independently of the use which MOSST may make of the proposed approach to the determination of priorities, the procedure followed was enthusiastically

received by the participants in the Delphi exercise. They were unanimous in stating that the adoption of objectives and criteria for use as parameters in making R&D decisions could only help create a more rational decision-making process and improve management in this area - if only by providing a multi-dimensional frame of reference of which the various components were identified and structurally arranged.

As noted in the introduction, we propose in Appendix I a classification of technological research fields. The purpose of this classification is to list all research fields in which the government might take action, either as a direct participant or as a provider of funds. First, as an inventory, this classification provides a fairly high level of precision. Nevertheless, for present purposes, namely, the development of a tool for determining the priority or non-priority nature of research proposals, this level of precision proved not to be operational. Applying a grid consisting of 20 weighted objectives to more than 650 headings would give a table in which, theoretically, more than 13,000 cases would appear for evaluating the relative priorities of the various research fields. To obtain an operational assessment grid, we have abridged this classification and we shall apply the weighted objectives to these broad headings, for which we have tried to maintain aggregates of comparable sizes. Since quite broad fields of research are involved, we have applied - for the reasons given above - only the national objectives. In this context, the selection criteria and the headings in the detailed classification

are, in a sense, kept in reserve. The selection criteria are kept in reserve, so that they can be used when managers have to decide on the relevance and importance of specific research projects. The headings of the detailed classification are kept in reserve to serve as a data bank fcr use in locating research proposals in the system made up of the broad headings listed in the classification. In other words, in both cases - with regard to project-selection criteria and the elements listed in the detailed classification - an a priori weighting is not essential. We shall therefore propose a matrix that is composed of weighted and indexed objectives and main headings from the classification; this matrix will be the first grid used in evaluating the relative priorities of research proposals.

Chapter 4

An assessment grid for research proposals

The purpose of the assessment grid is to determine the weights for the headings derived from the classification[30] - these headings, together with the weights so found, would supply the manager of the R&D funds with an initial indication of the relative importance of the proposals falling under these headings, taking into account each of the various objectives individually and the group of objectives as a whole.

This weighting of the headings which establish the research fields requires a two-stage operation:

(1) first, we determine whether, with respect to each objective, a particular heading is considered:

(a) essential

(b) very important

(c) important

(d) useful

(e) marginal

(f) of no value.

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30 Cf. the vertical axes in Appendixes IV and V.

A score of from 5 to 0 is assigned to each of these headings.[31] The results of this scoring exercise are given in Appendix IV;

(2) second, we apply the indexed weighting grid for the objectives [32] to the scores obtained for each objective in the evaluation of all the headings. In other words, the score obtained is multiplied by the weighted index to determine a point total. The results obtained using this scoring method are given in Appedix V.

We therefore have a grid in which each heading has a point total, with a maximum possible total of 100 points (that is, a maximum of 35 for political objectives, 40 for economic objectives, 10 for social objectives and 15 for scientific and technical objectives). Consequently, by totalling the points for all headings, it is possible to classify these headings by order of priority. The results of this sample classification are given in Appendix VI.

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31 These scores could be assigned by the participants in a Delphi exercise. Since time was short, the scoring was done by two members of the Government Projects Division. It is important to note that the scores used were obtained on the basis of a consensus established by the two members of the GPD who carried out the exercise. Clearly, each of these scores could be debated, for in spite of the care that was taken, the results of the exercise necessarily remain subjective. Note also that sometimes a single consideration proved very strong by comparison with a large number of others and thereby tended to produce a score which was either very high or very low. In other words, to be significant, the exercise should be repeated in a formal manner, using outside resources.

32 Obtained from the Delphi exercise, the results of which are given under the heading "Objectives" in Appendix III.

Research proposals submitted to MOSST can therefore be identified under one of the headings and initially evaluated with respect to the weighted and indexed objectives considered individually, class-by-class, or all together. For specific projects, the same exercise can be carried out, but it is then necessary to add the further step of weighting by means of selection criteria.

Note that this weighting exercise was not applied to either the pure sciences or the health sciences, because although these sciences appear in the detailed classification, they involve a completely different philosophy with regard to the allotment of research funds.

The results of the first phase, which dealt with objectives and criteria, were final. Since only two members of the GPD participated in the second phase of the exercise, the results found in Appendixes IV, V and VI serve only as examples. For such results to be significant, it would be necessary to consult outside experts - for example, by organizing another, more extensive Delphi exercise.

CONCLUSIONS

Concerning the possibility of establishing priorities in S&T

Although it would be utopian to hope to obtain a reliable, permanent and objective system for determining priorities in S&T, it is nevertheless possible to develop a number of tools enabling decision-makers to evaluate proposals for research programs or projects on the basis of their relative priorities.

We have proposed an evaluation method based on the priority or non-priority nature of research programs or projects; the method proposed has two stages: (1) the compilation of a list of research fields and the determination of national objectives and selection criteria; (2) the evaluation of groups of research fields on the basis of these objectives and, possibly, weighted criteria.

We now have available an assessment grid for evaluating proposed research programs and projects; this grid consists of the weighted criteria and objectives. Recall, though, that however complete the lists of objectives and criteria might be, unknown factors will always have to be considered in the decision-making process.

Since priorities are continually being changed, such a weighting exercise should be repreated at regular intervals. These

re-evaluations and regular re-adjustments of the methodology do not, however, involve an inordinate amount of work.

The classification of the headings derived from the detailed classification must, itself be the subject of a more rigorous study. Nevertheless, the approach proposed here might suggest that this would be one step in rationalizing the management of scientific and technical resources by considering society's preferences as described by the political authorities. In other words, by endeavoring to combine the inevitably prescriptive nature of political choices and the multiple-stage process of evaluating concrete proposals (using a series of filters), it is possible to use a flexible tool which measures the priority nature of research proposals submitted to the federal government.

In conclusion, recall that we now have available a weighting for the objectives and selection criteria that can be used for determining the relative priorities of the various elements in the classification of research fields. Obtaining a classification of the 81 headings derived from the detailed one therefore involves consulting a group of outside experts, who would evaluate these headings on the basis of the weighted objectives that we have established.

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Appendix I

CLASSIFICATION OF TECHNOLOGICAL RESEARCH FIELDS AND SELECTED BIBLIOGRAPHY

Fields of technological research - Classification

- ENERGY -

Energy sources:
I. Fossil fuels
II. Nuclear energy
III. Hydrogelectric energy
IV. New and revived energy sources
V. Conservation

Fields:
Exploration
Extraction and/or exploitation
Production
Transportation
Storage
Use
Treatment of wastes

- PROTECTION OF THE ENVIRONMENT -

Fields:
I. Wastes
II. Water
III. Air
IV. Soil
V. Noise
VI. Prevention of natural disasters

Classification of research fields:
Identification of pollutants and understanding of pollution mechanisms

Control and elimination of pollution

- NATURAL RESOURCES MANAGEMENT -

Fields:
I. Ecosystems and ecodistricts
II. Climate
III. Water
IV. Forests
V. Fisheries
VI. Minerals
VII. Plant and animal life

- AGRICULTURE AND FOOD -

Fields:
I. Food sources currently being exploited
II. New food sources and/or development of neglected food sources
III. Nutrition
IV. Development and improvement of production
V. Processing
VI. Distribution and marketing

- SPACE -

Fields:
I. Satellites
II. Related technological developments
III. Space sciences

- COMMUNICATIONS -

Fields:
I. Technological developments
II. Socio-economic impact

- TRANSPORT -

Fields:
I. Air transport
II. Marine transport
III. Rail transport
IV. Road transport
V. Pipelines

Classification of fields
Vehicles
Infrastructure
Management and communication

- CONSTRUCTION AND HOUSING -

Fields:
I. Design and use of buildings
II. Building structures
III. Materials
IV. Energy conservation
V. Fire
VI. Geotechnical studies
VII. Noise and vibration

- BASIC SCIENCES -

- MILITARY SCIENCES -

- HEALTH SCIENCES -

Fields:
I. Clinical sciences
II. Epidemiology
III. Pharmacology and clinical pharmacology
IV. Occupational medicine
V. Preventive medicine
VI. Cancerology
VII. Neurology
VIII. Cardiovascular medicine
IX. Toxicology

- MANUFACTURING INDUSTRIES -

Sectors:
I. Food and agricultural products
II. Plastics
III. Textiles
IV. Metal industries
V. Non-electrical machinery
VI. Transportation equipment
VII. Electrical and electronic products
VIII. Non-metallical minerals
IX. Chemicals industries
X. Others

- CONSTRUCTION INDUSTRIES -

Sectors:
I. Industrial construction and engineering
II. Services

- COMMUNICATION INDUSTRIES -

Sectors:
I. Telecommunication broadcasting
II. Telecommunication carriers

ENERGY

Energy sources:
- I. Fossil fuels
- II. Nuclear energy
- III. Hydroelectric energy
- IV. New and revived energy sources
- V. Conservation

Fields:
- Exploration
- Extraction and/or exploitation
- Production
- Transportation
- Storage
- Use
- Treatment of wastes

I. Fossil fuels

Liquid and gas fossil fuels (hydrocarbons)

Exploration

(1) Detection techniques
(2) Exploration on land
- Exploration in non-arctic waters at depths not exceeding 100 metres
  (3) climatological, geophysical, geological and oceanological studies
  (4) construction of drilling platforms and studies on corrosion
  (5) impact of drilling and spills on the marine environment and prevention of explosions
  (6) protection against incebergs
- Exploration in non-arctic waters at depths in excess of 100 metres
  (7) climatological, geophysical, geological and oceanological studies
  (8) construction of drilling platforms and studies on corrosion
  (9) impact of drilling and spills on the marine environment and prevention of explosions
  (10) protection against icebergs
- Exploration in arctic environments
  (11) climatological, geophysical, geological and oceanological studies
  (12) construction of drilling platforms, studies on corrosion and effects of ice
  (13) impact of drilling and spills on the marine environment and prevention of explosions
  (14) ice structure, formation of icebergs and protection against icebergs
  (15) climatological predictions and predictions of ice movements

Extraction and/or exploitation

(16) Oil sands
(17) Oil shales
(18) Petroleum (secondary and tertiary recovery) and heavy oils
(19) Conventional petroleum
- Gas
  (20) conventional gas (secondary and tertiary recovery)
  (21) gas extracted from hydrates
  (22) release of gas from compact rock formations and oil fields
  (23) gas extracted from other formations and separation of gas and petroleum

Production

(24) Desulphurization
(25) Gas liquefaction
(26) Methanization of liquid hydrocarbons
(27) Gasification of coal
(28) Liquefaction of coal
(29) Processing of heavy oils
(30) Processing of lighter fractions (improvement of the octane rating)

Transportation

(31) Pipelines (including studies on corrosion and construction in arctic environments)
(32) Design and structure of marine carriers
(33) Transportation of light natural gas from remote regions by sea
(34) Transportation of hydrocarbons in dangerous waters

Storage

(35) Storage of natural gas under high pressure
(36) Underground storage of hydrocarbons
(37) Storage at sea
(38) Other storage methods

Use

(39) Research on fuels for internal and external combustion engines
(40) Additives
(41) Research on cold climates
(42) Compressed natural gas
(43) Propane
(44) Improvement of furnaces
(45) Coal and liquid hydrocarbon slurries
(46) Other uses

Coal

(47) Exploration

Extraction and/or exploitation

(48) Mining techniques
(49) Land redevelopment following open-pit mining

Production

(50) Desulphurization
(51) Other processes

(52) Transportation

(53) Storage

Use

(54) Fluidized-bed combustion
(55) Coal and hydrocarbon slurries
(56) Other uses

II. Nuclear energy

Exploration

(57) Uranium

Extraction and/or operation

(58) Operation of uranium mines
(59) Residues and other environmental problems

Production

(60) Fuel bundles
(61) Yellowcake, etc
(62) CANDU
(63) Production of heavy water
(64) Advanced fuel cycles
(65) Reprocessing of fuel bundles

(66) Transportation of radioactive material

Storage

(67) Storage of irradiated fuel bundles
(68) Vitrification (or other forms of fixation)
(69) Storage of radioactive wastes in stable geological formations

Use

(70) Mini-nuclear energy sources
(71) Other uses

III. Hydroelectric energy

Exploration and/or extraction and/or operation

(72) Choice of dam sites
(73) Dams on low-head rivers

Production

(74) Research on turbines, etc
(75) Tidal energy

Transportation

(76) High-tension research
(77) Transmission and distribution (including cryogenics)

(78) Storage

Use

(79) Hybrid heating
(80) Other uses

IV. New and revived energy sources

Solar energy

(81) Exploration

Production

(82) Photovoltaic conversion
(83) Other

Storage

(84) Chemical storage
(85) Underground storage in large volumes of liquid
(86) Other methods

Use

(87) Passive solar heating
(88) Active solar heating
(89) Other

Wind energy

Production

(90) Wind generators
(91) Windmills

Fusion

Production

(92) Tritium
(93) Magnetic confinement
(94) Confinement by inertia

Biomass energy

Production

(95) Agriculture wastes
(96) Crop residues
(97) Municipal wastes
(98) Grass, trees and other plants
(99) Algae
(100) Research on geological formations
(101) Biophotolysis
(102) Waste storage after production

Transportation

(103) Problems of alcohol transportation
(104) Transportation of materials prior to production

Use

(105) Use of methanol in combination with hydrocarbons in internal and external combustion engines
(106) Use of ethanol in combination with hydrocarbons in internal and external combustion engines
(107) Alcohol-burning engines
(108) Problems of emission control with alcohol combustion

Hydrogen

Production

(109) Production of hydrogen by electrolysis
(110) Production of hydrogen from natural gas, coal, etc...
(111) Production of hydrogen by photocatalysis
(112) Production of hydrogen by other methods

Transportation

Storage

(113) High pressure
(114) Cryogenic storage
(115) Storage in hybrid form
(116) Storage by absorption
(117) Other methods of storage

Use (as a fuel)

(118) Fuel cells
(119) Hydrogen-powered combustion engines
(120) Aviation fuel
(121) Fuel for rail transport
(122) Hydrogen as a means of storing excess electricity

Geothermal energy

Exploration

(123) Identification of high-temperature sites
(124) Identification of low-temperature sites
(125) High-temperature drilling techniques

Production

(126) Evaluation of reservoir potential
(127) Equipment for electrical production
(128) Equipment for the use of thermal waters for heating
(129) Production of hot water or steam by injection of water into dry hot geological formations
(130) Environmental impact and chemical changes in reservoirs

V. Conservation

Use

(131) Technological development in the field of construction
(132) Technological development in the field of transport
(133) Technological development in the industrial field

PROTECTION OF THE ENVIRONMENT

Fields:
- I. Wastes
- II. Water
- III. Air
- IV. Soil
- V. Noise
- VI. Prevention of natural disasters

Classification of fields of research:

Identification of pollutants and understanding of pollution mechanisms

Control and elimination of pollution

I. Wastes

Identification of pollutants and understanding of pollution mechanisms

Solid wastes

Effects of handling and elimination of solid wastes

(1) Identification of toxic and pathogenic substances
(2) Understanding of their effects
(3) Consequences of waste incineration
(4) Consequences of waste burial (including soil transport mechanisms)
(5) Consequences of dumping in water (including sea dumping)
(6) Elimination of heavy metals

Radioactive wastes

(7) Choice of sites for nuclear plants
(8) Effects of ionizing and non-ionizing radiation
(9) Long-term effects of exposure to low-radioactive bodies
(10) Consequences of transportation, storage and elimination of radioactive wastes
(11) Consequences of sea dumping of radioactive wastes on living organisms and on marine resources

Control and elimination of pollution

Solid wastes

(12) Recycling of residential wastes
(13) Treatment of municipal wastes (including energy production)
(14) Treatment of agricultural and forest-industry wastes (including energy production)

Raditoactive wastes

(15) Storage before treatment

- After treatment:
  (16) storage of wastes in liquid form
  (17) storage by fixation in insoluble form: vitrification of high-activity fission products - conditions governing leaching and transfer from such glasses
  (18) research on appropriate geological formations for long-term deep storage

II. Water

Identification of pollutants and understanding of pollution mechanisms (including diffusion and resulting consequences)

(19) Effect of water quality on morbidity rates
(20) Human diseases caused by the presence of toxic substances of human synthetic and/or natural origin
(21) Congenital malformations caused by the presence of teratogenic substances
(22) Consequences on aquatic life of the presence in water of metals and/or toxic substances
(23) Effect of thermal shock on aquatic ecosystems
(24) Detection of pollutant dumping
(25) Eutrophication of waters as a result of macropollutants (phosphate - and/or nitrogen-based fertilizers and organic chemical pesticides)
(26) Movement of pesticides in water
(27) Pesticide studies: studies of metabolic reactions

Control and elimination of pollution

(28) Expansion of reserves and improvement of quality of drinking water
(29) Waste water treatment
(30) Control of thermal pollution from generators
(31) Protection of the marine and coastal environment against oil slicks
(32) Development of non-toxic synthetic chemical pesticides

III. Air

Identification of pollutants and understanding of pollution mechanisms

(33) Standardization of metrological techniques

Combustion of hydrocarbons and solid fossil fuels

(34) composition of emissions
(35) studies of low-level long-term effects
(36) studies of short-term effects
(37) toxicological and epidemiological studies of their effects - on man and animals
- on other biotic systems
(38) measurement and prediction of polluant movement by dispersion and transportation
(39) effects of large-scale use of coal

(40) Chemical and physical processes of newly identified atmospheric pollutants
(41) Structure and effects of micropollutants from chemical industries and electrical engineering
(42) Effects of dust emissions

Control and elimination of pollution

(43) Development of collection and control systems
(44) Purification of fuels
(45) Definition of acceptable standards for fuels
(46) Development of clean combustion methods (for example, gasification and/or liquefaction of coal)
(47) Implications of transborder pollution
(48) Improvement of carriers for toxic substances

IV. Soil

Identification of pollutants and understanding of pollution mechanisms

(49) Pesticide displacement in the soil
(50) Overutilization of soils

Control and elimination of pollution

(51) Redevelopment of open-pit mines, particularly coal mines

V. Noise

Identification of sources of noise and understanding of the effects of noise

(52) Studies of principal sources of noise
(53) Effects of noise on humans, animals and plants
(54) Measurement and effects of aircraft noise

Control and elimination of pollution

(55) Technologies for the control and reduction of the principal sources of noise

VI. Prevention of natural disasters

Fire

(56) Prevention and control of forest fires

Earthquakes

(57) Prediction
(58) Improvement of construction techniques

Volcanic eruptions

(59) Prediction
(60) Geophysical prevention

Tornadoes and hurricanes

(61) Prediction

NATURAL RESOURCES MANAGEMENT

Fields:
I. Ecosystems and ecodistricts
II. Climate
III. Water
IV. Forests
V. Fisheries
VI. Minerals
VII. Plant and animal life

I. Ecosystems and ecodistricts

Characteristics of ecosystems and ecodistricts*

(1) Systematics
(2) Metrology

II. Climate

Characteristics of climatic regions

(3) Coastal climate
(4) Arctic climate

Climatic and meteorological phenomena

- Climatic variations and changes

(5) microclimates
(6) climatic variations and changes in metropolitan areas

(7) Collection of meteorological data
(8) Long-, medium- and short-term meteorological predictions
(9) Collection of data on atmospheric circulation models
(10) Chemical substances and upper-atmosphere meteorological phenomena

III. Water

Evaluation of reserves

(11) for drinking water
(12) for agriculture
(13) for energy production

(14) Water quality
(15) Understanding of the major systems of lakes and rivers
(16) Relationships between systems
(17) management of national systems
(18) management of transborder systems

IV. Forests

Protection

(19) Control of pollution factors (for example, acid rain)
(20) Research on forest fires
(21) Entomological research (for example, spruce budworm)
(22) Research on tree diseases

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*ecodistricts: geographically defined ecosystems

Development

(23) Use of raw timber
(24) Sylviculture
(25) Agroforestry
(26) Forestry operations
(27) Site regeneration and reforestration
(28) Forest management for recreational purposes
(29) Pulp and paper research

Use of forest biomass

(30) production of energy in the form of alcohol
(31) production of energy in the form of electricity
(32) production of energy in the form of fuelwood
(33) production of chemical substances
(34) production of feed for animals

Knowledge of the forest

(35) Forest hydrology

- Forest biology
  (36) tree physiology
  (37) forest genetics

V. Fisheries

Inventory of resources

(38) Resource behaviour
(39) Interactions between different species

Development

- Marine and freshwater aquiculture:
  (40) physiology of aquatic species
  (41) pathology of aquatic species
- Intensive development (including industrial)
  (42) identification of promising sectors
  (43) processing of fish into products for human consumption
  (44) research on materials and design of fishing vessels

Protection

(45) Research on aquatic ecosystems

- Research on the habitat of aquatic species
  (46) inventory and description of habitats
  (47) effects of pollutants
  (48) cleaning and regeneration

(49) Research on the ecological aspects of sport fishing

VI. Minerals

Location and evaluation of resources

- Inventory of resources (including marine and arctic resources)
  - (50) Geological cartography
  - (51) Precision location
  - (52) Teledetection
  - (53) Geophysical prospecting
  - (54) Geochemical prospecting
  - (55) Subterranean stratigraphy
  - (56) Geostatistics

Extraction and exploitation

- Mining operations
  - (57) Improvement of drilling techniques
  - (58) Standardization of remote control techniques
  - (59) Automation through the use of microprocessors
  - (60) Underground communications systems
  - (61) Explosives chemistry
  - (62) Pit-opening techniques
  - (63) On-site leaching
  - (64) Deep-mining techniques

(65) Separation and isolation of microminerals
(66) Health and safety

Processing

(67) Automation of crushing techniques
(68) Ore concentration
(69) Use of mineral wastes
(70) Repurification of degraded alloys
(71) Recycling of composition materials

VII. Plant and animal life

(72) Faunistics
(73) Floristics

AGRICULTURE AND FOOD

Fields:
- I. Food source currently being exploited
- II. New food sources and neglected food sources
- III. Nutrition
- IV. Development and improvement of production
- V. Processing
- VI. Distribution and marketing

I. Food sources currently being exploited

Production and development

(1) Improvement of exploitation techniques
(2) Use of residues of food products

II. New food sources and/or development of neglected food sources

Production and development

(3) Use of oilseeds
(4) Use of residues of food products
(5) Identification of new food products (of marine and land origin)
(6) Improvement of methods of processing proteins of marine and non-animal origin into edible products

III. Nutrition

(7) Effects of food additives and preservatives
(8) Natural technologies for food preservation
(9) Identification and evaluation of damages caused by different types and levels of malnutrition
(10) Identification of food products offering the best nutritional value

IV. Development and improvement of production

Crops

- Development of new and hybrid varieties, particularly those characterized by
  (11) better resistance to parasites
  (12) better resistance to high and low temperatures

(13) Increased nutritional value
- Reduction of crop vulnerability
  (14) studies of morphological, physiological and biochemical differences between resistant and vulnerable varieties
  (15) identification and control of toxic compunds in soils

(16) Improvement in the use and quality of pesticides
- Improvement in techniques for the control of weeds, parasites and plant diseases
  (17) entomological studies

(18) biosystematics
(19) physiological and biochemical studies

- Improvement of soil productivity
  (20) evaluation of soil potential
  (21) improvement of fertilization techniques and fertilizer quality
  (22) improvement of irrigation techniques
  (23) improvement of water management

(24) Improvement of techniques and equipment for planting and harvesting

- Climatological research
  (25) long-term meteorological predictions
  (26) effects of climatic and meteorological variations
- Exploratory research
  (27) photosynthesis
  (28) biological fixation of nitrogen

Animal production

(29) Improvement of stock-rearing methods

- Research on veterinary medicine:
  (30) improvement of parasite, insect and predator control
  (31) improvement of animal resistance to parasites, weather and disease
- Physiological and genetic research
  (32) improved understanding of livestock nutritional needs
  (33) research on metabolic synthesis
- Improvement of fodder quality
  (34) soil quality
  (35) resistance to weeds, rust, bad weather and disease

Marine production

(36) Improvement of the nutritional value of aquatic fauna
(37) Improvement of the nutritional value of aquatic flora

V. Processing

(38) Improvement of bulk storage and processing methods
(39) Preservation of the nutritional value of foods during processing
(40) Reduction of costs and losses

VI. Distribution and marketing

(41) Improvement of transportation techniques
(42) Improvement of methods of preservation
(43) Reduction and control of contamination factors.

SPACE

Fields:
I. Satellites
II. Related technological developments
III. Space sciences

I. Satellites

Teledetection

- Fields of application
  - (1) Data collection - earth
    - resources
    - oceans
    - ice
    - atmosphere
  - (2) Territorial surveillance
  - (3) Meteorological and environmental surveillance
  - (4) Resource management
- Technological developments
  - (5) Development of a synthetic aperture radar unit
  - (6) Image correction system
  - (7) Data extraction system
  - (8) Detection of chlorophyll A

Telecommunications

(9) Telemedicine
(10) Tele-education
(11) Multipurpose satellite system
(12) Direct radio and television broadcasting by satellite
(13) Mobile communications satellite
(14) Scientific satellites
(15) Meteorolocial satellites
(16) Military satellites

II. Related scientific developments

(17) Development of a family of advanced semi-conductor devices
(18) Hyperfrequencies
(19) 30/20 GHz band
(20) Research on cell use systems

- Mechanisms for space quipment
  - (21) deployable antennas
  - (22) arrays of deployable photovoltaic cells

(23) Improvement of earth stations
(24) Testing of space equipment: simulation techniques and instruments

III. Space sciences

(25) Upper-atmosphere chemistry and physics
(26) Magnetosphere
(27) Astronomy

COMMUNICATIONS

Fields: I. Technological developments

II. Socio-economic impact

I. Communications: technological developments

(1) Telidon - interface research
(2) Videodisks
(3) Microprocessors
(4) Mobile telephone
(5) Mobile radio
(6) Optic telecommunications, including fibre optics
(7) High-frequency telecommunications
(8) Office of the future
(9) Radar
(10) New techniques of spectrum utilization
(11) Biotransistor: molecular and biomolecular ultramicrocircuits

II. Communications: socio-economic impact

Effects of the use of microprocessors:

(12) Effects of the development of communication technologies on human relations
(13) Effects on respect for privacy and confidentiality
(14) Manpower:
- production of employment
- manpower retraining and displacement
(15) Data ownership
(16) Effects on workers health

TRANSPORT

Fields:
I. Air transport
II. Marine transport
III. Rail transport
IV. Road transport
V. Pipelines

Classification of fields: Vehicles
Infrastructure
Management and communication

I. Air transport

Vehicles

(1) Production of aircraft with reduced energy consumption
(2) Non-conventional aircraft
(3) Development of aircraft powered by various fuels, particularly non-conventional fuels
(4) Fuel safety
(5) Equipment design
(6) Resistance of materials and navigational equipment (particularly to cold)
(7) Development of instruments and techniques for flight simulation

Infrastructure

(8) Improvement of road surface quality

- Choice of airport sites
  (9) effects of noise
  (10) microclimates

- Improvement of airport design
  (11) organization and planning - baggage
  - passengers

(12) Effects of glycol on the airport environment
(13) Development of instruments and techniques for simulation

Management and communication

(14) Air traffic control

- Air navigation in remote regions, particularly the vast northern and ocean areas
  (15) development of surveillance satellites to replace radar
  (16) safety of navigational instruments

(17) Improvement of radar systems
(18) Air/ground communications via satellite
(19) Automation of flight planning
(20) Automation of information retrieval
(21) Development of techniques for bilingual and multilingual communication

II. Marine transport

Vehicles

(22) Hull design

- Research on materials
  (23) flammability
  (24) resistance (to wear, climate, ice)

(25) Research on hull-ice contact
(26) Development of engines powered by various non-conventional fuels
(27) Reduction of pollutant emissions
(28) Non-conventional marine vehicles

(29) Infrastructure

- Management and communication
  (30) Bathymetry
  (31) Detection of ice thickness and movement and iceberg movement
  (32) Icebreaking by hovercraft
  (33) Propulsion systems for polar ice breakers
  (34) Development of buoys adapted for use in ice
  (35) Buoy handling
  - Improvement of communication systems
    (36) radio
    (37) radar
    (38) signalling

III. Rail transport

Vehicles

(39) Expansion of capacity, performance and reliability of passenger and freight trains
(40) Reduction of energy consumption
(41) Transportation safety for toxic substances
(42) Electropneumatic breaking
(43) High-speed trains
(44) Electrification of trains

(45) Infrastructure

- Management and communication
  (46) Choice of rail routes
  (47) Safety of level crossings
  (48) Electronic shunting
  (49) Transportation safety for toxic substances
  (50) Integration of various modes of transportation (for example, trains - trucks)

IV. Road transport

Vehicles

(51) Electric automobile vehicles
(52) Hybrid automobile vehicles
(53) Automobile vehicles powered by various fuels, including non-conventional fuels

(54) Propulsion technologies
(55) Research on lubricants
(56) Maximization of truck capacity
(57) Reduction of energy consumption
(58) Transportation safety for toxic substances

Infrastructure

(59) Road surfaces in cold environments and in environments with wide seasonal variations in temperature
(60) Bridge stability
(61) Improvement of snow-removal techniques

Management and communication

(62) Transportation of toxic substances by truck
(63) Transportation of perishable foodstuffs by truck
(64) Automation of road traffic control
(65) Detection of obstacles

- Highway safety
  (66) effects of landscape, light and darkness
  (67) effects of drug consumption, including alcohol
  (68) effects of fatigue
  (69) integration of various modes of transport

(70) Public transit systems

V. Pipelines

Infrastructure

- Pipelines building materials
  (71) corrosion
  (72) materials resistance in artic climate

Management and communication

(73) Systems analysis

CONSTRUCTION AND HOUSING

Fields:
I. Design and use of buildings
II. Building structures
III. Materials
IV. Energy conservation
V. Fire
VI. Geotechnical studies
VII. Noise and vibration

I. Design and use of buildings

(1) Access and movement by the handicapped
(2) Emergency traffic flow
(3) Modular design

II. Building structures

(4) Effects of wind
(5) Effects of snow
(6) Effects of temperature variations

III. Materials

- Properties of materials
  (7) durability of concrete
  (8) durability fo clay masonry
(9) Behaviour of materials
(10) Properties of jointing materials
(11) Surfaces
(12) Repair of materials
(13) Aging of materials

IV. Energy conservation

- Energy production
  (14) conversion equipment
- Thermal insulation
  (15) thermal performance of windows
  (16) thermal performance of walls
  (17) sealed windows
  (18) techniques for measurement of air leaks
  (19) heat recovery

(20) Heat transmission characteristics

- Air movements
  (21) techniques for simulation of air movements
  (22) ventilation
  (23) air quality

(24) Solar heating
(25) Performance standards
(26) Research on toxicity of insulating materials

V. Fire

(27) Flammability of materials
(28) Behaviour of plastic materials
(29) Thermal decomposition of polymers
(30) Toxicity of emissions
- Movements of fire and smoke
(31) propagation

VI. Geotechnical studies

(32) Soil movement
(33) Soil deformation
(34) Soil resistance
(35) Effects of frost on soils
(36) Construction in permafrost zones
(37) Deep excavations

VII. Noise and vibration

(38) Measurement of noise
(39) Noise propagation
(40) Noise control
(41) Soundproofing of buildings
(42) Measurement of vibrations
(43) Control of vibrations

BASIC SCIENCES

- Atmosphere
  (1) Astronomy
  (2) Upper-atmosphere chemistry and physics
  (3) Magnetosphere

- Soils
  (4) Geology
  (5) Geophysics
  (6) Other earth sciences

- Waters
  (7) Oceanology
  (8) Limnology
  (9) Other freshwater-related sciences

(10) Chemistry

(11) Nuclear physics

(12) Physics

(13) Mathematics

- Biological sciences
  (14) Molecular biology
  (15) Genetic biology
  (16) Basic biotechnology

HEALTH SCIENCES (1)

Fields:

I. Clinical sciences

II. Epidemiology

III. Pharmacology and clinical pharmacology

IV. Occupational medicine

V. Preventive medicine

VI. Cancerology

VII. Neurology

VIII. Cardiovascular medicine

IX. Toxicology

(1) Source: National Objectives and Research Priorities, ASTEC, Canberra, September 1981

I. Clinical sciences

(1) Clinical genetics
(2) Clinical microbiology
(3) Clinical pathology
(4) Dermatology
(5) Diagnostic techniques
(6) Gynaecology and obstetrics
(7) Ophthalmology
(8) Paediatrics
(9) Radiology
(10) Radiotherapy
(11) Syphiligraphy
(12) Endocrinology
(13) Gastroenterology
(14) Haematology
(15) Infectious diseases
(16) Nephrology
(17) Pulmonary diseases
(18) Rheumatology
(19) Allergies
(20) Comparative pathology
(21) Histopathology
(22) Neuropathology
(23) Parasitology
(24) Oncology
(25) Osteopathology
(26) Radiation pathology
(27) Stress
(28) Teratology
(29) Psychiatry

- Surgery
  - (30) abdominal surgery
  - (31) plastic surgery
  - (32) anaesthesiology
  - (33) orthopaedic surgery
  - (34) otorhinolaryngologic surgery
  - (35) bone surgery
  - (36) orthodontics
  - (37) graft surgery
  - (38) vascular surgery

(39) Physiotherapy
(40) Proctology
(41) Traumatology
(42) Urology and nephrology
(43) Traumatology
(44) Virology

II. Epidemiology

III. Pharmacology and clinical pharmacology

(45) Drug consumption
(46) Effects of drugs
(47) Metabolic processes
(48) Composition of drugs
(49) Standardization of drugs
(50) Catalysis, autocatalysis, immunocatalysis
(51) Chemotherapy
(52) Interaction of antigens
(53) Pharmacognosy
(54) Pharmacopeia
(55) Phytopharmacy
(56) Psychopharmacology
(57) Molecular pharmacology

IV. Occupational medicine

(58) Nuclear medicine
(59) Occupational diseases
(60) Occupational health
(61) Occupational therapy

V. Sports medicine

VI. Preventive medicine

VII. Cancerology

(62) Food toxicity
(63) Carcinogenic substances
(64) Immunopathology
(65) Experimental pathology
(66) Oncology
(67) Chemotherapy
(68) Molecular biology
(69) Cellular biology
(70) Microbiology
(71) Virology
(72) Endocrinology

VIII. Neurology

(73) Human neuroanatomy
(74) Neurophysiology

(75) Physiology of the central nervous system
(76) Molecular biology
(77) Behavioural sciences
(78) Chemical psychology
(79) Effects of drugs on the brain
(80) Psychopharmacology
(81) Neuropharmacology
(82) Neurosurgery
(83) Psychiatry
(84) Immunochemistry

IX. Cardiovascular medicine

(85) Molecular biology
(86) Cardiovascular physiology
(87) Neurophysiology
(88) Cardiography
(89) Geriatrics
(90) Cardiovascular diseases
(91) Hypertension
(92) Food deficiencies
(93) Effects of diet
(94) Arteriosclerosis
(95) Cardiovascular pathology
(96) Experimental pathology
(97) Cardiac surgery

X. Toxicology

XI. Medical technologies

(98) Instruments

MANUFACTURING INDUSTRIES

Sectors:

I. Food and other agricultural products

II. Plastics

III. Rubber products industries

IV. Textiles and leather

V. Metal industries

VI. Non-electrical machinery

VII. Transportation equipment

VIII. Electrical and electronic products

IX. Non-metallic minerals

X. Chemical industries

XI. Others

I. Food and other agricultural products

(1) Food processing for human consumption
(2) Food processing for animal consumption

- Agricultural products transformation for means other than consumption
  (3) tabacco

(4) Storage and conservation

II. Plastics

(5) Transformation methods of synthetic resins
(6) Transformation and use of non-resin plastics
(7) Plastics safety (eg. polyvinyle chloride (PVC) toxity)
(8) Recycling

III. Rubber products industries

IV. Textiles and leather

Textiles

(9) Natural fibres processing
(10) Synthetic fibres processing

- Technologies of fibres processing
  (11) automatisation and robotisation of weaving
  (12) automatisation and robotisation of knitting

Leather

(13) Treatment of leather

- Automatisation and robotisation of leather processing
  (14) footwear
  (15) luggage
  (16) sports equipment

V. Metal industries

(17) Heating products
(18) Structural metal products
(19) Hardware and tools
(20) Machine shop industry
(21) Moulding and casting

- Metal refining

VI. Non-electrical machinery

(22) Agricultural implement

- Heavy machinery
  (23) machining and tooling
  (24) construction
  (25) mining
  (26) power transmission

- forestry
  (27) pulp making technologies
  (28) pulp processing
  (29) printing

VII. Transportation equipment

(30) Aircrafts and parts
(31) Motor vehicles (automobiles, trucks, cars and parts)
(32) Railroad rolling stock
(33) Ship building
(34) Pipelines

- Others
  (35) snowmobiles
  (36) pleasure crafts and boats

VIII. Electrical and electronic products

Electrical and electronic material

(37) Non-commercial
(38) Domestic robots
(39) Communication and telecommunication

- Office equipment
  (40) office of the future

- Industrial equipment
  (41) industrial robotics

(42) Batteries
(43) Cables and wires

IX. Non-metallic minerals

(44) Insulation products
(45) Cement
(46) Abrasives
(47) Glass

X. Chemical industries

(48) Industrial inorganic chemical industries
(49) Industrial organic chemical industries
(50) Agricultural chemical industries
(51) Plastic and synthetic resin industries
(52) Pharmaceutical and medicine industries
(53) Cleaning compounds and toilet preparations
(54) Enamel and vanish

XI. Others

(55) Scientific and professional equipment
(56) Other communication and telecommunication material
(57) Toys
(58) Sporting goods

COMMUNICATION INDUSTRIES

Sectors: I. Telecommunication broadcasting

II. Telecommunication carriers

I. Telecommunication broadcasting

(1) Radio broadcasting
(2) Television broadcasting
(3) Combined radio and television broadcasting
(4) Cable television

II. Telecommunication carriers

(5) Telecommunication carriers

CONSTRUCTION INDUSTRIES

Sectors: I. Industrial and heavy (engineering) construction

II. Services

I. Industrial and heavy (engineering) construction

(1) Power plants
(2) Transmission lines
(3) Gas and oil structures
(4) Gas and oil pipelines
(5) Highways, streets and bridges
(6) Waterworks and sewage system
(7) Others

II. Services

(8) Construction works management
(9) Others

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ENERGY POLICY

ENVIRONMENTAL S&T

INFOBRIEF - RESEARCH AND TECHNOLOGY

PETROLEUM ECONOMIST

SOLAR ENERGY

TECHNOLOGY REVIEW

RECHNOCATION

Appendix II

WEIGHTING OF OBJECTIVES AND CRITERIA

Political Objectives

Political visibility and public support	16.11
Reduction of regional disparities	18.89
Improved and increased federal-provincial cooperation	17.22
Improved and increased inter-sectoral cooperation (government-industry-university)	18.89
International prestige and visibility	7.78
Improved and increased international cooperation	10.56
Aid to developing countries	10.56
	100

Economic Objectives

Increased industrial growth	16.33
Improved product quality	11.67
Increased productivity	19.44
Expansion of internal markets	7.89
Increased exports and improved commercial trade balance	15.00
Canadianization of industry ownership	10.56
Increased availability of resources	6.89
Regional economic balance	12.22
	100

Social Objectives

Environmental protection	38.33
Improved quality of life, with regard to:	61.67
a) the physical environment	
b) work conditions	
c) hours of work	
d) increased purchasing power	
e) improved access to cultural services	
	100

Scientific and Technical Objectives

Theoretical developments	27.22
Training of highly qualified manpower	35.56
Development of advanced technologies a) satisfying national needs b) reinforcing Canada's economic and cultural visibility	37.22
	100

Internal Criteria

State-of-the-art -level of theoretical difficulty -probability of success	16.11
Availability of qualified researchers	12.78
Adequate research infrastructure	12.22
Theoretical spin-offs for other fields	10.56
Possibility to foresee - performance time-space - application time-space - costs	12.22
Life expectancy of the project's relevance	8.89
Scope of the use of results	13.33
Nature of the use of results (relevance vs. prestige)	13.89
	100

External Criteria

Urgency to develop the field	23.89
Strategic importance of affected industrial sectors	35.00
Availability of funds, according to different funders	22.22
Forecasted needs in human ressources	18.89
	100

Appendix III

INDEXED WEIGHTING OF OBJECTIVES AND CRITERIA

Political Objectives

Political visibility and public support	1.13
Reduction of regional disparities	1.32
Improved and increased federal-provincial cooperation	1.21
Improved and increased inter-sectoral cooperation (government-industry-university)	1.32
International prestige and visibility	0.54
Improved and increased international cooperation	0.74
Aid to developing countries	0.74

Economic Objectives

Increased industrial growth	1.31
Improved product quality	0.98
Increased productivity	1.56
Expansion of internal markets	0.63
Increased exports and improved commercial trade balance	1.20
Canadianization of industry ownership	0.84
Increased availability of resources	0.55
Regional economic balance	0.98

Social Objectives

Environmental protection	0.77
Improved quality of life, with regard to:	1.23
a) the physical environment	
b) work conditions	
c) hours of work	
d) increased purchasing power	
e) improved access to cultural services	

Scientific and Technical Objectives

Theoretical developments	0.82
Training of highly qualified manpower	1.07
Development of advanced technologies	1.12
a) satisfying national needs b) reinforcing Canada's economic and cultural visibility	

Internal Criteria

State-of-the-art -level of theoretical difficulty -probability of success	1.29
Availability of qualified researchers	1.02
Adequate research infrastructure	0.98
Theoretical spin-offs for other fields	0.84
Possibility to foresee - performance time-space - application time-space - costs	0.98
Life expectancy of the project's relevance	0.71
Scope of the use of results	1.07
Nature of the use of results (relevance vs. prestige)	1.11

External Criteria

Urgency to develop the field	0.96
Strategic importance of affected industrial sectors	1.40
Availability of funds, according to different funders	0.89
Forecasted needs in human ressources	0.76

Appendix IV

Score of research fields by objectives

	POLITICAL							ECONOMIC								SOCIAL			SCIENTIFIC & TECHNICAL		
	Political visibility and public support	Reduction of regional disparities	Improved and increased provincial cooperation	Improved and increased federal-cooperation	International prestige and visibility	Improved and increased international cooperation	Aid to developing countries	Increased industrial growth	Improved product quality	Increased productivity	Expansion of internal markets	Increased exports and improved commercial trade balance	Canadianization of industry ownership	Increased availability of resources	Regional economic balance	Environmental protection	Improved quality of life	Theoretical developments	Training of highly qualified manpower	Development of advanced technologies
ENERGY																				
1. Hydrocarbons																				
Exploration	4	3	3	3	2	2	2	4	0	0	3	5	3	4	3	3	0	2	4	4
Extraction/exploitation	4	3	3	3	2	2	2	4	0	0	3	5	3	4	3	0	4	2	4	4
Production	4	1	3	3	2	2	2	4	0	0	3	5	3	4	3	2	3	3	4	4
Transportation	3	2	3	3	2	2	2	4	0	0	3	5	3	3	3	3	3	0	4	4
Storage	3	0	3	3	2	2	2	4	0	0	3	5	3	3	3	2	0	0	4	4
Use	4	1	3	3	2	2	2	4	3	0	3	5	3	3	3	3	0	2	3	4
2. Coal																				
Exploration	3	1	2	2	0	0	0	2	0	0	1	2	0	1	1	0	0	2	2	1
Extraction	3	2	2	2	1	1	0	3	0	0	2	2	0	2	1	3	3	2	2	0
Production	3	0	2	2	1	1	0	4	0	0	3	2	0	3	1	3	1	3	3	3
Transportation	1	0	2	2	1	1	0	3	0	0	1	2	0	1	1	1	0	0	0	0
Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Use	3	0	2	2	1	2	0	4	3	0	2	2	0	2	2	3	0	3	3	3
3. Nuclear energy																				
Exploration	1	0	0	0	0	0	1	1	0	0	0	3	0	1	0	3	0	0	0	0
Extraction/exploitation	3	0	0	0	0	0	1	1	0	0	0	3	0	1	0	3	0	0	0	0
Production	4	0	1	3	4	1	1	4	3	0	3	3	0	2	1	3	0	5	5	5
Transportation	4	0	4	3	3	1	1	3	0	0	0	3	0	0	0	5	0	5	5	5
Storage	4	0	4	3	5	1	1	3	0	0	1	3	0	1	1	5	0	5	5	5
Use	1	0	0	3	1	1	1	1	0	0	1	3	0	1	1	3	2	3	5	5
4. Hydroelectric energy																				
Exploitation	1	0	0	0	3	0	3	4	0	0	0	3	0	2	0	4	3	0	0	2
Production	2	0	0	0	4	0	3	4	0	0	0	3	0	3	0	3	3	0	0	3
Transportation	2	0	1	1	4	0	3	4	0	0	0	3	0	1	0	2	2	2	2	3
Use	2	0	2	2	2	0	0	4	3	2	2	3	0	2	0	1	3	1	2	3
5. New and revived energy sources	3	0	1	1	2	2	3	1	0	0	0	0	0	4	2	3	3	5	5	5
6. Conservation																				
Construction	4	0	0	2	3	2	0	1	0	1	0	1	0	1	1	1	1	1	0	1
Transportation	4	0	0	2	3	2	1	1	0	1	0	1	0	1	1	1	1	1	0	1
Industry	4	0	0	2	3	2	0	1	0	1	0	1	0	1	0	1	1	1	0	1
PROTECTION OF THE ENVIRONMENT																				
1. Wastes	3	0	3	4	4	3	1	4	0	0	0	0	0	3	0	5	4	5	5	4
2. Water	4	0	3	4	4	4	3	4	0	0	0	0	0	3	1	5	4	5	5	4
3. Air	4	0	3	4	4	4	3	4	0	0	0	0	0	3	2	5	4	5	5	4
4. Soil	2	0	2	4	4	3	3	3	0	0	0	0	0	3	2	5	4	5	5	4
5. Noise	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	4	3	5	4
6. Natural disasters	1	0	4	1	2	3	3	2	0	0	0	0	0	2	0	4	1	5	5	4
NATURAL RESOURCES MANAGEMENT																				
1. Ecosystems and ecodistricts	1	0	3	2	1	2	2	0	0	0	0	0	0	1	1	5	4	5	5	0
2. Climate	1	0	1	2	1	2	1	0	0	0	0	0	0	2	1	3	1	5	5	2
3. Water	2	0	3	2	1	3	4	3	0	0	0	0	0	3	1	5	4	5	5	0
4. Forests																				
Protection	3	3	3	3	2	3	3	3	0	0	2	3	0	3	3	5	4	4	5	3
Development	3	3	3	3	2	2	3	3	3	3	2	3	0	3	3	5	4	3	5	3
Use of forest biomass	3	3	3	3	2	2	3	3	3	0	2	3	0	3	3	5	4	4	5	3
Knowledge of the forest	3	3	3	3	2	2	3	3	0	0	2	3	0	3	3	5	4	5	5	1
5. Fisheries																				
Inventory of resources	3	4	4	3	3	2	1	3	1	3	3	2	0	3	4	1	3	3	5	3
Species behavior	3	4	4	3	3	2	1	3	0	3	3	2	0	3	4	3	3	3	5	3
Development	3	4	4	3	3	2	1	3	2	3	3	2	0	3	4	1	3	4	5	3
Protection	3	4	4	3	3	2	1	3	0	3	3	2	0	3	4	1	3	4	5	3
6. Minerals																				
Location and evaluation of resources	1	0	2	3	2	1	3	3	0	3	0	2	1	2	1	0	0	1	1	3
Extraction and exploitation	1	0	2	3	2	1	3	3	0	3	2	2	1	2	1	2	1	1	1	3
Processing	1	0	2	3	2	1	3	3	3	3	2	2	1	2	1	2	1	1	1	3
7. Plant and animal life	0	0	1	2	1	1	3	0	0	0	0	0	0	0	0	5	4	5	5	0
AGRICULTURE AND FOOD																				
1. Development of food sources	3	3	3	3	4	2	5	1	3	0	0	3	0	4	3	1	4	4	5	2
2. Nutrition	3	0	1	4	4	2	5	1	3	0	2	1	0	4	2	1	4	5	5	3
3. Development and improvement of production	3	3	3	3	4	1	5	1	3	2	2	3	0	4	4	3	4	5	5	3
4. Processing, distribution and marketing	2	1	1	2	3	1	5	1	2	3	2	3	2	4	4	0	4	2	2	4
SPACE																				
1. Satellites	3	3	1	3	4	3	2	3	0	0	2	2	2	3	1	4	4	5	5	5
2. Related technological developments	3	3	1	3	4	3	0	3	1	0	0	2	2	1	0	0	1	5	5	5
3. Space sciences	3	3	1	3	4	3	0	1	0	0	0	0	2	1	0	3	1	5	5	5
COMMUNICATIONS																				
1. Technological developments	3	3	2	4	4	2	1	4	3	4	3	4	3	0	2	0	4	5	5	5
2. Socio-economic impact	4	0	3	4	2	1	3	3	0	4	2	1	2	0	0	0	5	5	5	5
TRANSPORT																				
1. Air transport	3	2	1	3	4	3	1	4	4	0	1	3	3	0	3	3	3	3	3	5
2. Marine transport	2	3	1	2	3	2	1	4	4	0	1	1	1	3	4	4	3	3	3	3
3. Rail transport	3	1	3	3	4	1	1	4	4	0	4	3	3	2	2	4	4	2	3	3
4. Road transport	2	1	3	1	1	0	1	4	4	0	4	3	3	2	3	4	4	0	0	3
5. Pipelines	3	3	2	2	2	1	1	4	3	0	4	2	3	3	4	4	1	2	2	3
CONSTRUCTION AND HOUSING																				
1. Design and use of buildings	1	0	0	3	3	2	2	3	4	2	0	3	0	0	0	0	4	0	3	2
2. Building structures	1	0	0	3	3	2	2	4	4	2	0	3	0	0	0	0	4	0	2	1
3. Materials	1	0	0	3	3	2	2	4	3	2	0	3	0	0	0	0	3	1	1	1
4. Energy conservation	2	0	0	3	3	2	2	3	2	1	0	1	0	0	0	3	3	0	2	1
5. Noise, fire, vibrations	2	0	0	3	3	2	2	2	2	0	0	1	0	0	0	2	5	1	2	1
MANUFACTURING INDUSTRIES																				
1. Food and other agricultural products	2	2	3	3	3	0	0	3	4	4	3	3	0	0	0	0	4	0	2	4
2. Plastics	2	0	1	1	0	0	0	4	4	4	3	3	0	0	0	0	1	0	2	4
3. Rubber products industries	1	0	0	0	0	0	0	1	4	4	2	0	0	0	0	0	1	0	2	2
4. Textiles and leather	3	0	3	3	0	0	0	3	4	4	4	1	0	0	0	0	2	0	2	3
5. Metal industries	3	0	3	3	0	0	0	4	4	4	3	3	0	0	0	0	2	0	2	3
6. Non-electrical machinery	3	0	0	0	0	0	0	4	4	4	2	1	0	0	0	0	3	0	2	3
7. Transportation equipment	3	2	3	3	3	0	0	4	4	4	4	4	0	0	0	0	4	0	2	4
8. Electrical and electronic products	3	0	3	3	3	0	0	4	4	4	3	4	0	0	0	0	4	2	2	5
9. Non-metalic minerals	1	0	0	0	0	0	0	2	4	4	2	1	0	0	0	0	1	0	2	3
10. Chemical industries	3	0	0	3	0	0	0	4	4	4	4	4	0	0	0	0	3	2	2	4
11. Others	1	0	0	0	0	0	0	2	4	4	2	2	0	0	0	0	3	0	2	3
COMMUNICATION INDUSTRIES																				
1. Telecommunications broadcasting	3	0	0	3	3	2	3	1	4	1	1	2	0	0	0	0	4	2	3	4
2. Telecommunication carriers	3	1	0	3	3	2	2	1	4	1	1	0	0	0	0	0	4	0	3	4
CONSTRUCTION INDUSTRIES																				
1. Industrial construction and engineering	3	0	1	3	1	0	3	4	3	4	0	3	0	0	0	0	1	0	2	1
2. Services	3	0	1	3	1	0	3	4	3	4	0	3	0	0	0	2	1	0	4	1

Appendix V

Weighting of research fields by objective

	Political visibility and public support	Reduction of regional disparities	Improved and increased provincial cooperation	Improved and increased federal-cooperation	International prestige and visibility	Improved and increased international cooperation	Aid to developing countries	Increased industrial growth	Improved product quality	Increased productivity	Expansion of internal markets	Increased exports and improved commercial trade balance	Canadianization of industry ownership	Increased availability of resources	Regional economic balance	Environmental protection	Improved quality of life	Theoretical developments	Training of highly qualified manpower	Development of advanced technologies
ENERGY																				
1. Hydrocarbons																				
Exploration	4.5	4	3.6	4	1	1.5	1.5	20.1	5.2	0	0	1.9	6	2.5	2.2	3	20.8	2.3	0	2.3	1.6	4.3	4.5	10.4
Extraction/exploitation	4.5	4	3.6	4	1	1.5	1.5	20.1	5.2	0	0	1.9	6	2.5	2.2	3	20.8	0	4.9	4.9	1.6	4.3	4.5	10.4
Production	4.5	1.3	3.6	4	1	1.5	1.5	17.4	5.2	0	0	1.9	6	2.5	2.2	3	20.8	1.5	3.7	5.2	2.5	4.3	4.5	11.3
Transportation	3.4	2.6	3.6	4	1	1.5	1.5	17.6	5.2	0	0	1.9	6	2.5	1.6	3	20.2	2.3	3.7	6.0	0	4.3	4.5	8.8
Storage	3.4	0	3.6	4	1	1.5	1.5	15.0	5.2	0	0	1.9	6	2.5	1.6	3	20.2	1.5	0	1.5	0	4.3	4.5	8.8
Use	4.5	1.3	3.6	4	1	1.5	1.5	17.4	5.2	3	0	1.9	6	2.5	1.6	3	20.2	2.3	0	2.3	1.6	3.2	4.5	9.3
2. Coal																				
Exploration	3.4	1.3	2.4	2.6	0	0	0	9.7	2.6	0	0	0.6	2.4	0	0.5	1	7.1	0	0	0	1.6	2.1	1.1	4.8
Extraction	3.4	2.6	2.4	2.6	.5	.75	0	12.25	4	0	0	1.3	2.4	0	1.1	1	9.8	2.3	3.7	6.0	1.6	2.1	0	3.7
Production	3.4	0	2.4	2.6	.5	.75	0	9.65	5.2	0	0	1.9	2.4	0	1.6	1	12.1	2.3	1.2	3.5	2.5	3.2	3.4	9.1
Transportation	1.1	0	2.4	2.6	.5	.75	0	7.35	4	0	0	0.6	2.4	0	0.5	1	8.5	0.8	0	0.8	0	0	0	0
Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Use	3.4	0	2.4	2.6	.5	1.5	0	10.4	5.2	3	0	1.3	2.4	0	1.1	2	15.0	2.3	0	2.3	2.5	3.2	3.4	9.1
3. Nuclear energy																				
Exploration	1.1	0	0	0	0	0	.75	1.85	1.3	0	0	0	3.6	0	0.5	0	5.4	2.3	0	2.3	0	0	0	0
Extraction/exploitation	3.4	0	0	0	0	0	.75	4.15	1.3	0	0	0	3.6	0	0.5	0	5.4	2.3	0	2.3	0	0	0	0
Production	4.5	0	1.2	4	2	.75	.75	13.2	5.2	3	0	1.9	3.6	0	1.1	1	15.8	2.3	0	2.3	4.1	5.4	5.6	15.1
Transportation	4.5	0	4.8	4	1.6	.75	.75	16.4	4	0	0	0	3.6	0	0	0	7.6	3.9	0	3.9	4.1	5.4	5.6	15.1
Storage	4.5	0	4.8	4	2.7	.75	.75	17.5	4	0	0	0.6	3.6	0	0.5	1	9.7	3.9	0	3.9	4.1	5.4	5.6	15.1
Use	1.1	0	0	.4	.5	.75	.75	7.1	1.3	0	0	0.6	3.6	0	0.5	1	7.0	2.3	2.5	4.8	2.5	5.4	5.6	13.5
4. Hydroelectric energy																				
Exploitation	1.1	0	0	0	1.6	0	2.2	4.9	5.2	0	0	0	3.6	0	1.1	0	9.9	3	3.7	6.7	0	0	2.2	2.2
Production	2.3	0	0	0	2	0	2.2	6.5	5.2	0	0	0	3.6	0	1.6	0	10.4	2.3	3.7	6.0	0	0	3.4	3.4
Transportation	2.3	0	1.2	1.3	2	0	2.2	9.0	5.2	0	0	0	3.6	0	0.5	0	9.3	1.5	2.5	4.0	1.6	2.1	3.4	7.1
Use	2.3	0	2.4	2.6	1	0	0	8.3	5.2	3	3.1	1.3	3.6	0	1.1	0	14.3	0.8	3.7	4.5	0.8	2.1	3.4	6.3
5. New and revived energy sources	3.4	0	1.2	1.3	1	1.5	2.2	10.6	1.3	0	0	0	0	0	2.2	2	5.5	2.3	3.7	6.0	4.1	5.4	5.6	15.1
6. Conservation																				
Construction	4.5	0	0	2.6	1.6	1.5	0	10.2	1.3	0	1.5	0	1.2	0	0.5	1	6.5	0.8	1.2	2.0	0.8	0	1.1	1.9
Transportation	4.5	0	0	2.6	1.6	1.5	.75	10.9	1.3	0	1.5	0	1.2	0	0.5	1	6.5	0.8	1.2	2.0	0.8	0	1.1	1.9
Industry	4.5	0	0	2.6	1.6	1.5	0	10.2	1.3	0	1.5	0	1.2	0	0.5	0	5.5	0.8	1.2	2.0	0.8	0	1.1	1.9
PROTECTION OF THE ENVIRONMENT																				
1. Wastes	3.4	0	3.6	5.3	2	2.2	.75	17.2	5.2	0	0	0	0	0	1.6	0	6.8	3.9	4.9	8.8	4.1	5.4	4.5	14.0
2. Water	4.5	0	3.6	5.3	2	3	2.2	20.6	5.2	0	0	0	0	0	1.6	1	7.8	3.9	4.9	8.8	4.1	5.4	4.5	14.0
3. Air	4.5	0	3.6	5.3	2	3	2.2	20.6	5.2	0	0	0	0	0	1.6	2	8.8	3.9	4.9	8.8	4.1	5.4	4.5	14.0
4. Soil	2.3	0	2.4	5.3	2	2.2	2.2	16.4	4	0	0	0	0	0	1.6	2	7.6	3.9	4.9	8.8	4.1	5.4	4.5	14.0
5. Noise	1.1	0	0	0	.5	0	0	1.6	1.3	0	0	0	0	0	0	0	1.3	0.8	4.9	5.7	2.9	5.4	4.5	12.8
6. Natural disasters	1.1	0	4.8	1.3	1	2.2	2.2	12.6	2.6	0	0	0	0	0	1.1	0	3.7	3	1.2	4.2	4.1	5.4	4.5	14.0
NATURAL RESOURCES MANAGEMENT																				
1. Ecosystems and ecodistricts	1.1	0	3.6	2.6	.5	1.5	1.5	10.8	0	0	0	0	0	0	0.5	1	1.5	3.9	4.9	8.8	4.1	5.4	0	9.5
2. Climate	1.1	0	1.2	2.6	.5	1.5	.75	7.6	0	0	0	0	0	0	1.1	1	2.1	2.3	1.2	3.5	4.1	5.4	2.2	11.7
3. Water	2.3	0	3.6	2.6	.5	2.2	3	14.2	4	0	0	0	0	0	1.6	1	6.6	3.9	4.9	8.8	4.1	5.4	0	9.5
4. Forests																				
Protection	3.4	4	3.6	4	1	1.5	2.2	19.7	4	0	0	1.3	3.6	0	1.6	3	13.5	3.9	4.9	8.8	3.3	5.4	3.4	12.1
Development	3.4	4	3.6	4	1	1.5	2.2	19.7	4	3	4.7	1.3	3.6	0	1.6	3	21.2	3.9	4.9	8.8	2.5	5.4	3.4	11.3
Use of forest biomass	3.4	4	3.6	4	1	1.5	2.2	19.7	4	3	0	1.3	3.6	0	1.6	3	16.5	3.9	4.9	8.8	3.3	5.4	3.4	12.1
Knowledge of the forest	3.4	4	3.6	4	1	1.5	2.2	19.7	4	0	0	1.3	3.6	0	1.6	3	13.5	3.9	4.9	8.8	4.1	5.4	1.1	10.6
5. Fisheries																				
Inventory of resources	3.4	5.2	4.8	4	1.6	1.5	.75	21.2	4	1	4.7	1.9	2.4	0	1.6	4	19.6	0.8	3.7	4.5	2.5	5.4	3.4	11.3
Species behavior	3.4	5.2	4.8	4	1.6	1.5	.75	21.2	4	0	4.7	1.9	2.4	0	1.6	4	18.6	2.3	3.7	6.0	2.5	5.4	3.4	11.3
Development	3.4	5.2	4.8	4	1.6	1.5	.75	21.2	4	2	4.7	1.9	2.4	0	1.6	4	20.6	0.8	3.7	4.5	3.3	5.4	3.4	12.1
Protection	3.4	5.2	4.8	4	1.6	1.5	.75	21.2	4	0	4.7	1.9	2.4	0	1.6	4	18.6	0.8	3.7	4.5	3.3	5.4	3.4	12.1
6. Minerals																				
Location and evaluation of resources	1.1	0	2.4	4	1	.75	2.2	11.4	4	0	4.7	0	2.4	0.8	1.1	1	14.0	0	0	0	0.8	1.1	3.4	5.3
Extraction and exploitation	1.1	0	2.4	4	1	.75	2.2	11.4	4	0	4.7	1.3	2.4	0.8	1.1	1	15.3	1.5	1.2	2.7	0.8	1.1	3.4	5.3
Processing	1.1	0	2.4	4	1	.75	2.2	11.4	4	3	4.7	1.3	2.4	0.8	1.1	1	18.3	1.5	1.2	2.7	0.8	1.1	3.4	5.3
7. Plant and animal life	0	0	1.2	2.6	.5	.75	2.2	7.2	0	0	0	0	0	0	0	0	0	3.9	4.9	8.8	4.1	5.4	0	9.5
AGRICULTURE AND FOOD																				
1. Development of food sources	3.4	4	3.6	4	2	1.5	3.8	22.3	1.3	3	0	0	3.6	0	2.2	3	13.1	0.8	4.9	5.7	3.3	5.4	2.2	10.9
2. Nutrition	3.4	0	1.2	5.3	2	1.5	3.8	17.2	1.3	3	0	1.3	1.2	0	2.2	2	11.0	0.8	4.9	5.7	4.1	5.4	3.4	12.9
3. Development and improvement of production	3.4	4	3.6	4	2	.75	3.8	21.5	1.3	3	3.1	1.3	3.6	0	2.2	4	18.5	2.3	4.9	7.2	4.1	5.4	3.4	12.9
4. Processing, distribution and marketing	2.3	1.3	1.2	2.6	1.6	.75	3.8	13.5	1.3	2	4.7	1.3	3.6	1.7	2.2	4	20.8	0	4.9	4.9	1.6	2.1	4.5	8.2
SPACE																				
1. Satellites -	3.4	4	1.2	4	2	2.2	1.5	18.3	4	0	0	1.3	2.4	1.7	1.6	1	12.0	3	4.9	7.9	4.1	5.4	5.6	15.1
2. Related technological developments	3.4	4	1.2	4	2	2.2	0	16.8	4	1	0	0	2.4	1.7	0.5	0	9.6	0	1.2	1.2	4.1	5.4	5.6	15.1
3. Space sciences	3.4	4	1.2	4	2	2.2	0	16.8	1.3	0	0	0	0	1.7	0.5	0	3.5	2.3	1.2	3.5	4.1	5.4	5.6	15.1
COMMUNICATIONS																				
1. Technological developments	3.4	4	2.4	5.3	2	1.5	.75	19.3	5.2	3	6.2	1.9	4.8	2.5	0	2	25.6	0	4.9	4.9	4.1	5.4	5.6	15.1
2. Socio-economic impact	4.5	0	3.6	5.3	1	.75	2.2	17.3	4	0	6.2	1.3	1.2	1.7	0	0	14.4	0	6.2	6.2	4.1	5.4	5.6	15.1
TRANSPORT																				
1. Air transport	3.4	2.6	1.2	4	2	2.2	.75	16.1	5.2	4	0	0.6	3.6	2.5	0	3	18.9	2.3	3.7	6.0	2.5	3.2	5.6	11.3
2. Marine transport	2.3	4	1.2	2.6	1.6	1.5	.75	13.9	5.2	4	0	0.6	1.2	0.8	1.6	4	17.4	3	3.7	6.7	2.5	3.2	3.4	9.1
3. Rail transport	3.4	1.3	3.6	4	2	.75	.75	15.8	5.2	4	0	2.5	3.6	2.5	1.1	2	20.9	3	4.9	7.9	1.6	3.2	3.4	8.2
4. Road transport	2.3	1.3	3.6	1.3	.5	0	.75	9.7	5.2	4	0	2.5	3.6	2.5	1.1	3	21.9	3	4.9	7.9	0	0	3.4	3.4
5. Pipelines	3.4	4	2.4	2.6	1	.75	.75	14.9	5.2	3	0	2.5	2.4	2.5	1.6	4	21.2	3	1.2	4.2	1.6	2.1	3.4	7.1
CONSTRUCTION AND HOUSING																				
1. Design and use of buildings	1.1	0	0	4	1.6	1.5	1.5	9.7	4	4	3.1	0	3.6	0	0	0	14.7	0	4.9	4.9	0	3.2	2.2	5.4
2. Building structures	1.1	0	0	4	1.6	1.5	1.5	9.7	5.2	4	3.1	0	3.6	0	0	0	15.9	0	4.9	4.9	0	2.1	1.1	3.2
3. Materials	1.1	0	0	4	1.6	1.5	1.5	9.7	5.2	3	3.1	0	3.6	0	0	0	14.9	0	3.7	3.7	0.8	1.1	1.1	3.0
4. Energy conservation	2.3	0	0	4	1.6	1.5	1.5	10.9	4	2	1.5	0	1.2	0	0	0	8.7	2.3	3.7	6.0	0	2.1	1.1	3.2
5. Noise, fire, vibrations	2.3	0	0	4	1.6	1.5	1.5	10.9	2.6	2	0	0	1.2	0	0	0	5.8	1.5	6.2	7.7	0.8	2.1	1.1	4.0
MANUFACTURING INDUSTRIES																				
1. Food and other agricultural products	2.3	2.6	3.6	4	1.6	0	0	14.1	4	4	6.2	1.9	3.6	0	0	0	19.7	0	4.9	4.9	0	2.1	4.5	6.6
2. Plastics	2.3	0	1.2	1.3	0	0	0	4.8	5.2	4	6.2	1.9	3.6	0	0	0	20.9	0	1.2	1.2	0	2.1	4.5	6.6
3. Rubber products industries	1.1	0	0	0	0	0	0	1.1	1.3	4	6.2	1.3	0	0	0	0	12.8	0	1.2	1.2	0	2.1	2.2	4.3
4. Textiles and leather	3.4	0	3.6	4	0	0	0	11.0	4	4	6.2	2.5	1.2	0	0	0	17.9	0	2.5	2.5	0	2.1	3.4	5.5
5. Metal industries	3.4	0	3.6	4	0	0	0	11.0	5.2	4	6.2	1.9	3.6	0	0	0	20.9	0	2.5	2.5	0	2.1	3.4	5.5
6. Non-electrical machinery	3.4	0	0	0	0	0	0	3.4	5.2	4	6.2	1.3	1.2	0	0	0	17.9	0	3.7	3.7	0	2.1	3.4	5.5
7. Transportation equipment	3.4	2.6	3.6	4	1.6	0	0	15.2	5.2	4	6.2	2.5	4.8	0	0	0	22.7	0	4.9	4.9	0	2.1	4.5	6.6
8. Electrical and electronic products	3.4	0	3.6	4	1.6	0	0	12.6	5.2	4	6.2	1.9	4.8	0	0	0	22.1	0	4.9	4.9	1.6	2.1	5.6	9.3
9. Non-metalic minerals	1.1	0	0	0	0	0	0	1.1	2.6	4	6.2	1.3	1.2	0	0	0	15.3	0	1.2	1.2	0	2.1	3.4	5.5
10. Chemical industries	3.4	0	0	4	0	0	0	7.4	5.2	4	6.2	2.5	4.8	0	0	0	22.7	0	3.7	3.7	1.6	2.1	4.5	8.2
11. Others	1.1	0	0	0	0	0	0	1.1	2.6	4	6.2	1.3	2.4	0	0	0	16.5	0	3.7	3.7	0	2.1	3.4	5.5
COMMUNICATION INDUSTRIES																				
1. Telecommunications broadcasting	3.4	0	0	4	1.6	1.5	2.2	12.7	1.3	4	1.5	0.6	2.4	0	0	0	9.8	0	4.9	4.9	1.6	3.2	4.5	9.3
2. Telecommunication carriers	3.4	1.3	0	4	1.6	1.5	1.5	13.3	1.3	4	1.5	0.6	0	0	0	0	7.4	0	4.9	4.9	0	3.2	4.5	7.7
CONSTRUCTION INDUSTRIES																				
1. Industrial construction and engineering	3.4	0	1.2	4	.5	0	2.2	11.3	5.2	3	6.2	0	3.6	0	0	0	18.0	0	1.2	1.2	0	2.1	1.1	3.2
2. Services	3.4	0	1.2	4	.5	0	2.2	11.3	5.2	3	6.2	0	3.6	0	0	0	18.0	1.5	1.2	2.7	0	4.3	1.1	5.4
	POLITICAL							Total	ECONOMIC								Total	SOCIAL			Total	S & T		Total

Appendix VI

Ranking of research fields accroding to their relative priority

Fields	Score obtained out of a maximum possible of 100
1. Communications - technological developments	64.9
2. Forests development	61.0
3. Agriculture & food - development and improvement of production	60.1
4. Development of fisheries	58.4
5. Use of forest biomass	57.1
6. Fisheries - species behavior	57.1
7. Fisheries - inventory of resources	56.6
8. Fisheries - protection of resources	56.4
9. Hydrocarbons - exploitation	56.2
10. Production of hydrocarbons	54.7
11. Forests protection	54.1
12. Hydrocarbons - exploration	53.6
13. Satellites	53.3
14. Communication - socio-economic impact	53.0
15. Rail transport	52.8
16. Knowledge of the forest	52.6
17. Transportation of hydrocarbons	52.6
18. Air transport	52.3
19. Protection of the environment - air	52.2
20. Development of food sources	52.0
21. Protection of the environment - water	51.2
22. Transportation equipment industry	49.4
23. Use of hydrocarbons	49.2
24. Electrical and electronic products industry	48.9

Fields		Score obtained out of a maximum possible of 100
25.	Transport - pipelines	47.4
26.	Processing, distribution and marketing of agricultural products	47.4
27.	Marine transport	47.1
28.	Protection of the environment - water	46.8
29.	Protection of the environment - soil	46.8
30.	Nutrition	46.8
31.	Nuclear energy production	46.4
32.	Radio active waste storage	46.2
33.	Storage of hydrocarbons	45.5
34.	Food and other agricultural products industry	45.3
35.	Transportation of nuclear energy	43.0
36.	Road transport	42.9
37.	Space - related technological developments	42.7
38.	Chemical industries	42.0
39.	Metal industries	39.9
40.	Management of natural resources - water	39.1
41.	Space sciences	38.9
42.	Minerals - processing	37.7
43.	Services in construction industries	37.4
44.	New and revived energy sources	37.2
45.	Textiles and leather industries	36.9
46.	Use of coal	36.8
47.	Telecommunications broadcasting	36.7
48.	Extraction and exploitation of minerals	34.7
49.	Design and use of buildings	34.7
50.	Protection of the environment - natural disasters	34.5
51.	Coal production	34.3
52.	Building structures	33.7
53.	Industrial construction and engineering	33.7
54.	Plastics industries	33.5
55.	Use of hydroelectric energy	33.4

Fields	Score obtained out of a maximum possible of 100
56. Tele communications carriers	33.3
57. Use of nuclear energy	32.4
58. Coal extraction	31.7
59. Construction and housing-materials	31.3
60. Minerals - localisation and evaluation of resources	30.7
61. Eco-systems and eco-districts - knowledge & management	30.6
62. Non-electrical machinery industry	30.5
63. Hydroelectric energy transportation	29.4
64. Construction and housing - energy conservation	28.8
65. Construction and housing - noise, fire, vibrations	28.4
66. Miscellaneous manufacturing industries	26.8
67. Hydroelectric energy production	26.3
68. Plant and animal life	25.5
69. Climate management	24.9
70. Hydroelectric energy exploitation	23.7
71. Non-metallic minerals industries	23.1
72. Coal exploration	21.6
73. Energy conservation in transport	21.3
74. Protection of the environment - noise	21.0
75. Energy conservation in construction	20.6
76. Energy conservation in industry	19.6
77. Rubber industry	19.4
78. Coal transportation	16.6
79. Uranium extraction and exploitation	11.8
80. Uranium exploration	9.5
81. Coal storage	0