MEASUREMENT OF STOCKS OF S&T PERSONNEL IN CANADA

MINISTRY OF STATE FOR
SCIENCE AND TECHNOLOGY

SEPTEMBER, 1981

Prepared for OECD Workshop on Measurement of Stocks of Scientific and Technical Personnel, Paris, 12 to 13 October, 1981.

TABLE OF CONTENTS

I INTRODUCTION

S&T personnel are of strategic importance to the country. These are the persons who are essential to economic development, industrial production, education, defense, communication, health, and so on. In the 1980s and 90s, adequate supplies of S&T manpower will become even more important as the pace of technological change accelerates due to priorities and imperatives in energy, transportation, communication, biotechnology, etc. The Ministry of State for Science and Technology (MOSST) is keenly aware of the needs and developing trends in the requirements for S&T manpower. A number of background papers have been published by MOSST covering various issues concerning the training and needs for S&T manpower, and a list is contained in Appendix I.

There are two basic methods or approaches to defining the stock of S&T personnel. Conceptually, one could define the stock in terms of the number of persons who are employed or seeking work in S&T jobs, regardless of educational qualifications. This is an occupationally-based definition providing a measure of the number of economically active scientists and technologists.

.../2

Alternatively, one could define the stock of S&T personnel in terms of educational characteristics. For example, those persons who have at least a college diploma or certificate in fields of science and technology could be defined as scientists and technologists irrespective of their labour force activity. This latter approach is a "capacity" or education-based definition providing an index of the scientific personnel capability residing in the country.

Neither of these conceptual definitions is, in our view, by itself capable of providing an adequate index of the stock of science and technology manpower. Educational attainment provides a method to identify the potential capacity or capability of the S&T personnel, whereas occupation or job function provides an index of the use and deployment of such manpower.

The issue of determining national S&T stocks tends to get clouded unnecessarily by these conceptual difficulties. Of importance in the collection of S&T manpower data is not so much the attainment of a total stock estimate per se but the provision of relevant policy-related information on

.../3

the attributes of this resource base. The usefulness of the S&T stock data, regardless of the scope of the definition, depends on the following types of criteria:

- consistency over time
- compatibility with other information classification systems (e.g. education, immigration, graduate surveys, industrial classifications, etc.)
- characteristics, attributes and deployment of the stock (e.g. by sex, age, industry of employment, occupation, education, job-function, etc.)

In short, of importance in the collection of S&T manpower data are the parameters or attributes of the stock and how it interfaces with educational, industrial and science policy.

An essential element in the development of statistics on science personnel is the formulation of a workable definition of S&T manpower, and one approach to this is given in the next section. The third section of this note describes the various methods of collecting S&T manpower data, and the final section provides some general comments on Canada's S&T manpower data bases, and the challenges that lie ahead.

.../4

II AN APPROACH TO THE OCCUPATIONAL DEFINITION OF S&T MANPOWER

Most of the developmental work on occupational definitions is based on the Canadian Classification and Dictionary of Occupations (CCDO) and the 1971 Occupational Classification Manual (OCM)[(1)]

The CCDO structure encompasses 23 major groups (specified by a 2-digit code) which are the highest level of aggregation of occupations and represent broad fields of work rather than specific types of work performed. These major groups are sub-divided into 81 minor groups (designated by a 3-digit code) which are in turn disaggregated into 498 unit groups (represented by a 4-digit code). The narrowest categories specified in the CCDO classification system are the individual occupations; they are listed by a 7-digit code and encompass over 25,000 occupational titles.

---

(1) Although Statistics Canada has provided data on occupations via the census mechanism since 1931, the CCDO represents the first attempt to define the qualifications required for each occupational group. For an excellent summary of the intercensal occupational definitions, see "Establishing Comparable Census Occupations for Historical Comparisons of Earnings and Other Data" by N.H. Meltz and D.A.A. Stager, Centre for Industrial Relations, University of Toronto, August 12, 1976.

A unique feature of this classification system which distinguishes it from previous census classifications is the delineation of the educational and vocational training required within each 7-digit occupational group. In particular, the descriptions of each of the 7-digit occupations also include indices of their requirements in the form of "General Educational Development" (GED) and "Specific Vocational Preparation" (SVP). These indices help define those occupational groups which require a university degree.

Each 7-digit occupation is assigned a General Educational Development index (GED) which "...embraces those aspects of education (formal and informal) which contribute to the worker's (a) reasoning development and ability to follow instructions, and (b) acquisition of 'tool' knowledges, such as mathematical and language skills. GED refers to education of a general nature which does not have a recognized, specific occupational objective. Ordinarily, such education is obtained in elementary school, high school, or college; however it is derived also from experience and self-study".[2]

(2) Department of Manpower and Immigration, Canadian Classification and Dictionary of Occupations, (henceforth referred to as the CCDO), Vol. 1, Appendix A, p. 1161. For a discussion concerning reading, mathematical and language requirements see P. 1162.

An interpretation of GED levels in terms of years of schooling is shown in Table 1.

TABLE 1

LEVELS OF GENERAL EDUCATIONAL DEVELOPMENT, CCDO

Levels	Approximate Duration of Schooling
6	17 years plus
5	13 to 16 years
4	11 to 12 years
3	9 to 10 years
2	7 to 8 years

Source: Department of Manpower and Immigration, CCDO, Vol. 2, p. XV.

The Specific Vocational Preparation (SVP) index pertaining to each occupation is: "...measured by the amount of time needed to acquire the information, techniques, and skills needed for average work performance in a specific occupation. This training may be acquired in a school, work, military, or institutional environment, or through vocationally-oriented hobbies. It does not include orientation training required of a worker to become accustomed to the special conditions of a new job for which he is already fully qualified".(3) The various levels of SVP are shown in Table 2.

(3) Department of Manpower and Immigration, CCDO, Vol. 1 p. 1163.

TABLE 2

LEVELS OF SPECIFIC VOCATIONAL PREPARATION - CCDO

Level	Period of Preparation
1	Short demonstration only
2	Anything beyond short demonstration up to and including 30 days
3	Over 30 days up to and including 3 months
4	Over 3 months up to and including 6 months
5	Over 6 months up to and including 1 year
6	Over 1 year up to and including 2 years
7	Over 2 years up to and including 4 years
8	Over 4 years up to and including 10 years
9	Over 10 years

SOURCE: Department of Manpower and Immigration, CCDO, Vol. 1, Appendix A, Sec. II, p. 1163.

.../8

MOSST has used the CCDO and the GED/SVP indices for defining a highly qualified manpower (HQM) occupation. An HQM job is defined as that which requires at least two years post-secondary education, i.e. an average GED/SVP index of 12 or more. These occupations are shown in Table 3. It should be noted as well that the occupations are classified such that the data can be linked with information on both employment by industry and educational qualifications.

Although MOSST developed this classification schema for its work on HQM, it may be useful for those who wish to classify S&T jobs (see Table 3). As was pointed out, the occupation categories take account of educational requirements (GED) and specific vocational preparation (SVP) indexes of groupings of individual job titles. For example, the "health" grouping includes the traditional professions such as dentistry and medicine as well as other jobs with a large scientific and technological knowledge component, such as nursing. The classification scheme could be further disaggregated down to the 7-digit job title level, if more precision is required, but for most national statistics purposes this would entail great expense in coding survey responses, etc.

One of the issues to be considered is the extent to which S&T jobs are included in the Table 3 schema. This listing includes occupations that are clearly S&T in character, such as engineering and the physical and life sciences. It also includes jobs which have a close relationship to science and technology, but for certain purposes may not be included in S&T stock statistics. These would include education, humanities, commerce and administration and the social sciences. As well, the schema in Table 3 does not elaborate on the technical and technological (with GED/SVP numbers lower than those of HQM) jobs which are included in the OCM code numbers, although these titles could be broken out for categorization.

Clearly, having a specific purpose in mind in collecting S&T stock data provides guidance on the scope of the jobs to be included. MOSST has taken the view that the crucial factor in defining the scope of the S&T occupational universe is the training times required to prepare people for a job. The HQM list, therefore, includes only those job titles that require two or more years of post-secondary education; most of the job groupings require, in fact, a university degree. We believe that training time is the main factor to be taken into account because jobs which require long preparation times also involve

.../10

considerable costs to the person and to the educational system. These jobs, if not filled by qualified persons, could result in lost opportunities and bottle-necks in economic and social development. Conversely, oversupply conditions represent misallocations of resources in an economic sense. Technical occupations which require training times of less than two years are equally important but do not require the same degree of long term human resources planning as HQM.

MOSST has found the occupational framework related to HQM to be a useful one because it is flexible, adaptable and clear in terms of its content. This system has been used to organize stock data from the 1971 census and employment data from surveys of university graduates. It will be used to aggregate occupational data from the 1981 census as well. The interest of the Ministry encompasses the whole spectrum of HQM occupations, including the human and natural sciences, as these relate to economic and social development. Although a more narrowly defined grouping of S&T occupations might be restricted to the jobs in natural sciences and engineering, the human sciences are instrumental from a social development perspective and are especially relevant to society's ability to accommodate technological change.

.../11

TABLE 3

HQM PROJECTION MODEL - CLASSIFICATION OF HQM OCCUPATIONS

MAJOR GROUP	OCM NUMBER	OCCUPATION
Health	3113	Dentistry
	3111	Medicine
	3151	Pharmacy
	3130-31	Nursing
	3137	Rehabilitation Therapy
	1134	Health Administration
	3117-19-53	Other HQM Health
Engineering	2141	Architecture
	2142	Chemical Engineering
	2143	Civil Engineering
	2144	Electrical Engineering
	2147	Mechanical Engineering
	2151	Metallurgical Engineering
	2155	Aeronautical Engineering
	2153	Mining Engineering
	2154	Petroleum Engineering
	2145	Industrial Engineering
	2157-59	Engineering n.e.s.
Life Sciences	3115	Veterinary Medicine
	3152	Dietetics and Nutrition
	2131	Agriculture and Related
	2133	Biology and Related
Physical Sciences and Mathematics	2112	Geology
	2114	Meteorology
	2111	Chemistry
	2113	Physics
	2181-89	Mathematics
	2183	Computer Sciences
Humanities and Fine Arts	2511-13-19	Religion
	2350-51	Library and Archival
	3355	Translation
	3311-13-14-30-32-33-52	Other HQM Humanities and Fine Arts
Education	2711	University Teaching:
		Dentistry
		Medicine
		Pharmacy
		Nursing
		Rehab. Therapy
		Health Adm. & Other
		Medical Research
		Architecture
		Chemical Engineering

.../12

TABLE 3 (cont'd)

HQM PROJECTION MODEL - CLASSIFICATION OF HQM OCCUPATIONS

MAJOR GROUP	OCM NUMBER	OCCUPATION
Education (cont'd)		Civil Engineering
		Electrical Engineering
		Mech., Aero. Engineering
		Metall. Engineering
		Mine., Geol. Engineering
		Indust. & Other Engineering
		Agric. Engineering
		Veterinary Medicine
		Dietetics
		Agriculture
		Forestry
		Biochemistry
		Biology
		Botany
		Zoology
		Household Sci.
		Agric., Bio. Sci.
		Geol., Meteor., Ocean.
		Chemistry
		Physics
		Mathematics
		Computer Sciences
		Metallurgy
		Other Math., Phys.
		Theology
		Library, Archiv.
		Translation
		Fine, Applied Arts
		History
		English
		French
		Mod. Languages
		Classics, Philos.
		Other Humanities
		Secondary School Teaching
		Elementary School Teaching
		Education Admin.
		Counselling
		Special Education
		Other Teaching
		Educ. Psychology
		Other Non-teaching Ed.
		Education, Other
		Law
		Accounting
		Commerce, Admin.
		Social Work
		Clinical Psych.

.../13

TABLE 3 (concl'd)

HQM PROJECTION MODEL - CLASSIFICATION OF HQM OCCUPATIONS

MAJOR GROUP	OCM NUMBER	OCCUPATION
Education (cont'd)		Psychology (Other) Economics Anthrop., Archaeol. Geography, Env. Stud. Pol. Sci. Sociol., Demog., Crimin. Linguistics Other Soc. Sciences
	2731	Elementary and Preschool
	2733	Secondary School
	2791	Community College Teaching
	2719-39-92 93-95 and 2391 and 1133	Other HQM Education
Law	2341-43	Law
Commerce, Administration and Government	1111-13-15-16-19 6116	Government Officials and Administrators Commissioned Officers
	1130-31-32-35 36-37-41-42-43-45-47-49	General Administration
	1174-75-76-79	Related Management Occupations
	1171	Accounting
	5131	Technical Sales
	5170	Supervising - Sales and Services
	5173	Sales, Securities
	7131	Farm Management
Social Sciences	2331-99	Social Work
	2315	Psychology
	2311	Economics
	2313	Sociology, Anthropology and Related
	2319	Other Social Sciences and Related n.e.s.

.../14

III APPROACHES TO THE COLLECTION OF S&T DATA

A number of sources are available from which S&T manpower information can be collected. Generally these can be divided into three broad categories: administrative records, household surveys and establishment surveys. A review of each approach is contained below.

(1) Administrative Records

Based on administrative records, professional associations and institutions have the potential to report on their membership and staff in considerable detail, including occupation, education, industry of employment, job function, etc. In Canada, two major administrative files of S&T personnel include the university teacher file compiled by Statistics Canada and the engineering manpower inventory being developed by the Canadian Council of Professional Engineers.

The University and College Academic Staff System (UCASS) is a computerized data base at Statistics Canada. This data resource has been in operation since the early 1970s and contains extensive individual profile records on all full-time university teachers in Canada. All degree-granting institutions have agreed to report to Statistics

Canada on their full-time teaching staff each year by about mid-October using either computer tapes, punched cards or paper copy printouts. The records for each member are presented in a consistent format and use a coding system that is described in a standard coding manual. Individual records are assured confidentiality by the reporting university through the use of permament file membership numbers that are unique to the individual and assigned by the institution. No names or addresses of faculty members are reported.

For each member of the teaching staff, such details as the following are reported:

- institution name, and faculty, department
- salary
- leave status
- sex
- year of birth
- year of appointment, termination
- previous employment and location
- year of first degree and location
- year, level, location of highest degree
- citizenship
- rank, position and responsibilities
- principal subject taught

.../16

Teaching staff, for the purposes of the file, include all full-time teachers regardless of rank, academic staff in teaching hospitals and visiting staff in faculties, but exclude administrators, librarians, graduate teaching assistants, postdoctoral fellows and academic staff hired as researchers rather than teachers.

The UCASS file is a valuable information source. Statistical tabulations can be prepared on request using any of the variables in the data base. Examples of useful reports include: faculty age and rank structure by teaching field (retirement analysis); profile of new entrants to teaching; citizenship status by teaching field; and mobility. The data base is used frequently by the institutions, faculty associations and educational authorities. At MOSST, we have made use of faculty age distributions by sex and teaching field in calculating the replacement demand for teaching faculty for future years.

The Canadian Council of Professional Engineers, through their Canadian Engineering Manpower Council (CEMC), have taken a lead role in planning for the establishment of a Canadian engineering manpower inventory based on membership files of the provincial associations.

.../17

This inventory, when established, is expected to bring reliable and detailed information and analysis to discussions of engineering manpower problems in Canada and would serve as a model for similar inventories. Over the long term the objective of the model would be to build a coherent picture of Canada's engineering work force. The short term goals would be to respond to annual "bench mark" questions about the stock of engineers and to provide reliable information on changes in the profile of the profession.

The provincial associations are now in various stages of automating their membership and financial records in EDP machine-readable form. A task force at CEMC developed an overall plan for the organization of the inventory system, the minimum data content to be provided by the member associations, and the reports to be generated from the national data tapes. It is expected that the inventory will be fully operational by 1984.

The data elements to be provided initially by participating associations include:

- surname, initials;
- year, month, day of birth;
- postal code of residence;

.../18

- sex;
- languages of communication (French, English, Other);
- year of registration in provincial association;
- degree(s): year(s), institution(s), field(s) of study;
- whether academic examinations required for registration;
- employer classification;
- occupation;
- work function; and
- current status (e.g. transferred out, deceased, etc.).

Once these initial elements are entered into the information base, other data such as year of immigration and employment status are expected to be added as each provincial association expands its own records. Complete confidentiality is being guaranteed by CEMC and only aggregate tabulations will be released.

Standard national reports would include topics such as:

- total number of engineers;
- age groups of members of the engineering profession;
- years since qualifying degree;
- fields of study of professional engineers;

.../19

- occupations and work functions;
- employer classifications;
- deaths and retirements in past year; and
- male and female professional engineers.

Several other inventories now exist, such as the health manpower inventory (nurses, dentists, doctors), but only the university teachers file and the engineering manpower inventory have the capacity to respond to detailed analyses covering occupation, age, field of study, etc.

It is expected that other professional groups will follow the example of the engineers and university teachers and organize their membership files on a data element basis. Files like these can be electronically processed to report on the current status of the group along any of a number of dimensions (sex, age, etc.) with a high degree of accuracy and flexibility. Once the system is established by the associations, the marginal costs of maintaining it are very reasonable since most inventory changes are captured in connection with financial and mailing list changes. The inventory, therefore, is a relatively inexpensive by-product of automated files that are already required for financial and other purposes. As the costs of computing decline during the 1980s, we expect a large number of professional data bases to emerge in Canada and elsewhere.

.../20

The main challenge is to help make these emerging databases useful beyond the needs of the professional groups themselves. In order to do this, the detail useful for analysis must be captured (eg. age, sex, education, occupation) and the classification systems must be compatible to each other.

If all graduates belonged to some kind of professional group, this method of obtaining occupational stock estimates would be feasible. Unfortunately, only a few fields or professions (medicine, law, engineering, for example) either require membership or have strict criteria for membership. In addition to membership lists being incomplete and not related to definite criteria, lists are often out of date, inaccurate and may exclude immigrants. Even for the few groups, such as medical practitioners and engineers for which membership lists may be up-to-date and accurate, the group may exclude persons who have the required qualifications but are not practicing their professions.

In summary, administrative records can provide an appropriate mechanism to study the characteristics of S&T personnel employed in specific professions, particularly where membership is a requirement. However, a large number of S&T personnel are not required to join a particular association and for these groups it would not be feasible to use this mechanism to obtain total stock estimates.

.../21

(2) Household Surveys

In Canada, the major recent sources of S&T personnel information based on household surveys are census information, the 1973 Post-Censal Survey and graduate employment surveys by Statistics Canada. Each of these are described below.

(a) Census

Census information is one of the major sources of data on S&T personnel. For example, the 1971 Census contained detailed information on the employment, age, sex, sector, ethnicity etc. of scientists and technologists. Canada's 1981 Census will also contain information on these characteristics using classifications that are compatible with the 1971 Census.

One of the major achievements of the 1971 Census was the classification of occupations according to a structure documented in the Canadian Classification and Dictionary of Occupations (CCDO). (As explained in Section II of this report, the CCDO classification system could provide an operational framework for defining an S&T job.)

Despite the fact that the Censuses provide comprehensive estimates of the stocks and attributes of S&T personnel, the usefulness of this source is limited by five main factors. First, a major census is conducted only once every 10 years and thus this information gradually becomes out-of-date during the intercensal period. Secondly, census occupation data are not classified according to work function (eg. R&D, administration, etc.) which means that estimates of R&D manpower cannot be obtained via this mechanism. Third, and perhaps most important, censuses do not contain enough information (due to cost constraints) to estimate the stocks of S&T personnel by educational qualifications. For example, census information will not indicate the number of graduates in engineering who are employed in administration. Thus, estimates of the S&T capacity and utilization cannot be obtained from census data. Fourth, censuses are very expensive to conduct and there is a long delay in releasing the results, despite the use of sophisticated technology. Lastly, there are substantial classification problems in a self-enumerating survey such as a census. Despite great care in wording the questions and in coding the responses, individuals may misreport their occupations, sometimes on a substantial scale as in the case of engineering where the educational qualification and the job have the same name.

(b) The 1973 Highly Qualified Manpower Post-Censal Survey

Although the 1971 Census contained a great deal of information on the employment of S&T personnel, few data were collected on educational qualifications. Without stock data on educational qualifications, educational and manpower planners lacked sufficient information to measure the capacity, utilization and future requirements for S&T manpower.

As a result, the Federal Government conducted the Highly Qualified Manpower Post-Censal Survey in the fall of 1973. Its basic objective was to supplement the 1971 Census data on university graduates in Canada with additional information on types of degrees, fields of study, occupations and career profiles.

The 1973 Highly Qualified Manpower Survey was a sample based on the 1971 Census. In 1971, one third of all households in Canada received the Census "long" form which included questions on the education level of members of the household. The HQM population file was created by extracting from the 1971 Census file the records of those persons who indicated to have a university degree. This frame therefore represented one-third of all degree-holding permanent residents of Canada as of June 1, 1971. Since the survey was linked to the 1971 Census, information available included a wide range of census data such as secondary schooling, immigration status, ethnicity earnings and so on.

.../24

The methodology of the survey consisted of the following main steps:

1. The creation of the HQMS population file by extracting from the 1971 Census sample file all those persons reporting a university degree.
2. Selection of a sample of these persons.
3. Manual identification of selected persons in Census returns and the recording of names and addresses.
4. Mail-out and follow-up operations carried out in Regional Offices.
5. Head Office coding, transcription and data capture.
6. Computer editing, manual correction and imputation.
7. Weighting
8. Tabulation and estimation of standard error.

In all, questionnaires were sent to 137,971 persons. During the survey it became apparent that many of those believed to have at least one university degree did not, in fact, have such a degree. Usable returns were received for 96,066 persons with university degrees, representing 15% of the estimated total population of university graduates.

.../25

These survey data are unique in Canada in that they provide a comprehensive basis for analysing important issues in manpower and education planning. For example, the educational information from the 1973 HQM Survey constitutes an essential element in the MOSST model that was constructed to project the demand for university graduates by field of study. The model estimates occupational demand trends, and calculates the educational implications arising in the process of staffing the required jobs. In particular, estimates are made on the number of university graduates demanded from each of 70 fields of study, at the various degree levels. This permits the manpower estimates to be tied into specific educational policies. Without the HQM Survey, which supplies the information on the likelihood of a particular kind of graduate filling a particular kind of job, this would not be impossible.

(c) Employment Surveys of Graduates

During the 1970s, a number of surveys of recent university graduates were conducted by Statistics Canada for the purposes of identifying the employment status of graduates, the occupations being filled and the industries of employment. A recent example is the new annual PhD Survey which is being conducted in 1981.

.../26

The Federal Granting Councils (which provide graduate training support through research grants and scholarships), Statistics Canada, and the Canadian Association of Graduate Schools, have combined forces to establish an annual survey of doctorate recipients at Canadian universities, starting in 1981. The survey questionnaire is completed by the PhD candidate at the time of fulfillment of the formal requirements for the degree. These questionnaires are collected by the graduate deans and forwarded to Statistics Canada for tabulation and reporting.

The PhD questionnaire collects background information on the graduate (previous degrees, major fields of study, age, sex, citizenship status), data on the PhD research specialization, financial support received from government sources, and extensive information on post-graduation plans. These plans might include the acceptance of postdoctoral fellowships or entry to the labour market on a full-time or part-time basis. For those who plan to take up employment, details are requested on the intended occupation, salary, the major activities of the job (eg. research, teaching, management, consulting), the geographic location of employment;

.../27

industry of employment, etc. Additional information is captured on those candidates who plan to leave Canada in order to determine the reasons for this departure (eg. better job offer or foreign student status, etc.).

It was determined from previous graduate surveys that had been conducted during the 1970s, that the post-graduation employment plans of PhD graduates were clear and precise at the time of graduation and reasonably stable in the sense that most of the graduates were in the same occupation two years after graduation as at the time of graduation. This was not true of first and second cycle graduates who tended to undergo a prolonged period of job-search and mobility for at least two years after graduation.

The annual PhD Survey presents an opportunity to build up a valuable data base on research-trained manpower and to monitor the deployment of highly educated personnel. As well, the survey results will be published in aggregate form each year, and this information should be useful to

.../28

undergraduates in planning their educational programs and to government in targetting graduate training support. However, although graduate surveys such as this provide data on the flow into the stocks of S&T manpower, no information can be obtained on the size or characteristics of the stocks as such, or on the mobility and outflows from the S&T stocks. Graduate surveys are useful as a monitoring device in connection with educational policy and manpower planning, but they provide only one part of the total picture.

(3) Establishment Surveys

Establishment surveys are those in which the firm or institution is questioned as to the characteristics of its work force. Surveys of this nature have been particularly useful in defining the features of that segment of the S&T personnel which perform the R&D function. The major surveys of R&D performers are described below.

.../29

(a) Federal Government Sector

Federal R&D scientific manpower estimates are based on establishment surveys conducted cooperatively by Statistics Canada and MOSST in conjunction with the Treasury Board budgetary estimates process. These surveys employ science addenda questionnaires, which are completed by government departments and agencies at the same time as total expenditure data are gathered. MOSST publishes details of the federal science surveys annually in Federal Science Expenditures and Personnel.

The S&T manpower data for the federal service are reported on the basis of the Public Service Commission bargaining group categories rather than the traditional R&D classifications used by Statistics Canada. Statistics Canada states that this presents only minor problems for international comparisons[4]. Table 5 shows the number of federal R&D personnel by year from 1975-76 to 1978-79 based on the federal science surveys of 1977, 1978 and 1979.

[4] Statistics Canada, Federal Government Activities in the Natural Sciences, 1974-76, Cat. No. 13-202, P. 36.

TABLE 5

FEDERAL R&D PERSONNEL
(INTRAMURAL R&D IN THE NATURAL SCIENCES)

CATEGORY	1975-76	1976-77	1977-78	1978-79
	PERSON-YEARS			
Scientists and engineers	5457	5632	5662	5710
Technicians	5098	4854	4810	4745
Other supporting staff	4904	4805	4697	4681
TOTAL	15459	15291	15169	15136

SOURCE: Statistics Canada, Annual Review of Science Statistics - 1979, Cat. No. 13-212.

(b) Industry Sector

Data on industrial S&T manpower have been collected through establishment surveys since 1955 by Statistics Canada from business enterprises, government enterprises and industrial research institutes and associations. Until 1969, the survey was biennial. Since 1969 all known performers of industrial R&D have been surveyed for odd numbered years and

.../31

a sample, including the leading performers, has been surveyed for even numbered years. Personnel estimates are expressed on a full-time equivalent basis and include professionals and supporting staff. Table 6 shows the estimates of S&T manpower in industry based on these establishment surveys.

TABLE 6

INDUSTRY R&D MANPOWER
(R&D IN THE NATURAL SCIENCES)

CATEGORY	1975	1976	1977
	FULL-TIME EQUIVALENT		
Scientists and engineers	8299	8990	9685
Technicians	6592	6900	7198
Other supporting staff	4952	4970	4636
TOTAL	19843	20680	21519

SOURCE: Statistics Canada, Annual Review of Science Statistics, 1979, Cat. No. 13-212.

.../32

(c) Provincial Government Sector

There are two main sources of establishment survey information on provincial government activities in the natural sciences:

Provincial Government Activities in the Natural Sciences; and

Provincial Non-Profit Industrial Research Institutes.

Statistics Canada surveys have been conducted annually on behalf of the participating provinces since 1974 in Nova Scotia, Ontario and Alberta and since 1975 in Saskatchewan[5]. British Columbia was included for the first time in 1977. These surveys collect data on expenditure and manpower and are used as a basis for estimating provincial R&D expenditures for the national GERD statistics. Estimates for Quebec are prepared from reports in the series "Inventaire de la R-D au gouvernement du Québec 1972-1973" and the provincial government expenditure estimates. Quebec is developing an expenditure survey this year in cooperation with Statistics Canada.

---

[5]Nova Scotia no longer participates in these provincial surveys.

.../33

Provincial research institutes are surveyed annually by Statistics Canada and certain statistics are available from 1963. These surveys provide data on expenditures for R&D and the number of scientists employed at the institutes. The personnel data, however, are in terms of numbers of staff but not full-time equivalent man-years.

Estimates of provincial S&T manpower for recent years are shown in Table 7.

TABLE 7

ESTIMATES OF PROVINCIAL R&D PERSONNEL[1]
(NATURAL SCIENCES)

CATEGORY	1975-76	1976-77	1977-78	1978-79
	FULL-TIME EQUIVALENT			
Scientists and engineers	880	965	1010	1020
Technicians	700	750	785	810
Other supporting staff	525	525	670	680
TOTAL	2105	2240	2465	2510

SOURCE: Statistics Canada, Annual Review of Science Statistics, 1979, Cat. No. 13-212.

NOTE: [1] Approximately 30 percent of the total are employees of the provincial research councils and foundations.

Estimates of S&T manpower based on establishment surveys are just that - estimates. The origin of the problem lies in the fact that science and technology activity is rarely the subject of a separate organizational structure and a full-time occupation. The staffing for various programs would be known in some detail, but the proportion of time devoted to R&D, as opposed to administration or operational requirements, is a matter of judgment by the person completing a survey questionnaire. Particularly in large government or industry programs, it is quite difficult to summarize the activities of people in anything like the degree of detail provided by financial reporting systems. The problem is compounded over time if different respondents make different judgments about the allocation of human resources.

In designing establishment surveys, it is important to provide comparability for aggregation purposes. This may be simpler said than done. In Canada, the various surveys had quite different bases of origin. For example, the federal survey of S&T manpower uses a "full-time equivalent" concept whereas data on provincial research institutes relates to total number of staff employed. Note as well that establishment-based survey

.../35

data do not cover the university sector. Estimates of the number of R&D personnel employed in the university sector are based on administrative records (full-time university teachers) rather than survey information. This problem makes it difficult to estimate a total Canada-wide stock estimate of S&T manpower. In practice, it is probable that a considerably larger number of people are involved in R&D than the full-time equivalent data would suggest.

A final problem area lies in the changing and evolving nature of science. Generally, there is not a specific program to fund science as such. In Canada, this problem is illustrated in the area of federal science statistics. The total federal resources expended on science are really an aggregate assembled in the course of conducting the MOSST/Statistics Canada Survey and are based on a departmental review and extraction of programs and sub-programs with a high scientific and technological content from the various programs of the departments and agencies of the Federal Government. Since the composition of the federal science program may change through time, the federal R&D manpower estimates are more volatile than, say, those of operational programs.

.../36

IV CONCLUDING REMARKS

The stock of S&T manpower can be defined on the basis of occupation, education or a combination of both. From a MOSST perspective, the main objective in the collection of S&T personnel statistics is not to develop a stock or population estimate per se but to develop an information base that will characterize the features or attributes of the stock. This base would include aspects such as educational attainment, utilization, flows into and out of the labour market and training requirements.

As in most countries, the Census is the main source of information on the total stock of S&T personnel. This source provides total population counts of S&T personnel based on an "occupational" definition of S&T. Fortunately, the further addition of the 1973 Post-Censal Survey and its corresponding linkages to the Census provided Canada with estimates of S&T personnel based on "education attainment" as well.

Between census years Canada, like most other industrial countries, relies on a number of other data sources and approaches to collect information on the attributes of the stock. There does not appear to be any one particular collection approach which will provide all the information

.../37

required. For example, we have found that the most appropriate method of gathering data on university teachers is through the "administrative" records approach. On the other hand, establishment surveys seem to be most appropriate for collecting information on R&D manpower. The challenge for Canada is to orchestrate and co-ordinate these various approaches and methods so as to provide consistent and comparable definitions of S&T occupational and educational classifications. For example, MOSST has been working closely with the engineering association in the development of their manpower inventory to make sure that their occupational definitions are consistent with the Statistics Canada definitions.

A particular problem that Canada now faces in measuring S&T stocks is the rapid pace in technological change and the corresponding growth in new technologies, such as biotechnology. These developments have created special problems in measuring S&T stocks and, more particularly, estimating future manpower requirements. Canada is facing prospective manpower shortfalls in a number of fields of high technology, engineering, applied life sciences and computer science. In order to base manpower policies on a strong footing, governments are using a number of techniques to gather information on the level of employment by occupation and on future industry needs:

- The Economic Council of Canada conducted a human resources survey in several key industries to better define prospective imbalances by skill level and occupation.

- Canada Manpower and Immigration is entering into industry manpower planning agreements with industrial associations (eg. aerospace, electronics, etc.) to define the current level of employment by occupation and future needs over the medium term.

- A federal task force on biotechnology identified the attributes of S&T manpower needed by this emerging technology, the capacity of the educational system to train and perform research in the field, and proposed an action plan for Canada.

- Provincial governments, especially, are actively engaged in consulting with industries and companies in the high technology fields to work out ways and means of solving S&T manpower shortfalls using local educational resources.

.../39

The high level of interest and the pace of activity in the S&T manpower planning area seems to underline the need to be flexible and, if need be, eclectic in approaching the estimation of S&T stocks and manpower requirements. No one method or system seems capable of meeting the diversity of informational needs in this area.

APPENDIX I