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The Measurement of Scientific and Technical Activities

PROPOSED STANDARD PRACTICE FOR SURVEYS OF RESEARCH AND DEVELOPMENT

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PROPOSED STANDARD PRACTICE FOR SURVEYS OF RESEARCH AND DEVELOPMENT

CONTENTS

24.523

CONTENTS
(Continued)

Abbreviation: "Research and Development" is sometimes abbreviated as "R. and D." in the text and tables.

References: All references are indicated by a number in brackets in the text and listed in numerical order at the end of the draft.

PREFACE

0.1 Resources devoted to R. and D.

Resources devoted to research and development activity have been growing rapidly over the last decade. This is true of all Member countries of the O.E.C.D. for which data are available, and also of such important non-Member countries as the Soviet Union and Japan. Whilst the measures of this activity are still unsatisfactory in some respects, there is no doubt about the fact of this rapid growth. Furthermore, all the indications are that this expansion will continue throughout the 1960s.

As a result, substantial resources are now being devoted to research and development activity in most industrialised countries. Expressed as a ratio R. and D. amount in many cases to more than 1 per cent of the Gross National Product, in the case of the United States of America to about 3 per cent of the Gross National Product. The proportion of national budget expenditures devoted to research and development is considerably higher, as the state is the principal source of finance for research activity in most countries. In the United States of America, in the 1961-1962 financial year, 11 per cent of the Federal Budget Expenditure was for the finance of research and development.

0.2 The Lag in R. and D. Statistics

Following this rapid increase in the scale of R. and D. activity, but lagging somewhat behind it, has come a significant shift in the emphasis of economic thought. Along with increased attention to the problems of economic growth, there has been a rising interest in the economics of research, development and innovation. This change of emphasis is perhaps long overdue. Indeed, Professor Jewkes has pointed out in his study of the Sources of Invention, that it is a mystery that so little attention was given to invention and innovation by economists in the first half of this century(1). Perhaps one of the reasons for this apparent neglect was the almost complete lack of any reliable statistics. As long as no statistics were available, applied economic research was hamstrung, and theoretical economics was confined to rather limited and abstract generalisations. The statistics are still very inadequate. Most countries still devote far more attention to the measurement of the number of chickens they possess, their rate of lay and the price of eggs, than they do to the measurement of the number of research scientists and technicians, their output and their cost. But the picture is beginning to change.

One of the best surveys of research and development which has yet been made was that done in Iceland in 1960. Another excellent survey was carried out in the Netherlands in 1960-1961. These two examples could serve as models for other countries which have been slower in getting to grips with this problem. It is to be hoped that

this manual will serve as an additional spur, for there is an urgent need for these statistics in all countries. The greater the number of countries which conduct surveys, and the longer the time series which are available, the more useful they will become.

0.3 The Need for Standardisation

However, some national surveys differ significantly in scope and methods, and to a lesser extent, in definitions. They differ, for example, in their treatment of the social sciences and humanities, of capital expenditure and depreciation, of patents and licensing, of geological and geographical exploration and survey work, and many other points. These differences make international comparison difficult and have led to an increasing need for some attempt at standardisation, as in the case of other economic statistics, such as foreign trade, industrial production and national income.

The O.E.C.D. has taken an interest in this question for several years. Already in 1957, the Committee for Applied Research of the former European Productivity Agency began to convene meetings for discussion of methodological problems between Member countries. Arising from these meetings an "Ad Hoc" Group of experts was set up under the Committee for Applied Research, specifically to study surveys of Research and Development expenditure. The Technical Secretary of this Group, Drs. J.C. Gerritsen, prepared two detailed case studies on definitions and methods employed in the measurement of R. and D. in the Government Sectors of the United Kingdom and France and later, of the United States and Canada. Other members of the Group assisted in these comparisons and circulated papers describing the methods and results of surveys in their own countries. In 1961, the Directorate for Scientific Affairs took over this part of the work of the European Productivity Agency, and as a result of the experience which had been accumulated, felt that the time was ripe to make specific proposals for standardisation.

It was decided at the meeting of the "Ad Hoc" Group in February 1962 to convene a Study Conference on the Technical problems of R. and D. measurement. In preparation for this Conference the Directorate for Scientific Affairs appointed a consultant, Mr. C. Freeman, to prepare a draft document which was then circulated to Member countries in the Autumn of 1962 and revised in the light of their comments. This Manual was discussed, revised and unanimously accepted by experts from the O.E.C.D. Member countries at a meeting held at Frascati, Italy, from 17th-21st June, 1963.

0.4 Objects of this Manual

It is hoped that this manual will serve two purposes:

(i) As a framework to facilitate international comparisons. National practice will of course continue to vary, but these variations may be gradually reduced, and at least become measureable in terms of an international standard.

The manual takes into account the results of all the national surveys so far available, but the standardised scheme, which it proposes, differs in some respects from all of them. It attempts to incorporate the best features of existing practice but to avoid over-elaboration. There must always be some compromise between what is theoretically most desirable, and what is actually possible in practical terms. This scheme takes into account that many countries are only just embarking on their first surveys, and in some respects it is a deliberate simplification. There will certainly be surveys which go beyond the standard framework in particular detailed fields of investigation. It may be that as international experience accumulates, more elaborate standards can be established. The scheme proposed here provides only for the first stages of serious

international comparison. On the other hand there will also be countries which are unable to make surveys on such an ambitious scale as that envisaged here, or only do so very infrequently. It is to be hoped that this manual will nevertheless provide a framework of reference for such countries, so that their successive surveys may gradually approximate to the scheme proposed here, and will in any case be broadly consistent with it, even if less detailed in many respects.

(ii) As a stimulus to those countries, which have not yet begun work in this field, to start it, and to those who have begun, to continue it more systematically, and on an increased scale.

A start has been made. A majority of the Member countries of the O.E.C.D. have now conducted or are conducting surveys of research and development. Others, which have not hitherto undertaken such surveys, are seriously contemplating this step, and in some cases have requested assistance from the O.E.C.D. One of the reasons for the relatively slow progress is that there are some difficult technical problems to solve. But it is possible to over-estimate these difficulties. They are in fact greatest in large industrialised countries. In the underdeveloped countries and in small countries, the measurement of resources devoted to research and development is simpler and probably more accurate, because this activity is concentrated in a very small number of organisations, all of which can be interviewed.

This manual does not attempt to lay down detailed standards for procedure in carrying out national surveys of R. and D. Whereas principles, definitions, conventions and classification can to some extent be standardised, procedure cannot. The variety of national circumstances is too great to permit the preparation of standard rules of approach to respondents, or of standard questionnaires, or sampling techniques. However in a separate publication, the questionnaires and instructions used in Member countries are being assembled, together with some notes and these will be available as a supplementary aid. Thus the manual should be regarded primarily as an intellectual tool to aid in the preparation of surveys and comparative analysis of their results.

0.5 Acknowledgements

The National Science Foundation deserves great credit for it has pioneered the systematic measurement of R. and D., although this task was probably more difficult in the United States than anywhere else. This manual owes a great deal to the work of the National Science Foundation on the methodology of R. and D. statistics, and in particular to the able summary of this experience by Dr. J. Perlman, in his paper at Cleveland in February, 1962(2). But it is by no means exclusively based on the work done in the United States. The author's own experience on the F.B.I. Survey of research and development in British industry(3) was a fruitful source of ideas; so also were his discussions with statisticians and scientists in several other Member countries; and the earlier work by the O.E.C.D. Committee for Scientific Research, and its predecessor, the Committee for Applied Research and of Dr. E. Rudd of the D.S.I.R. Thanks are due also to the Director of the National Institute for Economic and Social Research for making Mr. Freeman available at short notice and with him the accumulated experience of the Institute in this field. Following the circulation of the first draft of this document many valuable comments and criticisms were received from specialists in Member countries. A particular debt of gratitude is due to the Délégation Générale à la Recherche Scientifique et Technique and especially to M. Guieyess and M. Oger, who devoted a great deal of attention to the improvement of the draft. They are responsible for innumerable small improvements, as well as for a more logical and orderly arrangement of the whole draft,

and in addition they have contributed the whole of Section I on the objectives of R. and D. surveys, and of Appendix IX on criteria to aid in distinguishing the categories of R. and D. Finally a number of very useful improvements were made as a result of the Frascati Working Meeting itself in which all the O.E.C.D. Member countries took part.

SECTION I: THE PRINCIPAL AIMS OF SURVEYS OF RESEARCH AND DEVELOPMENT

1.1 Introduction

Clearly defined objectives for the use of statistical data are a necessary preliminary to drawing up survey methods and programmes.

In fact the choice of objectives will determine the scope of the survey and what data are necessary. Only on this basis is it possible to decide exactly what questions need to be asked and exactly who will have to answer them.

Theoretically, it is possible to design an ideal questionnaire but this must be modified to stand up to practical criticism, bearing in mind the need for these questions to be answered by the respondents truthfully and without serious ambiguity.

The precision of the data and the refinement of analysis required will vary with the objectives, depending on how ambitious these are. These objectives are at various "levels". Any one of them is often important enough to justify these surveys, even if the ultimate objectives cannot be reached. Of course the resources available for surveys will to some extent determine the level which can be attained and this will change over time.

It is possible to choose five "levels" of objective:

1. Compilation of descriptive information;
2. Evolution of R. and D. expenditures;
3. Comparison with data on other expenditures;
4. Analysis of R. and D. management;
5. Attempt to measure the effectiveness of R. and D.

1.2 Information and Description

This first objective may seem rather modest. However, adding quantitative financial data to a "year book" of research centres considerably enriches the information it contains. Thus it is easier to evaluate the means and capacity of these centres if there is an analysis of their capital and current expenditure. Furthermore, the addition of financial data makes it possible to find out the total effort for different sectors or branches of research.

1.3 Evolution

It is obviously essential to be able to follow the evolution of R. and D. expenditure. This task urgently demands a systematic statistical programme. The fact that historical data are inadequate is no reason to delay the establishment of reliable figures for future time series.

The setting up of consistent series makes it necessary to follow fixed rules in the establishment of the statistics and, if these have to be altered, a link must be devised to ensure comparability.

1.4 Comparisons

This is naturally one of the main aims of surveys on R. and D. activities.

Comparisons may be internal, within a particular country, or in a given sector of R. and D. For instance, it is possible to compare expenditures according to categories of research; between basic research and development; according to scientific fields, such as physics and biology; according to economic branches, such as applied research in agriculture and manufacturing industry; according to the means of financing research, such as government research and private research. The criteria for the classification of research activities should be chosen according to the objectives of the survey and to policy formulation. Inevitably there is a multiplicity of possible criteria, and some of these will be discussed in the next section.

On a larger canvas, international comparisons of R. and D. expenditures are needed. These comparisons again demand precise rules which are adhered to by all the different countries. But it is easy to see the difficulties involved in establishing a common pattern of statistics, because of the variety of national financial and administrative structures.

However, the more detailed the classification and the more latitude permitted in regrouping the basic data for purpose of analysis, the greater will be the possibility of meaningful comparisons.

It is worth noting here the possibility of comparing figures relating to R. and D. with other data, as for instance comparing research expenditures with the turnover of firms or of whole branches of industry; or comparing R. and D. data with G.N.P., or investment etc But, while the examples quoted earlier indicate the possibility of a choice between different types of research, these comparisons begin to involve economic considerations and open new perspectives which are now discussed.

1.5 The Management of Research

The use of the phrase "management control" presupposes, that the problems dealt with here are mainly concerned with the optimum use of resources by research management.

The simplest tasks may be the evaluation and comparison of the cost of a research worker, or of research work, in different research centres or different countries. To some extent a concept of "productivity" of research centres is involved in these studies.

From another angle it is possible to study the balance between various types of expenditure, e.g. capital and current expenditure and the associated scientific personnel and equipment.

Finally, on a broader basis still, it is desirable to determine the relationship between the resources applied to various types of research in order to attain the optimum development. For instance, a balance is needed between expenditure on basic research, applied research and development. It is also desirable to co-ordinate expenditures on research in different disciplines with common long-term objectives.

There is also a need to balance the allocation of resources between R. and D. and related scientific activities necessary to the advance of R. and D., such as scientific and technical information, data collection, geological measurement, standards etc.

1.6 The Returns to R. and D.

Dealing with the problem of the effectiveness of research involves the introduction of other economic and political considerations.

Up to this point R. and D. efforts have been considered only on the basis of the measurement of input. Much useful information can be gained on the best use of funds from the study of inputs alone.

Comparisons of R. and D. expenditures and other data, such as turnover and G.N.P., investments in scientific equipment or investments in education and training, make it possible to establish ratios, which at this stage are nothing more than the results of studies on the means used by firms or countries in implementing their research policies. These studies of empirical behaviour are nonetheless very important.

But in fact, in order really to assess R. and D. efficiency, some measure of output should be found. There is no hiding the difficulties of measuring research "production" in financial terms. The problems of measuring this output are increased by random factors inherent in R. and D. The uncertainty attached to all kinds of research usually prevents any precise evaluation of output except on a broad plane, involving the aggregation of large numbers of research operations. This underlines the importance of the general consistency and comparability of financial statistics.

In any event, the first stage in the measurement of output is a precise evaluation of the input with which it will have to be compared. It may even be a question of evaluating research efficiency not in accountancy terms with either plus or minus signs, but in terms of relationships with a more general economic model.

The ultimate aim of such information is to help decision-makers in industry and even more so in governmental circles. However, one should not think that such information is sufficient in itself; it can only provide part of the basis for a decision. The choices in research policy arise on an altogether different level. The criteria for these choices include not only accountancy or economic factors, but also often predominantly political and social considerations.

SECTION II: BASIC DEFINITIONS AND CONVENTIONS

2.1 The Scope of Research and Development

The basic definition of R. and D. used in surveys in most Member countries, are essentially similar. Those given below are based on them, but are not identical with those used in any one country. The UNESCO definitions differ principally in the elaboration of sub-division, motives, methods and results(4). It is of course possible to make much more elaborate definitions and there has been a long controversy on this subject, but the view taken here is that the brief and simple definitions below are the most generally practical.

Fundamental Research

Work undertaken primarily for the advancement of scientific knowledge, without a specific practical application in view.

Applied Research

The same, but with a specific practical aim in view.

Development

The use of the results of fundamental and applied research directed to the introduction of useful materials, devices, products, systems, and processes, or the improvement of existing ones.

Inevitably, a great deal depends on the judgment of investigators and respondents in making this classification, and the frontiers between basic and applied research and development on the other, may often be difficult to establish.

2.2 Frontiers to be Delimited

Of course, these definitions are not sufficient in themselves. It is necessary to amplify them by standard "conventions", which demarcate precisely the borders between research and non-research activities. Two main frontiers which require such definitions are:

(a) The boundaries between R. and D. as a whole and several related scientific activities discussed in 2 below;

(b) The boundaries between R. and D. and a number of non-scientific activities of which industrial production is perhaps the most important.

It is in these that the main differences exist between Member countries of the O.E.C.D., that is to say in the detailed interpretation of the definitions, rather than their main content. Methods for delineating the frontiers under (a) and (b) are therefore dealt with at some length in this Section.

The measurement of all economic activities involves an element of arbitrariness in settling borderlines. For example, in foreign trade statistics a decision must be taken about the inclusion or exclusion of military supplies, of gift parcels, of gold and so forth. There will always be room for argument about the particular definition which is chosen, and there will always be a zone of activities for which it could be plausibly

argued that they should be either included or excluded. However, as long as the frontier is clearly demarcated, and the magnitudes are relatively small compared with the main economic variable which is being measured, it does not really matter where the borderline is drawn. This will be a matter of convention, and the most important requirement will be to attain a generally accepted convention so that international comparisons are facilitated. Usually an international convention will have to take account of existing practice and the real possibilities of including or excluding statistics of a particular adjacent activity. These considerations will in fact usually determine the actual delineation of the frontier, and scientific activities are no exception.

2.3 The Three Stages of Measurement

R. and D. activities are only one part of a broad spectrum of scientific activities which include scientific information activities, training and education, general purpose data collection, and (general purpose) testing and standardisation. Indeed, in some countries one or more of these related activities may claim a larger share of material and human resources than R. and D. It may well be desirable for such countries to begin their statistical inquiries by surveying one or more of these areas rather than R. and D.

Whether this approach is followed or whether R. and D. is to be the main focus of a national inquiry, it will be necessary to employ some system for making a clear demarcation between what is and is not included. Since the measurement of R. and D. is the major problem under consideration here, the demarcation of R. and D. might proceed with the following consideration in mind.

Research Institutes and the R. and D. Departments of large firms often have their own separate accounts and statistical records. If the measurement of R. and D. activity involved simply the aggregation of these statistics, it would be a comparatively simple matter. But unfortunately, R. and D. activity cannot be defined simply as the activity of research organisations. There are two main reasons for this. First, important R. and D. work may be carried out by personnel and institutions which could not be classified as "research personnel" or "research organisations". Secondly, as noted above, specialised research institutes or departments are frequently involved not only in R. and D. activity, but also in other activities.

Thus, R. and D. activity is not just what research organisations do; it is both less than this and more than this. Surveys of research activity in various countries have shown, that a high proportion of specialised industrial R. and D. establishments undertake a wide variety of activities. For example, in his analysis of industrial R. and D. in Great Britain(5), Dr. Rudd presented a table showing the numbers of industrial R. and D. Departments, performing such functions as technical sales service, production control, routine testing of raw materials and other "non-research" functions. (This table is shown in Appendix X).

Although their activities are usually more restricted non-industrial Research Institutes and Organisations may also often undertake a range of activities which is wider than any generally accepted notions of R. and D. Sometimes as much as one third of the total activity of such Research Departments and Institutes may consist of "non-research" activities. The proportion will vary in different organisations and it will, of course, also depend on the precise definitions, which are used to delineate the related activities. But whatever definition may be used, it is evident that there is a substantial area which cannot be designated as "R. and D." and that the total activity of research organisations cannot be equated with R. and D.

Consequently, measurement involves three stages:

(i) The identification and measurement of the total activity of all specialised research organisations, including those in industry.

(ii) The subtraction from this total of that proportion of their activity which is defined as "non-research" activity. The exact proportion will depend on the precise definitions and conventions adopted to deal with the various related scientific activities and the non-scientific activities.

(iii) Adding to this total that R. and D. activity which is not performed in research organisations, but in such other organisations as production units, educational establishments, and so forth.

Even though our main interest may be in the measurement of R. and D. activity, it will also be useful to know:

(a) How far specialised research establishments are also involved in other activities.

(b) How much R. and D. activity is performed outside specialised units.

Unfortunately, although respondents to R. and D. Surveys have had to make their own estimates on these points, hitherto they have not been recorded in most national surveys.

This manual, therefore, makes a general recommendation on a method of dealing with this problem:

All calculation of deductions for "non-research" activities of research organisations, and of additions for R. and D. activities of "non-research" organisations should be made explicitly, that is to say, recorded both by individual respondents and by those compiling national totals from the data furnished by individual respondents. Furthermore, whenever possible, related scientific activities such as documentation and routine testing, should be measured simultaneously with R. and D. and reported separately.

The main advantage of using explicitly a "3-stage" calculation is that it facilitates the identification and measurement of other scientific activities. Practical experience suggests that, among the sources of error in most of the national surveys so far undertaken, are the respondents' own calculations (or lack of calculations) of what "non-research" activities should be deducted from the accounts of a Research Institute or Department, and what should be added for research performed outside specialised establishments. Since accounts exist, if at all, only for a "Department" or an "Institute" and not for an "activity" more narrowly defined, the temptation is strong to make a return using these accounts and not to bother with rather tiresome adjustments which involve imputing a proportion of overheads to "non-research" activity and so forth. Obviously the questionnaires to respondents should be so designed as to facilitate the most accurate response and this will involve an explicit estimate for "related scientific activities".

However, even though it is desirable to collect data on "related activities" performed by research organisations, simultaneously with the collection of R. and D. data, it is not possible here to make detailed standard recommendations for the measurement of these related activities. Such measurement would involve not only the "residual" activities of research organisations, but also the main activities of bodies specialising in survey work, scientific documentation, materials testing and so forth. The objective

of this manual is to attain international comparability in the narrower field of R. and D., and it therefore concentrates exclusively on this primary purpose. But it is very much hoped that national surveys will attempt the measurement of all scientific activities, and that arising from this experience, further international standards can be elaborated by the O.E.C.D., for "related activities" as well as R. and D. These proposals may thus be considered as only the first stage in a programme for measuring all scientific and technical activities on a comparable international basis.

2.4 Conventions of "Related Activities" excluded from R. and D.

With the foregoing aims in mind, the following general definitions of the related scientific activities are proposed. The definitions should facilitate the identification and measurement of these activities, particularly in cases where a country proposes to begin its survey programme by measuring one of the related activities. It must be recognised that the scientific activities concept is formalised rather than realistic in the sense that it postulates a separateness for these components which often does not actually exist. But such a distinction must be made for survey purposes.

(a) Scientific information activity comprises all aspects of communication among scientists, including such activities as the publication, dissemination, and translation of information resulting from research and development. General library services are included.

(b) Training and education includes formal university education in science and engineering as well as formal scientific training, in or supported by places of employment, where scientific and engineering personnel and being trained. The latter is to be distinguished from on-the-job or in-service training. Excluded are specific grants for research fellowships or research projects.

(c) General or broad purpose data collection refers to that continuing gathering of data on natural and social phenomena which is part of the broad general welfare function of most central governments and which may also be carried on elsewhere. Included are such activities as: geological and geophysical survey work, mapping and exploration activities, including those of oil and mineral companies; hydrographic and oceanographic survey work of a routine nature not specifically related to the development of new knowledge or theories; daily meteorological records, monthly production statistics, the collection and arrangement of specimens for museums, zoological gardens, and so forth.

(d) Testing and standardisation includes such public and quasi-public functions as the establishment of standards, calibration of secondary standards, and non-routine quality testing which are separately identifiable from research and development.

It is evident that there is a case for including some or all of the activities grouped under items (a) and (c) above within the scope of R. and D. This has not been done, partly for practical and partly for theoretical reasons. However, these activities may be measured simultaneously with R. and D., (but separately accounted for), and as soon as international experience is adequate, standard definitions and methods should be formulated by the O.E.C.D. for this purpose.

It is fairly generally agreed that training and education should be excluded from the scope of R. and D., although this has not always been clear in the actual instructions issued for particular national surveys. Again, some of these activities, such as testing and training, may be measured simultaneously with R. and D. The exclusion of a particular sphere of activity from the total R. and D. of any research organisation, would involve careful consideration by respondents, and possibly also discussions with those responsible for the questionnaires. There will be many cases where such functions as library and documentation services and various technical services are performed directly and solely for the research organisation's own R. and D. activity. These should not be excluded and neither should general administrative functions which directly serve the research organisation itself.

2.5 Non-Research Activities

In addition to the scientific activities related to R. and D. there are a number of other activities which draw on the services of scientific personnel but which must be excluded from R. and D. These include:

All legal administrative work in connection with patent applications, records and litigation. Work involved in the sale of patents and licensing arrangements. Experimental work performed solely for the purposes of patent litigation.

Routine testing and analysis of all kinds, whether for control of materials, components or products, and whether for control of quantity or quality.

Other technical services for production units, customers' or other non-research bodies. For example, technical sales services including installation, servicing and minor adaptations to meet individual requirements, or technical aid to advertising campaigns, "trouble-shooting" for production units not involving any original research or development work; i.e. assistance of a type simply enabling them to operate in accordance with previously determined formulae, standard practice instructions or established specifications(6).

2.6 Distinction between Research and Non-research Activities

It is evident that there will be cases, when the same function may serve both research and non-research purposes. For example, a testing laboratory may be used principally for the routine testing of raw materials, but occasionally for the testing of completely new or improved materials developed by R. and D. personnel. In principle, an estimate of the latter should be included within R. and D. activity, whilst the former should be excluded. In all such cases, the guiding line to distinguish R. and D. activity from non-research activity is the presence or absence of an element of novelty or innovation. Insofar as the activity follows an established routine pattern it is not R. and D. Insofar as it departs from routine and breaks new ground, it qualifies as R. and D. Thus, for example, the collection of daily routine statistics on temperature or atmospheric pressure, is not R. and D. but the investigation of new methods of measuring temperature or the investigation of temperatures under circumstances, in which they have never been previously recorded (for example, outer space or the interior of the earth), is research. Likewise, the publication of a book which simply records daily information on the temperature or pressure is not R. and D. but general purpose data collection. The systematic analysis of these recordings with a view to explaining long-term changes in climate, or the possible effects of changes in ocean currents, is research activity.

To take another example: in the field of medicine, routine general autopsy on the causes of death is not research, but special investigation of a particular mortality in order to establish the side effects of certain forms of cancer treatment is research. Routine tests on patients, carried out for doctors, as for example, blood tests and bacteriological tests, are not research. But a special programme of blood tests in connection with the introduction of a new drug is research. The collection and publication of regular general statistics on the incidence of particular illnesses is not research. The statistical analysis of such records in order to establish, for example, connections between the incidence of a particular illness and occupation or smoking habits is research.

Or again, the routine collection and arrangement of specimens for a museum is not research, but a study of comparative anatomy using these specimens is research.

It can be maintained, that the collection and publication of routine general purpose statistics is necessary for the performance of more original research work, and it could be argued that this and other forms of "inventory research" are a special part of fundamental research i.e. the advancement of knowledge with no specific practical aim. Those who hold this view would probably agree that it is in any case useful to separate this type of work from the more original contributions to human knowledge, which are here defined as R. and D. activity. Therefore this activity should in any case be separately measured.

It is evident that the application of these conventions requires careful examination and judgement, and that inevitably, they are to some extent arbitrary. They do, however, provide a rational and practical basis for making the difficult distinction between R. and D. and "related activities" and measuring them in such a way that international comparability may be attained.

2.7 Development and Production

Probably the greatest source of error in measurements of R. and D. is the difficulty in precise demarcation of the frontier between development and production in the industrial sector. This is partly because the costs of development are many times greater than the costs of research, and the costs of trial production may be greater still. It is also because government military R. and D. contracts, with their emphasis on speed, tend to telescope the development and production phases so that they are sometimes hard to distinguish. For this reason, one of the recommendations later in this manual is, that separate estimates should be made of military, atomic energy and space R. and D., and (within the industrial sector) of R. and D. in the Aircraft and Missile industry. Estimates for civil R. and D. and for industry excluding aircraft, spacecraft and missiles are likely to be more reliable. Measurement in the latter industries is difficult for technological reasons in addition to the complications caused by government contracts. However, despite the practical difficulties, it is obviously desirable to attempt a demarcation which is applicable even in the government-military sphere of development.

It is generally accepted that the design, development, construction and testing of prototypes and pilot plant is an essential part of R. and D. The main difficulty arises in determining the point at which this development work ceases and production begins. Preparation for normal production of a new product may involve one or several trial production runs, which, in turn, may indicate a need for further development work. Or in the development of a new process, pilot plant, which has initially been constructed

for experimental purposes, may subsequently be used for normal commercial production.

In determining the "cut-off" point between development and production, individual judgement is bound to play some part, as no definition could possibly embrace the infinite variety of circumstances which arise in practice. So far, only in the United States, have detailed indications been given to industrial respondents to assist them in the solution of this problem. Consequently, the remainder of this section draws to a large extent on the instructions elaborated by the National Science Foundation, although the emphasis on individual points is somewhat different, taking some account of European experience. This applies particularly to the treatment of prototypes and "engineering follow-through".

The fundamental criterion laid down by the N.S.F. provides a rational and practical basis for the exercise of judgement in difficult cases. It states(7):

"If the primary objective is to make further improvements on the product or process, then the work comes within the definition of R. and D. If, on the other hand, the product or process is substantially "set" and the primary objective is to develop markets or to do pre-production planning, or to get the production process going smoothly then the work is no longer R. and D."

Prototypes and Trial Production

Applying this basic criterion: the design, construction and testing of prototypes normally falls within the scope of R. and D. This applies, whether only one prototype is made or several and whether consecutively or simultaneously. But after the prototype(s) with any necessary modifications, have been satisfactorily tested, the costs of the first trial production runs cannot be attributed to R. and D. as the primary objective is no longer further improvement of the product, but getting the production process going. The first units of a trial production run for a mass production series should not be regarded as R. and D. prototypes, even if they are loosely described as "prototypes".

Development includes "the engineering activity required to advance the design of a product or process to the point where it meets specific functional or economic requirements and can be turned over to manufacturing units". But it is evident, that after a new product or process has been "turned over to manufacturing units", there will still be technical problems to be solved, before normal production is flowing smoothly. This process of "getting the bugs out" may involve some further R. and D. work, as a "feed-back" from specific problems encountered in trial production. To this extent only the "engineering follow-through" in the early production phase will be included in R. and D. But normally, the costs of trial production runs or "experimental production" including tooling up for full-scale production, (tool-making and tool try-out) are not to be included in R. and D.

In some cases an R. and D. prototype may subsequently be sold. In principle, such a sale does not affect the issue, as long as the original primary purpose in constructing the prototype was R. and D. But in a completely different category is the construction of several "prototypes" to meet a temporary military, commercial, or medical requirement, after an original prototype has been successfully tested and further development work is no longer in hand. This is sometimes done by R. and D. staff to fill the gap before normal production commences, or even as a profitable "sideline". It may be objected that "stop-gap" products of this kind are not strictly speaking "prototypes", but since they are sometimes so designated, it is necessary to make this

distinction. Whoever may perform this work, such activity and transactions should be excluded from measurements of R. and D. activity.

Design and Drawings

A special problem is the assessment of the costs of design which are attributable to R. and D. The design of prototypes and pilot plant is included, and so is the design of special equipment, structures or tools required for a new process or product. After the successful completion of the testing of prototypes or pilot plant, the design and other information necessary for normal production must be transmitted to operating units. This will necessitate the preparation of drawings, reports, standard practice instructions, operating manuals, formulae, specifications and so forth. This activity is a part of R. and D. But before production trials can begin, it will often be necessary to prepare and reproduce a mass of detailed construction drawings and manufacturing blue-prints. Whether these are produced by the Organisation's own drawing office, or sub-contracted they should be excluded from R. and D. In practice, they are rarely done by R. and D. staff, so that exclusion does not present great difficulties. Also excluded from R. and D. activity are design costs, necessary to meet changes of fashion and style unaccompanied by technological innovation; for example, in the furniture and textile industries.

Pilot Plant

The construction and operation of pilot plant is a part of R. and D. as long as the "principal purposes are to obtain experience and to compile engineering and other data to be used in evaluating hypotheses, in writing product formulae or in establishing finished product specifications, in designing special equipment and structures required by a process, and in preparing operating instructions or manuals".(8) But as soon as this experimental phase is over, if a pilot plant continues to operate temporarily as a normal commercial production unit, the activity can no longer be considered R. and D., even though it may still be described as a "pilot plant", and even though R. and D. staff may be called upon for "trouble-shooting" in connection with its normal operation. As long as the primary purpose in operating a pilot plant is non-commercial, it makes no difference in principle if part or all of the output happens to be sold. Receipts from this source should not be deducted from the costs of R. and D. activity. The same applies to receipts, if the pilot plant itself is ultimately sold. But if development work is no longer the main purpose in operating a pilot plant, the costs of operation and all commercial transactions should be excluded from R. and D.

2.8 Social Sciences and Humanities

Research work in the social sciences and humanities should be included within the scope of R. and D. activity. Most European countries do in fact use the term "science" to embrace the whole range of human knowledge, and not in the more restrictive "Anglo-Saxon" sense of natural sciences and technology. Surveys in some European countries have actually measured R. and D. activity on the basis of a definition including research in the social sciences. They have done so, however, only in the government sector, the higher education sector and other non-profit research institutes. The N.S.F. has also measured research in the social sciences separately in the government and non-profit sectors in the United States. But no country has so far successfully defined and measured research in the social sciences and humanities in industry. There is therefore still insufficient practical experience to provide a basis for standard definitions and conventions in this field.

All those countries which have succeeded in measuring the total national resources devoted to R. and D. in all major sectors of the economy, have done so on the basis of a definition which excluded research in the social sciences and humanities.

Consequently, although these disciplines should certainly be included in principle within the total of R. and D. they should be separately measured and recorded. Otherwise it would not be possible to make any consistent time series or comparisons with surveys which have already been carried out. The O.E.C.D. should regard it as a matter of urgency to bring together the available international experience in the measurement of research in the social sciences and humanities, and to conduct its own research on the outstanding problems. There are in particular, procedures for definition and measurement in such areas as work study, market research and operational research in the business enterprise sector. Otherwise there is some danger that the social sciences and humanities will become a kind of Cinderella and their importance overlooked.

SECTION III: CLASSIFICATION OF RESEARCH AND DEVELOPMENT ACTIVITY

3.1 Introduction

Having defined the scope of R. and D. activity and delineated the outer boundaries by means of conventions on related activities and production, it is now possible to proceed to the classification of the central activity - R. and D. itself. R. and D. activities can be classified in many ways, which may be envisaged as various "dimensions" for measurement and comparison.

But for the purposes outlined in Section I of this manual, one "dimension" is of paramount importance: classification in terms of the principal sectors of the economy. This classification largely corresponds to the practical requirements of data collection, which may often necessitate a different type of approach and questionnaire to each of the main sectors. It also appears to be the only reliable way of building up a reasonably accurate national aggregate of the total resources committed to R. and D. activity in any particular country, and the sources of finance for this activity. Finally, it corresponds in most respects to the definitions and classification employed in other statistics of national income and expenditure, thus facilitating comparison with existing statistical series, such as gross national product, net output, investment in fixed assets and so forth. In this way it facilitates understanding and interpretation of the role of R. and D. in economic development and the formulation of a science policy related to economic possibilities and objectives. Consequently, the greater part of this section is devoted to the classification of R. and D. activity in terms of economic sectors. However other "dimensions" or systems of classification are also considered:

(i) The three categories of basic research, applied research and development work.

(ii) Scientific fields or disciplines.

Measurement of these additional dimensions is extremely useful for purposes of international comparison. Finally, some subsidiary forms of classification are very briefly discussed. These are not essential to international comparisons but may provide useful data for the formulation of national science and economic policies. In this section the discussion is mainly in terms of performers of R. and D. but it is also necessary to measure expenditure in terms of sources of funds. The relationship between performers and sources is discussed in Section IV.

3.2 The Sectors of the Economy

The standard division proposed here has four main sectors:

(i) Business enterprise sector.

(ii) General government sector.

(iii) Private Non-profit sector.

(iv) Higher education sector.

The definitions of the first three sectors are basically the same as in national accounts(*), but higher education is included as a separate main sector here because of the concentration of a large part of fundamental research activity in the Universities, and the crucial importance of these Institutions in the formulation of an adequate national policy for R. and D. There are also specific technical problems of measurement which make it desirable to treat these institutions as a separate sector.

3.3 The Business Enterprise Sector

Business enterprises include "all firms, organisations and institutions which produce goods and services for sale to the general public at a price intended approximately to cover the cost of production, and the non-profit institutions serving them". In considering R. and D. activity, the last clause is particularly important and the standardised system of National Accounts particularly mentions among non-profit institutions serving enterprises: "different kinds of associations and research units which, while not principally engaged in commercial activity, are established by particular branches of business in order to increase their efficiency or their earning capacity". Industrial research associations, the research functions of trade associations and commercial research institutes or consultants all come within the scope of this definition. But excluded are government research institutes, such as, for example, national physical laboratories or defence research organisations, which do not normally sell their services, or serve a particular industry. The latter meet a general social need and come within the scope of "General Government".

However, the research organisations of public enterprises are a part of the business enterprise sector. The legal form of ownership is immaterial in this connection: it does not make any difference whether such enterprises are fully state owned, or whether the state has only a part interest. Nor does the particular form of management or control affect the issue. Nationalised industries, public utilities, transport undertakings, post offices, communications and broadcasting, central banks and all other government enterprises are included within this sector.

3.4 Sub-Division of the Business Enterprise Sector

It will frequently be useful for purposes of comparison and analysis to sub-divide the business enterprise sector in various ways. In principle this sub-division should follow the International Standard Industrial Classification. For countries embarking on Surveys for the first time or for those in which the manufacturing industry is less developed, it may only be possible to sub-divide business enterprises into a few main divisions such as:

NOTE (*) The standard national income statistics now in use in most countries are classified into three main sectors (it should be noted that these sectors do not correspond strictly either to a legal or to a functional classification but were set up by economists and statisticians specifically for purposes of economic analysis as described in Chapter III of the O.E.E.C. "Standardised System of National Account").

The three standard sectors are:

(i) Business enterprise sector.

(ii) General government sector.

(iii) Private Non-profit sector.

In the standard national accounts definitions, institutes of higher education are divided between the general government sector (if they are part of the public education system), the private non-profit sector and the business enterprise sector).

1. Agriculture, forestry, hunting and fishing.
2. Mining and quarrying.
3. Manufacturing industry.
4. Construction, utilities, commerce, transport and services.

But most countries will be able to sub-divide group 3 and 4 into the Standard 2 - digit headings of the I.S.I.C. and this is essential for useful comparisons between industrialised countries. In a few cases it is desirable to go beyond the I.S.I.C. 2 - digit classification. For example in R. and D. statistics it is essential to separate the aircraft industry from other forms of transportation equipment in Group 38 of the I.S.I.C. There are some other industries which are particularly research-intensive and of special interest from the standpoint of R. and D.; these also necessitate sub-division of the I.S.I.C. 2 digit headings. On the other hand there are a few of the I.S.I.C. 2 digit headings which are relatively insignificant at present for R. and D., and some of these may be combined. A suggested form of industrial classification which takes into account these variations from the standard 2 - digit headings is shown in Appendix I.

3.5 The General Government Sector

The function of "General Government" is to organise for, but not normally to sell to, the community those common services which cannot otherwise be conveniently and economically provided, and to act as the administrative agency for the economic and social policy of the community. This sector includes central and local government agencies which undertake such activities as administration, defence and health services. They are included irrespective of their treatment in the government budget. They include government research establishments of various kinds, such as defence research organisations, atomic research institutes, space research agencies, agricultural and medical research establishments, institutes for basic research and applied research in physics, chemistry, biology, engineering and so forth.

3.6 Sub-division of the General Government Sector

"General Government" accounts in the national income definitions are not the same as the Budget of the Central Government. The latter may include some items, such as the financing of state owned enterprises, which are classified in the business enterprise sector in national accounts. On the other hand the national income concept of "General Government" includes local and regional Government authorities as well as the Central Government. Nevertheless, bearing in mind these important conceptional differences, it is still necessary to analyse Government expenditure for R. and D. by financial source, according to the programme categories which appear in the budget. Such an analysis is useful both from the point of view of government policy (especially when discussing the budgets and research policies of the various ministerial departments and government institutions), and of international comparison. It is particularly useful to distinguish separately such activities as space research, military research and atomic energy research. They consume a very large volume of funds, whenever they are undertaken, and have their own peculiarities which make separate measurement work desirable. This analysis may be made by combining budget information with information obtained from departments and institutions on the amount of each budget item devoted to R. and D. It is recommended, in order to facilitate international comparison, that results be presented according to the outline shown in Appendix XI.

3.7 The Private Non-Profit Sector

The private non-profit sector includes all private organisations, which are not established primarily with the aim of earning a profit, and are not mainly rendering services to enterprises. They are maintained by fees, dues and donations from members and sponsors, by grants from government and enterprises, and often they will also obtain revenue from the direct sale of some of their services, or for example, sale of publications. Typical examples of research organisations belonging to this sector are all voluntary scientific societies, philanthropic research foundations and non-profit research institutes which are not specifically serving industry. Although they may sometimes be operated on a profit basis or as a part of general government service, zoos, botanical gardens and museums also belong typically to this sector, and in the scheme adopted here all such organisations are included in it irrespective of their sources of finance and mode of operation. Finally, voluntary health agencies belong to this sector, such as for example cancer research institutes operated by charitable funds and private donations.

Research performed by individual inventors in private households or elsewhere is hardly included at all. This is a serious omission, but perhaps no more serious than the omission of "do-it-yourself" activities from the statistics of national income. In both cases practical problems of measurement prevent the achievement of the solution which is theoretically most desirable. In principle, private households and non-profit activities of individuals are included in the private non-profit sector, but measurement is possible only of private donations to finance research in other sectors and in non-profit institutes, and of some payments to individual inventors from other sectors.

3.8 The Higher Education Sector

The higher education sector includes all universities, colleges of technology and other institutes of higher education, whatever their sources of finance or legal status. It includes also institutes exclusively engaged in research, which are attached to or under the general supervision of institutes of higher education and their subsidiary or affiliated bodies such as experimental stations and clinics.

For reasons noted in paragraph 3.2 it is useful to sub-divide the higher education sector into the three standard national accounts sub-divisions, in accordance with their sources of finance and mode of operation.

3.9 Fundamental Research, Applied Research and Development in addition to the classification by economic sectors

A second important form of classification of research activity is the division between:

(i) Fundamental research;
(ii) Applied research;
(iii) Development.

It is well known, for example, that a high proportion of total R. and D. expenditure in the chemical industry, is for fundamental and applied research, whereas in the aircraft industry a very high proportion is for development. Such differences between industries or enterprises, between sectors, and between countries, are of the greatest interest for analysis and policy.

The basic definitions of these categories have already been given at the beginning of Section II. Inevitably, a great deal depends on the judgement of respondents in making this classification, and the frontiers between basic and applied research on the one hand, and between applied research and development on the other, may often be difficult to establish. As a practical aid in classification the following supplementary criteria have been elaborated by the Délégation Générale à la Recherche Scientifique et Technique, and is shown in Appendix IX.

3.10 Classification by Fields of Science

Thirdly, it is useful to classify R. and D. by scientific field. As the O.E.C.D. has already done some work on the classification of scientific and technical personnel, the same basic system has been used to avoid the complication of more than one system of classification being used by the same international organisation (see Appendix II). In its surveys of scientific manpower, the O.E.C.D. has based itself on the UNESCO system, which offers an additional advantage from the standpoint of international standardisation. The scheme shown here is therefore also based on that used by UNESCO in their surveys of higher education with very minor modifications. It has six principal divisions (Column 1) and about 30 sub-divisions (Column 2). For most purposes this degree of refinement is probably sufficient, and experience in the O.E.C.D. surveys has shown that most O.E.C.D. countries are able to adjust their own classification. It may be useful, however, occasionally to use a more elaborate system, and an example of this type, worked out by the N.S.F. is shown in Appendix IIa. Moreover, there appear to be still some ambiguities in the UNESCO/O.E.C.D. classification, and it is to be hoped that the work now in progress in this field will soon result in an improved standard rubric for this purpose, and more detailed guidance for respondents. Owing to new developments in science itself, this type of classification will require regular reconsideration and revision, and this type of work should be a normal part of O.E.C.D. activity in this field. It may be desirable at a later stage to work out a new classification specially suited to the requirements of R. and D. statistics and taking account of the growing importance of inter-disciplinary fields of research. The UNESCO classification is mainly suited to the needs of manpower measurement.

3.11 Other Methods of Classification

It is possible to conceive of many other ways of classifying R. and D. activity and some of these have been attempted in Member countries with varying degrees of success. For example, within the business enterprise sector, the N.S.F. has measured R. and D. activity not only in terms of the industrial classification of the enterprise conducting research, but also in terms of the "product field" of the objects of research and development. This is particularly useful because one difficulty in making international comparisons between industries lies in the company structure of the business enterprise sector. A company may operate in several different industries, but it is a common practice when statistics are collected on a company basis to classify companies in one industry only according to their principal product fields. This may lead to considerable "blurring" of the industrial classification borders. For this reason, where possible it is desirable, as in Census of Production Statistics, to classify by establishments rather than companies or at least (as in the United Kingdom 1962 Survey) by broad divisions of very large firms. But national circumstances vary and when this is not practical, a classification of the objects of Company R. and D. expenditures by principal product fields is a valuable (and in some respects better) alternative.

To take another example, it may be useful to measure the distribution of R. and D. activities in terms of the principal geographical regions of a country. Such studies may have an important bearing on policies relating to the location of industry, and regional economic development. They do not, however, lend themselves readily to any standard system of international comparison. The method of dealing with the operations of international companies and organisations is described in paragraph 4.8 and further discussed in Section VI. For some purposes it may be useful to classify the business enterprise sector according to the form of ownership or size of enterprises. For example it may be sub-divided between privately-owned enterprises, state-owned enterprises, and various forms of mixed ownership. Or it may be divided by size categories according to numbers employed, capital employed or turnover. Another method of classification is to distinguish R. and D. on <u>products</u> from that on <u>processes</u>, and to separate <u>improvements</u> of existing products and processes from new developments. None of these are included here in order to avoid over-elaboration but at a later stage it may be useful to include other categories and dimensions within the framework of the scheme.

SECTION IV: METHODS OF MEASURING R. AND D. ACTIVITY

4.1 Introduction

Ideally, it would be desirable to measure R. and D. activity both in terms of the input of resources and in terms of the output. But the difficulties in the way of output measurement are still too great to establish any satisfactory standards.

The two principal methods of input measurement are measures of expenditure on R. and D., and measures of manpower employed in R. and D. Each of these methods has its own specific advantages and disadvantages. It has generally been found in practice that surveys of manpower are easier to carry out than expenditure surveys. The reasons for this are inherent in the organisation of R. and D. activity itself. Research organisations frequently carry out "non-research" activities. It is relatively simple to make deductions for this, on the basis of a man/hours calculation even if it involves estimates of part-time activity. It is much more difficult to make calculations in terms of expenditure, as the accounting system, (even if separate accounts exist!) may not lend itself to this purpose - overheads may be shared with other departments and organisations; certain items such as capital expenditure, may be carried on a different budget and so forth. In fact, frequently the only satisfactory expenditure calculation may be via a man/hours calculation. For these and similar reasons, surveys of R. and D. activity have sometimes been confined exclusively to qualified scientific manpower engaged in research and development.

4.2 Measurement of R. and D. Manpower

Perhaps the most difficult problem in measuring manpower is that of part-time personnel, who divide their time between R. and D. and other activities. The solution proposed is that used in several national surveys: the concept of "full-time equivalent". For example, a research department may employ 80 scientists and engineers who are virtually full-time on R. and D. work; in addition it may employ 15, who spend part of their time on technical services to customers, and on an average, only two-thirds of their time on R. and D. The "full-time equivalent" employment of scientists and engineers in this Department would be 90.

Estimates of "full-time equivalent" are necessary to obtain a picture of the total input of man-years into R. and D. activity. But they are usually not necessary or practicable for more detailed classification by disciplines, qualification and so forth. For this purpose different concepts are needed: that of manpower engaged full-time and part-time, in research and development activity. In the example above, the number of full-time in R. and D. is 80 and part-time, 15, whilst the "full-time equivalent" is 90. But obviously the scientific disciplines and qualifications are best analysed for all 95. Very frequently, surveys of scientific manpower engaged in R. and D. will be a part of wider surveys of total employment of scientific manpower. The qualifications and discipline of those spending less than 50 per cent of their time on R. and D. will be recorded under other headings. This applies, for example, to University staffs. But where wider surveys are not being made, it will be necessary to measure all of those doing part-time research work.

4.3 Categories of R. and D. Manpower

Manpower employed on R. and D. may be divided into three principal categories:

(i) Qualified scientists and engineers, or their equivalent.

(ii) Technicians.

(iii) Other supporting personnel.

All three groups should be measured, but the first group requires greater detail of classification. Personnel who are engaged in the management and administration of R. and D. should be included throughout, but as a separate category.

The definitions of the three principal groups are identical with those used in the O.E.C.D. Survey of Scientific and Technical Personnel(20). A qualified scientist or engineer is a person who has obtained:

(a) A university degree in science or equivalent, or

(b) An equivalent diploma, or

(c) Any other diploma which, in some countries, though of less than university degree standard, is nationally recognised as qualifying a person as a professional scientist or engineer.

(d) Any other training which, though of less than university level or diploma as specified above, is nationally recognised as qualifying a person as a professional scientist or engineer, (e.g. admission to professional societies or institutions, or having the qualifications necessary for such admission).

Each of these categories should be distinguished. In group (d) there will be some persons who, whilst they do not possess any formal qualifications, are nevertheless performing the functions normally carried out by qualified engineers and scientists. Such people may include some, who have failed to complete their university or other education, and some who never embarked on it.

Scientists and engineers engaged in R. and D. should also be classified according to the scientific discipline of their qualifications or training. For this purpose the classification is that shown in Appendix: Table II.

Ideally it is desirable to measure R. and D. manpower in two ways; first, classified by qualifications or training ("trained as") and secondly classified by present occupation ("employed as"). It is essential to realise that these are not identical and that persons who qualify in a particular description may not be employed in the same branch of science, or indeed in any branch. Because of the amount of work involved in collecting manpower statistics on this "two-way" basis, it may often be necessary to make use of Surveys which are undertaken for purposes other than measurement of R. and D., for example, manpower Surveys undertaken for employment or education statistics, or for a Census of Population. The inclusion of a few additional questions in such wide Surveys will often obviate the need for additional separate inquiries and questionnaires.

Technicians are those who have received not less than one year of formal technical education, or equivalent part-time study, after leaving secondary school at the non-advanced level. They may also include some persons, who have attained the same level of technical training in some other way, without formal education, e.g. within enterprises or the armed forces. Examples of the occupations normally filled by this category of persons are draughtsmen, laboratory assistants, electronic technicians.

"Other supporting personnel" include skilled craftsmen such as electricians or fitters, and unskilled assistants, directly engaged in R. and D. activity, including the management and administration of this activity, when this is a specialised function, e.g. secretaries. All three groups exclude indirect labour engaged in providing or maintaining a subsidiary service such as heat, water, canteen facilities, office cleaning, cloakrooms and so forth, even though expenditure on these services is included in intra-mural expenditure estimates. Also excluded is all labour employed in the production of materials and equipment, purchased from outside the R. and D. organisation, and all labour employed on extra-mural contracts or sub-contracts.

4.4 Manpower Statistics related to Expenditure Statistics

On the basis of surveys on the one hand of manpower, and on the other hand of expenditure, it is possible to construct estimates of the costs per R. and D. scientist or engineer classified by sectors, by industries and various other categories of research organisation. It is also possible to assess the ratio of technicians and supporting personnel for each qualified scientist or engineer by sectors and by industries.

International cost comparisons will still be a difficult matter because of the problem of relative prices of inputs, such as scientists' salaries, in different countries. This problem can be resolved by the collection of price series and expenditure breakdowns in each country. But there remains the additional problem of comparability of qualifications between various countries. The quality of degrees and other qualifications cannot be assessed by these statistical comparisons and this limitation must be constantly kept in mind.

Although scientific manpower is undoubtedly the most important input, it is essential that manpower surveys be supplemented by expenditure surveys. These are the only satisfactory figures for some objectives of micro-economic analysis and for many public and private policy decisions. For example the budgets of governments and other organisations must use expenditure and cost data, and analysis of the flow of funds between sectors is one of the most interesting results of R. and D. surveys. Expenditure data are needed to compare investment in R. and D. with such other economic variables as investment in fixed assets or in education. Satisfactory data on expenditure will make it possible to measure all the principal inputs into R. and D. including materials and capital equipment, as well as manpower. It is true that a satisfactory time series on R. and D. expenditure would have to take account of changes in the value of money, arising from changes in the input prices for R. and D. activity. Also, satisfactory cross-country comparisons would have to take account of national differences in the prices of various inputs and the proportions in which they are combined. These technical problems are essentially similar to those involved in time series of national income, or cross-country comparisons of national product, and can be dealt with by the same sort of techniques(10). One of the most valuable results of measuring both manpower and expenditure, is the accumulation of data on the comparative costs of R. and D. activity. It is possible, for example, to compare the costs per research scientist in different industries or firms, or in the same industries in different countries. Thus, despite the practical difficulties involved in expenditure estimates, they are essential tools for economic analysis and policy decisions. Satisfactory national surveys must cover both expenditure and manpower.

4.5 Measurement of Expenditure: Capital Expenditure and Depreciation

The central principle adopted is that expenditure statistics should cover the full costs of R. and D. activity, that is all current operating costs including overheads and capital expenditure. One of the more difficult problems encountered in national surveys has been the treatment of depreciation in relation to capital expenditure. In principle it would be desirable to measure separately that part of capital expenditure, which is for replacement of the existing stock, and that part which constitutes a net addition to the stock. In practice, no country has succeeded in doing this. Some countries have, however, measured gross capital expenditure in all sectors on an annual basis, for example, Iceland and the Netherlands. The method which is proposed here is that which has been adopted in these two countries. It has two main features:

(i) The complete exclusion of all depreciation provisions for building, plant and equipment, whether real or imputed.

(ii) The separate measurement of the annual gross capital expenditure actually incurred by performers, irrespective of the method of finance the period over which this may be written off, or whether the expenditure is for replacement or an addition to assets.

This solution is proposed for three reasons. First, the actual sums set aside for depreciation are useless for purposes of international comparison, because of differences in tax laws. Thus, for example, in the United Kingdom, four-fifths of any capital expenditure shown to be for research purposes could be set against taxable income in the first year of its life, whereas in the German Federal Republic the normal rates for depreciation of capital equipment apply(11). Recently even more generous provisions have been made in the United Kingdom.

Secondly, in the general government sector no provision is normally made for depreciation of fixed assets. It is true that this is sometimes imputed, for example, for estimates of the net national product, but no satisfactory method for this calculation has yet been evolved(12). In the case of fixed assets for research and development the problem is more difficult as the variation in length of life of assets is greater. It is almost impossible to estimate the life of some research assets until after the event. Consequently even within a country, satisfactory comparisons between sectors cannot be made unless depreciation provisions are excluded, and aggregates for a national series cannot be compiled unless the sector totals are put on a comparable basis.

Thirdly, it is useful to know whether the cycle of capital expenditure for R. and D. purposes follows that for business investment in general, and the degree to which it is independent of other elements in its business cycle.

Thus, although for particular surveys it may be useful to collect figures on actual or imputed provisions for depreciation, it is desirable that these should be separately recorded and not included in a global figure of "current costs". In this way, valid inter-sector and international comparisons will be facilitated, and data on the real trend of capital expenditures assembled.

In measuring actual capital expenditure, small tools and instruments and minor improvements to existing buildings will normally be excluded, as in most accounting systems these items are carried on current expenditure accounts. All major items of equipment, apparatus, plant and pilot plant should be included, and all new buildings and major renovations or alterations to existing buildings. The boundary between "minor" and "major" items may vary slightly in different countries, according to taxation

practice, and between different firms and organisations in the same country, according to accounting practice. But these differences are rarely significant and it is probably neither necessary nor practical to insist on any rigid standard for this purpose. A breakdown between buildings on the one hand and apparatus and equipment on the other, is useful. In the case of buildings or other fixed assets which are shared between research organisations and other bodies or between research and "related activities", a proportion of the total cost must be allocated. In the case of buildings, this can probably be most easily made on the basis of the estimated use in hours or days. Legal payments or stamp duties in connection with the purchase of buildings should be included as part of the capital expenditure. Only the expenditure actually incurred during the given year should be recorded, even if this means dividing the total expenditure on a particular asset between two or more years.

4.6 Current Expenditure

In the scheme of measurement proposed here, current expenditure on R. and D. excludes actual or imputed provisions for depreciation. It includes:

(i) Wages and salaries and all related elements of labour costs (or "fringe benefits") such as bonuses, holiday pay, contributions to pension funds, payroll taxes and welfare expenditure.

(ii) Materials and equipment, other than major items of capital equipment, including books, journals, reference material, subscriptions to libraries, scientific societies, and so forth, whether incurred for individual research workers or for the research organisation as a whole. Including also the imputed or actual cost of prototypes or models made outside the research organisation.

(iii) Water and fuel, including gas and electricity.

(iv) Maintenance and repair of buildings and equipment. Rent and rates. Cleaning. Replacement of office furniture and fittings.

(v) Administrative expenses and a share of overhead costs in the case of research departments or institutes sharing premises or facilities with other parts of a large organisation. Including office expenses, telephone and telegraph, transport, travel, entertainment, printing and duplicating services, canteen facilities, storage expenses, accounting costs, insurance.

It will not normally be necessary, to require respondents in each sector to show annually a breakdown of their current expenditure into the above five or more sub-divisions. A global figure will usually be sufficient, but occasionally it will be necessary, whether by regular survey or by special sample enquiries, to obtain a detailed breakdown of current expenditure. This is needed first of all to provide data for comparison of R. and D. costs between different sectors, industries and organisations; secondly to provide the means for constructing indices of R. and D. costs. Such indices are essential for comparisons of expenditure over time and between countries.

As a general rule it is desirable always to measure R. and D. expenditure, both by the sources of finance and by the sectors of performance, or sub-divisions of these sectors. In itself, this is a check on the accuracy of the figures which are obtained, and it also gives an insight into the relationships between the various sectors of the economy. In order to measure the flow of funds between sectors, respondents to surveys are required to distinguish between "intra-mural" and "extra-mural" expenditure.

4.7 Intra-mural and Extra-mural Expenditure

"Intra-mural" expenditure includes all funds used for the performance of R. and D. within a particular organisation or sector of the economy, whatever the sources of finance.

"Extra-mural"expenditure includes all funds spent on the performance of R. and D. outside a particular organisation or sector of the economy. This includes the special case of expenditure on research performed abroad, here defined as "external" expenditure, which should however be separately recorded by respondents. Another category requiring separate measurement is expenditure on patents, licensing, and technical "know-how".

The sources of finance for intra-mural expenditure should be recorded and classified by sectors. For example, the research department of an industrial firm may receive money from the general government sector, and also for contract research performed on behalf of other business enterprises in addition to its own allocations for R. and D. These sources must be distinguished, so that it is possible to calculate, for example, for each branch of industry the proportion of expenditure financed by government. Income arising from the sale of prototypes or pilot plant or new materials developed in a research organisation, should be recorded, but it should on no account be deducted from the total of intra-mural expenditure. The same applies to income from the sale of patents, or income arising from licensing arrangements, or the sale of technical know-how (See Section V). If a research organisation sub-contracts part of its work to some other research organisation, this must be recorded as extra-mural expenditure to avoid double-counting. If work is performed by a "non-research" organisation, which will not be recorded in another respondent's return as "R. and D. activity", this should be treated as a purchase of equipment or services, and not as extra-mural expenditure. An example is the construction of a model, or the fabrication of specific components for a pilot plant.

Measurement of Extra-mural Expenditure on Research and Development

A business enterprise, or government department, or a non-profit institution which requires the performance of R. and D. work need not necessarily undertake this activity itself. There are various ways in which the work can be done on an "extra-mural" basis. Government departments may place research and development contracts with industrial firms, and in some countries this "extra-mural" expenditure is greater than the "intra-mural" expenditure of General Government. Enterprises themselves may place research contracts with each other, with universities, or with non-profit research institutes. In a somewhat different category are general donations for the promotion of research, without any specific contractual obligation on the part of the recipient. But these too should be measured in order to provide comprehensive data on the flows of funds for R. and D. Finally, the results of R. and D. performed elsewhere may be purchased by payment of royalties under licensing agreements, the outright purchase of patents, or the conclusion of arrangements for the sale or exchange of technical "know-how".

All of these transactions are important, but it is essential that they should be separately distinguished. Therefore, respondents to surveys in each sector are required to enter their extra-mural expenditure under two main headings: contract research and general donations: and to record payments for royalties, patents etc., separately. Each of these headings is sub-divided by sectors, and classified into "home" and "external". An example of the type of entry envisaged is part of the questionnaire

used in the Netherlands Survey of Research and Development (1959), which is shown in Appendix III and Appendix IV.

It will be noted that the classification of recipients of general subscriptions, grants and donations does not include business enterprises. This is for the obvious reason that nobody makes general donations to business enterprises in the Netherlands. Similar minor differences will apply to the questionnaires in various sectors in different countries, but the basic aim, whatever the local variations in design of the survey, will be to obtain a complete picture of the flow of funds from all organisations making extra-mural payments for R. and D.

Non-Performing Intermediary Organisations

This will include those in Category I.C.4, of the Netherlands form, even though they are not performers themselves. Well-known examples of such organisations outside the Netherlands are the Stifterverband für die Deutsche Wissenschaft, and the Deutsche Forschungsgemeinschaft in the German Federal Republic. Although such bodies introduce an extra complication for purposes of analysis of the flow of funds, the actual collection of data from them is relatively simple. As they are themselves concerned to promote R. and D. they are normally keen to assist in the collection of statistics, and in fact may take the initiative, as in Germany. Furthermore, as they are concerned almost exclusively with the acquisition and distribution of funds for R. and D., their accounts are comprehensive and relatively easily analysed.

But there is one important difficulty arising from the fact that they receive grants from several different sectors which are not "ear-marked" for any particular use. These may be distributed in differing proportions in other sectors, and some of them may be used by performers for purposes other than R. and D.

In the case of organisations which are purely intermediaries and not themselves performers, it is necessary to make an arbitrary convention on the sources and disposition of funds which are not "ear-marked" for a particular purpose. The sources of each grant are assumed to be in the same proportion as the total general income of the intermediary donors' organisation. For example, if a voluntary health fund derives 75 per cent of its general income from private individuals and 25 per cent from government, the recipients of its research grants whatever the amount may be will be deemed to receive their funds from these sources in the same proportion.

Government R. and D. Contracts

Government R. and D. contracts with industry present some special problems. Even though nominally designated as "R. and D." contracts, they may often include a procurement element or a "cost-plus" element. Alternatively, procurement contracts may include an R. and D. element of unknown dimensions. Consequently, although the budget figures of government departments provide a rough guide to the extent of R. and D. work financed by the government, they cannot be regarded as satisfactory substitutes for R. and D. estimates of the performers themselves. These estimates should be based on the same basic principles as those outlined above, and not on any separate principle, such as the inclusion of all expenditure incurred under a government R. and D. contract.

4.8 Adjustments for Non-research Activities

There is probably some tendency for specialised research establishments to over-estimate their R. and D. expenditure, as typically, a research organisation will be performing some non-research functions. It is necessary for the expenditure on these

activities to be deducted from the total expenditure of the organisation, and in the scheme proposed here, this calculation should be explicitly recorded. Respondents must in any case make this calculation so there seems to be no reason why it should not be used to furnish information on the extent of related activities carried out by research organisations. Normally, the calculation will probably be made, by estimating the percentage of man-hours devoted to various activities other than R. and D. and applying this to the expenditure figures. But sometimes, accounting procedures may have been designed to facilitate this type of analysis and introduce a greater degree of refinement. Obviously it is desirable to make some adjustment for major differences in costs other than manpower costs, such as equipment, materials and overheads, but it is impractical to insist on any elaborate system of accounts which would allow for all such variations. In the case of major items of capital equipment a precise allocation may often be possible if they serve either research or some other function.

In the case of organisations which are not primarily research establishments, there is probably some tendency to under-estimate their expenditure on R. and D. This will normally be due to the omission of indirect costs for personnel, who spend only a small part of their time on R. and D. work. It should be emphasised in the instructions to such respondents, that although the calculation of research expenditure may initially be based on a man-hour estimate, this should be applied not only to salaries and wages, but to all other items of cost including a share of overheads. This applies, particularly for example, to institutes of higher education.

In the case of respondents in the business enterprises sector, they should be requested to state whether they have a specialised R. and D. department. If they have such a department, they should show:

(i) The total intra-mural capital and current expenditure for this department, in the given year, including any expenditure for non-research activities.

(ii) The appropriate deductions for estimated capital and current expenditure on non-research activities. These may be classified to distinguish other scientific activities separately.

(iii) The estimated additional R. and D. expenditure incurred within the enterprise but outside the R. and D. department, for example, in production units.

4.9 Gross Expenditure on Research and Development (G.E.R.D.) within a country

Figures, collected from respondents in each sector of the economy, on their intra-mural and extra-mural expenditure and sources of finance, will make it possible to construct aggregates for each sector and for the country as a whole. Total expenditure on R. and D. within a particular country is here defined as "Gross Expenditure on Research and Development" (G.E.R.D.). This concept excludes all payments for patents, licences and know-how. It includes R. and D. financed from abroad, but performed inside the country; it excludes external payments or donations for R. and D. performed overseas. In the case of international enterprises, only that part of their R. and D. which is actually performed within the frontiers of the country concerned, is included. If the international enterprise imports the results of R. and D. performed by other associated or subsidiary concerns abroad, then the actual or imputed payments for this will be recorded, either under external extra-mural expenditure for contract research, or under external payments for patents, licences and know-how. Contributions by government to inter-governmental international research organisations, such as C.E.R.N., are

included in external payments. But the expenditure of such bodies in the countries in which their research facilities may be located should be excluded from the G.E.R.D. of the countries concerned. It will be also useful to supplement the figures for gross expenditure within a given country, with figures of gross expenditure by that country. This concept excludes R. and D. financed from abroad but performed within the country, but includes external payments for research performed abroad (although not external payments for licences and know-how, which are separately treated in Section V). In accordance with national income concepts, the territory of a given country includes, in addition to the territory within its political frontiers, ships, vehicles and aircraft operated by domestic carriers even while in the territorial waters or over the territory of another country, provided they are not exclusively employed on another country's territory.

Classification of G.E.R.D.

The G.E.R.D. within a given country may be sub-divided and classified in various useful ways. The principal forms of classification have already been discussed: by sectors of the economy, by the three main categories of R. and D., and by scientific fields. These forms of classification applied to the G.E.R.D. of any particular country will readily show, for example, the proportion of the total which is performed by institutes of higher education, or by business enterprises or by individual industries within this sector. They will show the approximate percentage of a country's G.E.R.D. which is spent on fundamental research or on applied research, and the amount spent annually in such fields as medical research, agricultural research, and (ultimately) social sciences research. Obviously, it is a simple matter to combine two or more forms of classification, as in the example shown in Appendix V, which indicates the expenditure on fundamental research in each sector of the economy.

Similarly it would be possible to show research in each scientific field by sectors of the economy. By combining the three forms of classification one can show, for example, the amount of basic research in chemistry in each sector of the economy. For some purposes, and particularly for analysis of economic sectors, the G.E.R.D. must be classified both in terms of performance and in terms of sources of finance. This is most easily done in the form of a simple standard matrix as illustrated in Appendix VI: (the figures are purely hypothetical).

It will often be possible to construct a more sophisticated and complex matrix than that shown above(15), but this model is sufficient for purposes of analysis of the main flows of funds between sectors. It is evident at a glance, for example, that the "intra-mural" expenditure of "general government" is $50 million, compared to $125 million of "extra-mural" expenditure in other sectors, consisting in all probability, mainly of R. and D. contracts with industry, general grants and funds for higher education, and supporting funds or grants for private non-profit institutes. Or, to take another example, it is evident that the higher education sector is not a source of funds for R. and D. in any other sector, but 50 per cent of the research expenditure in institutes of higher education is financed by the government, and 25 per cent from the private non-profit sector (charitable foundations, etc.). The matrix is based principally on data furnished by performers on their intra-mural expenditure and sources of finance. Data on extra-mural expenditure is used principally as a check, and to fill in gaps in the data furnished by performers. This method is preferred because source organisations may not know the actual disposition of their funds as between R. and D. and related activities or the actual year of the expenditure, or the extent to which sub-contracting takes place by performers.

A similar type of matrix may readily be constructed for the gross expenditure on R. and D. by a given country (as opposed to expenditure within the country). This matrix excludes the now showing "income from abroad" but includes an extra column showing external payments for R. and D. performed outside the territory of the country (See Appendix VII).

A more complex model which attempts to cope with the problem of intermediary organisations is shown in Appendix VIII, but to avoid over-elaboration, no proposals for standardisation of this type of presentation of results are made.

SECTION V: POSSIBILITIES OF MEASURING OUTPUT

5.1 Introduction

The output of research cannot be opposed to input in the sense in which the latter is normally used in economic terms. The output of research has implications which are not only economic, but also related to health, social and military questions, as well as to the disinterested search of knowledge. For this reason, the term "results" might be more apt than "output".

Precise measurement of output of research is impossible even in the economy. Correspondence cannot be established between the cost of a particular piece of research (in monetary or manpower term) and its economic results. However, correlations between the two can be found and other indicators, economic or otherwise, of the output of research can be sought. Generally speaking the crude quantitative presentation of these other indicators (number of patents, number of papers) should be avoided due to the overriding importance of quality factors, and more subtle indicators should be sought.

Measures of output have not yet reached the stage of development at which it is possible to advance any proposals for standardisation. In this field it is rather a question of encouraging further research, and already in terms of micro-economic analysis some useful work has been done on the output of R. and D. personnel. Among the measures which have been used with some success are patent statistics, lists of important inventions or innovations, the output of scientific papers, and the private or social returns accruing from a particular invention or development.

But all of these methods of measurement are open to objections if applied outside a rather limited field. For example, although it may be useful to list the major inventions in a particular industry and to investigate, the economic and social circumstances under which they were made, when it comes to measuring their relative significance or compiling a national aggregate, the problem of appropriate "weights" is almost insuperable. Furthermore, a measure of major "inventions" would necessarily omit altogether the myriad of minor improvements necessary for the satisfactory development of new products and processes. Similar objections apply to counts of the number of patents issued in a particular country over a certain period, see section 5.2.

Another hopeful possibility for output measurement is in studies of the output of scientific papers, and the National Science Foundation is conducting a research programme in this field. But this work will be of greatest value in the field of development activity. There are also some pioneering studies on the measurement of social and private returns on particular inventions, or the activities of particular research organisations. But each one of these studies involves exhaustive independent research and it is inconceivable that aggregate national measures could be derived from this type of detailed case study.

It seems inevitable that for some time to come it will not be possible to undertake macro-economic analysis and to make international comparisons on the basis of the measurement of output. It is important to be quite clear on the implications of this. It means that any variations which may exist between individuals, firms, industries or nations in the productivity or the quality of R. and D. activity will not be

measured. This is an important limitation, but it is one which applies also to measures of resources devoted to education, most activities in the government sector, and some other economic activities designated as "services".

5.2 Observations on the Use of Patents Statistics with a View to Measuring the Output of R. and D.

Patent statistics can be compiled at different periods from the time of invention.

Firstly, they can be compiled when the patent is applied for; a certain number of these applications will be rejected.

Secondly, they can be compiled at the time of issue of the patent. The period between application and issue varies from country to country, but it is generally longer in those countries which have a preliminary examination of patent applications, after which some applications are rejected.

Finally, patent statistics can be compiled several years (say five) after issue, when in certain countries, only those patents on which the annual fees have been paid remain in force. For the other countries a similar compilation can be made for those patents which have been declared void of novelty in legal patent suits. One can assume that this final compilation includes only those patents which are in fact being used.

However, the above statistics cannot give an indication of the total output of scientific research. The results of Fundamental Research hardly ever are patented. Furthermore, certain inventions are not patented.

There may be legal restrictions to patenting; for example, in France pharmaceutical products cannot be patented. Also, certain inventors may prefer to keep their inventions secret, or to publish them; - above all when novelty of a patented invention is difficult to uphold. Finally, there exist special rules for inventions related to National Defense.

There are a few difficulties involved in the use of patent statistics, the problem of appropriate weights is difficult and there are additional problems such as differences between firms or other agencies in patent policy. Nevertheless patent statistics are a fruitful source of information on particular industries of countries, although not yet satisfactory or purposes of international comparison of overall R. and D. activity.

5.3 Measurement of Expenditure on Patents, Licensing and Technical Know-How

Payments for patents, licensing and technical know-how are a distinct category which should be clearly distinguished from all other extra-mural and intra-mural expenditure. But although a distinct category and often neglected, they are extremely important. It is evident that no single country can lead simultaneously in all spheres of R. and D. Nor can any business enterprise be permanently ahead of all its competitors. Each country (or enterprise) will wish to "import" some of the results of R. and D. performed in the past elsewhere. This applies with particular force to small countries (or enterprises) where size is itself a limiting factor; and also to underdeveloped countries, and technologically backward industries. But it is also true of the largest countries such as the United States and U.S.S.R. Science and technology have always been and will remain essentially international in their character.

Consequently it is desirable to obtain some measure, however imperfect, of the transfer of research results and technical know-how from one country to another. A large part of this transfer, especially in the field of basic research, takes place without any payments, as the results are freely published and accessible to all. But some rough indication of the magnitude of the remaining flow, and of the "technological balance of payments" for any individual country, can be obtained by collecting information on patent, licensing and "know-how" expenditure. Such data must cover both receipts and payments. These statistics have two advantages compared with those based simply on numbers of patents registered. First, they are "weighted" by the valuation placed by the world market on a particular patent or licence. The market is of course very imperfect and so is the "weighting" but it is better than none. Only inventions of some economic significance will be the subject of licensing arrangements. Secondly, they include expenditure on inventions and developments which are not patented for a variety of reasons. This expenditure takes the form of payments for "technical know-how", and there is very little doubt that it is increasing rapidly.

What is true of countries is true also of individual enterprises. No firm is self-sufficient, and studies which have been made of the largest firms, with highly developed research facilities, suggest that frequently they depend to a large extent on the acquisition of the results of R. and D. performed elsewhere, often by means of licensing arrangements or technical know-how agreements.

For all these reasons, a measure of this flow of funds is desirable, both within a particular country and between countries. There are, however, serious defects of these statistics relating to the transfer of know-how between parent and subsidiary companies or associated companies. In some cases this is paid for in the normal way as a market transaction, but in other cases, there are probably also delayed or fictitious payments, or inflated payments, made with an eye on the tax position as between various countries. Some of these defects could be overcome by requesting enterprises (and other organisations benefiting from similar arrangements) to assign an imputed value to the know-how which they acquire from parent or associated companies. This valuation would be based on the price which would have to be paid on the open market for the transfer of the patents, licences or know-how which is received.

In some cases, statistics on external payments and receipts for patents, licences and know-how are obtained quite independently of R. and D. Surveys, for example, as a group of invisible transactions for balance of payments statistics, or by patent offices. If these statistics are sufficiently comprehensive it may not be necessary to include these questions within the framework of an R. and D. Survey. But in most cases it will be necessary, as it is desirable to obtain the figures with the same sector and industrial breakdown as other R. and D. statistics, and to cover the flow of payments within a country as well as outside it.

Some of these payments, such as the outright purchase of patents, may be regarded as a form of capital expenditure; others, such as royalties, as current expenditure. But it does not appear essential to attempt a classification of this expenditure along these lines.

SECTION VI: CONCLUSIONS

The standard scheme proposed here would permit international comparison of the Gross Expenditure on R. and D., of the principal sectors and industries, of the sources of finance, of the main fields of expenditure, of external expenditure, of the degree of specialisation of research organisations and of the expenditure and receipts for patents, licensing and know-how. Further, it would permit comparisons of the ratio of G.E.R.D. to G.N.P., of the ratio of R. and D. expenditure to net output in particular sectors or industries, the ratio of government R. and D. expenditures to other Budget outlays and so forth. Similar types of comparison are possible in the case of statistics of scientific manpower employed in R. and D. A few O.E.C.D. Member countries have already measured their R. and D. activity largely along these lines. But most have not, and a general move in this direction would represent a substantial advance. For one reason or another, not all countries will be able or willing to adopt all the standard conventions suggested here, but so long as the divergences are clearly defined and measurable, satisfactory international comparison will be possible.

The measurement of R. and D. is still in its early stages. Its level has been compared to that of national income statistics before the second World War. It is quite evident that there are still important conceptual and practical problems to be resolved, and that margins of error for some estimates are still too large for satisfaction. Nevertheless, even with their present imperfections, these statistics have already proved their worth as useful tools for analysis and policy formulation. All forms of measurement involve successive approximations and constant improvement and refinement of concepts and methods. This process will continue in the case of R. and D. statistics too.

It may be useful here to indicate some of the main lines of work, which are necessary for the improvement of these series. It would of course be completely Utopian to imagine, that all minor errors of computation and judgement could be eliminated from respondents' returns. It is well-known to statisticians that long-established economic series, with a justified reputation for reliability and low margins of error nevertheless contain innumerable minor errors in the individual returns of respondents. This is true, for example, of foreign trade statistics and employment statistics, not to mention most of the components of national income series. However, owing to the operation of the law of large numbers, in most cases these minor errors are mutually compensating and cancel each other out. Consequently small errors by respondents can be disregarded provided there is no systematic bias in any one direction.

In the case of R. and D. statistics it would be useful to find out, by detailed case studies and investigations in several countries, whether there is evidence of systematic bias in the returns of respondents on some doubtful questions. One obvious example is the treatment of developments costs, and trial production in such industries as the aircraft and motor vehicle industries. Detailed comparison of the R. and D. estimates of enterprises in the same industries, but in different countries, would be very useful for this purpose. Interviewing would be essential for satisfactory results. Another field for further study is the detailed analysis of government extra-mural R. and D. contracts. A third example is the whole treatment of non-research "related activities", carried out by research organisations.

A special problem requiring investigation is the R. and D. work of "international companies" operating in many different countries, such as the oil companies. The convention suggested here of measuring the R. and D. performed within each country, and attributing this only to the G.E.R.D. of the country concerned, is not wholly satisfactory and it might be possible, in co-operation with economists in such enterprises, to evolve a more satisfactory solution. Its importance may be gauged by examining the industrial R. and D. expenditure of the Netherlands. Four large international companies account for over half of the total expenditure(16). It was not possible to classify these companies by industry, so that although the Netherlands Survey is an extremely competent piece of work, this detracts considerably from its value for purposes of industrial analysis. Partly, of course, this is a problem of the possible identification of confidential data relating to individual firms. It must be hoped in this connection, that the great majority of firms will follow the example of those, who have already begun to publish data on their R. and D. expenditure and manpower, with their annual report and accounts. Provided that standard definitions are used, this would very much facilitate international studies and comparisons.

Another field where there is considerable need for further research work is on survey techniques in the higher education sector. At the Frascati Conference Member countries agreed to submit papers describing their experience in this field, where the problems of separating teaching from research expenditures and measuring part-time employment are particularly difficult.

In addition to research on ways of improving the existing measures, it is also essential to evolve new measures, and explore new fields. It is to be hoped, that the O.E.C.D. will initiate work on the measurement of all related scientific activities, and of research in the social sciences, so that this manual will be only the first stage of a prolonged effort in this vital, but hitherto neglected field of statistics. Continuous attention will also be needed to improve the concepts and conventions established in this manual and to keep them abreast of new developments in Member countries.

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(16) Central Bureau of Statistics, The Hague, op. cit. Table 9.

APPENDIX I

Suggested Standard Classification of Business Enterprises Sector and Reconciliation with International Standard Industrial Classification (I.S.I.C.)

Sub-Divisions	I.S.I.C. Group Numbers
I. Agriculture, forestry, hunting and fishing	01 - 04
II. Mining and quarrying	11, 12, 14, 19
III. Manufacturing	20 - 39
Food and drink	20.21
Tobacco	22
Textiles	23
Clothing and footwear, leather	24.29
Wood, cork and furniture	25.26
Paper	27
Printing and publishing	28
Petroleum refining and extraction	32.13
Drugs	Part of 31
Chemicals	Part of 31 (excluding drugs)
Rubber products	30
Stone, clay and glass	33
Ferrous metals	Part of 34 (34.1)
Non-ferrous metals	Part of 34 (34.2)
Fabricated metals products	35
Machinery, excluding electrical	Part of 36
Instruments	Part of 36
Other electrical machinery and apparatus	Part of 37
Aircraft and missiles	Part of 38 (38.6)
Motor vehicles and parts	Part of 38 (38.3)
Shipbuilding	Part of 38 (38.1)
Other transport equipment	Part of 38
Other manufacturing	39

Sub-Divisions	I.S.I.C. Group Numbers
IV. Utilities: construction, transport, commerce and services	40 - 90
Water-works, sanitary services	52
Electricity, Gas	51
Construction	40
Transportation, storage	71 - 72
Communications	73
Wholesale and retail trade, banking, insurance real estate, ownership of dwellings, and miscellaneous services	61 - 64, 83, 85 Part of 84
Engineering and Technical Services	Part of 84
Other activities	90

APPENDIX II

Classification by Scientific Fields

Column 1 Principal fields	Column 2 Sub-division of principal fields
A. Natural Sciences	1. Mathematics 2. Physics, mechanics, electronics, astronomy 3. Chemistry, physical chemistry 4. Biology, botany, zoology, bio-chemistry, bio-physics 5. Geology and earth sciences, meteorology, geophysics 6. Other
B. Engineering	1. Metallurgy, mining 2. Mechanical 3. Construction, civil 4. Electrical 5. Aeronautical 6. Chemical, fuel and petroleum technology 7. Textile 8. Geodesy 9. General technology and applied science 10. Other
C. Medical Sciences	1. Medicine 2. Dentistry 3. Pharmacy 4. Other
D. Agriculture	1. Agronomy, rural science 2. Forestry, horticulture 3. Dairying, animal husbandry 4. Veterinary science 5. Other
E. Social Sciences	1. Political science, diplomacy 2. Economics, commerce, banking 3. Sociology, ethnology 4. Other
F. Humanities and Fine Arts	1. Humanities 2. Fine Arts 3. Education 4. Other

APPENDIX IIa

Classification of Scientific Disciplines

Mathematics

- Algebra
- Theory of numbers
- Logic
- Functional analysis
- Topology
- Geometry
- General mechanics and engineering
- Probability and statistics
- Numerical analysis
- Applied mathematics
- Other mathematical disciplines

Physics

- Theoretical physics
- Mechanical physics
- Accoustics
- Thermodynamics
- Electricity
- Electronics
- Electronphysics
- Electromagnetic rays
- Optics
- Nuclear physics
- Atomic and molecular physics
- Physics of fluids
- Solid state physics
- Other disciplines in physics

Chemistry and Metallurgy

- Physical chemistry
- Analytical chemistry
- Chemical engineering
- Mineral chemistry
- Cements, ceramics
- Metallurgy
- Organic chemistry
- Agricultural and food chemistry
- Biochemistry
- Other Chemical disciplines

Astronomy and Meteorology

- Astronomy
- Space physics and astronautics
- Synoptic meteorology
- Specialised meteorology
- Meteorological equipment
- Other meteorology

Interdisciplinary subjects

- General geophysics
- Geophysical prospecting
- Geochemistry
- Soil sciences
- Hydrology, hydrography
- Oceanography
- Others

Technology

- Aeronautics
- Construction and civil engineering
- Sanitation engineering
- Equipment machinery
- Mineral exploitation and petrology
- Scientific work study
- Other technologies

For the Record

- Earth sciences
- Life sciences
- Psychology
- Human and social sciences

Source: N.S.F.

APPENDIX III

Netherlands Research and Development Survey:
Extract from Questionnaire relating to extra-mural expenditure (13)

I.B. Expenditure in 1959 on research and development performed by order of your enterprises by:

		Total	of which, payment abroad
		(Guilden)	
1.	Universities and colleges	....	....
2.	Netherlands Organisation for Applied Research (T.N.O.)	....	....
3.	Other research institutes	....	....
4.	Manufacturing industries	....	....
5.	Other industries	....	....
6.	Others	....	....

A similar breakdown should be made for each of the other main categories of extra-mural payments. The next section of the Netherlands questionnaire does this for general grants and donations.

APPENDIX IV

Netherlands Research and Development Survey:
Extract from Questionnaire (14)

I.C. Subscriptions, grants, donations, etc., for research and development purposes, in 1959, paid to:

	Total	of which, payment abroad
	(Guilden)	
1. Universities and colleges	....	....
2. Netherlands Organisation for Applied Research (T.N.O.)	....	....
3. Other Institutes which perform R. and D. themselves	....	....
4. Organisations which do not perform R. and D. themselves but which restrict their activities to financing and co-ordinating R. and D.	....	....
5. Others	....	....

APPENDIX V

Expenditure on Fundamental Research, Applied Research and Development in Country A by Economic Sectors ($ millions)

Sector of Performance	Fundamental Research	Applied Research	Development	Total
Business enterprises	10	45	145	200
General Government	5	15	30	50
Higher education	30	10	0	40
Non-profit institutes	5	5	10	20
Total	50	75	185 G.N.E.R.D.	310

APPENDIX VI

Standard Matrix of the G.N.E.R.D. of Country A
(expenditure within the territory) ($ millions)

Source of funds \ Sector of performance	Business Enterprises Sector	General Government Sector	Private non-profit Sector	Higher Education Sector	Total Sources of Finance
Business Enterprises Sector	100	-	5	5	110
General Government Sector	100	50	5	20	175
Private Non-profit Sector	-	-	10	10	20
Higher Education Sector	-	-	-	5	5
From Abroad	10	-	5	5	20
Total cost of Research and Development in each sector	210	50	25	45	330 (G.N.E.R.D.)

APPENDIX VII

Standard Matrix of the Gross Domestic Expenditures on Research and Development by Country A including external payments

Source of funds \ Sector of performance	Business Enterprise Sector	General Government Sector	Private Non-profit Sector	Higher Education	External payments (abroad)	Total
Business Enterprise Sector	100	-	5	5	5	115
General Government Sector	100	50	5	20	5	180
Private Non-profit Sector	-	-	10	10	-	20
Higher Education Sector	-	-	-	5	-	5
Total Research and Development in each Sector	210	50	25	45	10	320

APPENDIX VIII

Sources, Performers and Intermediaries: Matrix by Herbert E. Striner - John Hopkins University

Source of funds		Performers - Intermediaries performing R. & D.				
		General Government	Higher Education	Private Firms	Private Int.	Total
Gen. Govt.	1	50				50
	2	(15)	(20)	(15)		(100)
Gen. Govt.	3		20			20
	4		(20)			(20)
Gen. Govt.	5			100		100
	6		(10)	(80)	(10)	(100)
Gen. Govt.	7				5	5
	8				(5)	(5)
Higher Ed.	9		5			5
	10		(5)			(5)
Private	11			100		100
Firms	12		(5)	(90)	(4)	
Private	13				10	10
Int.	14		(1)		(9)	
Funds received directly		50	25	200	15)	
Funds spent for R. & D.		15	62	185	28)	290

Source: N.S.F.

APPENDIX IX

"Criteria and Categories of Research"

For the purpose of ascertaining whether a known single or aggregate expenditure constitutes a research expenditure or expenditure outside the field of research, the definitions given in section II may be complemented by a method of examination using more detailed criteria. These same criteria also enable a finer distinction to be made between fundamental and applied research as well as between applied research and development.

In accordance with the method proposed, 3 basic criteria remain which concern respectively:

- the aims of research
- the findings of research
- the type of research work

Each of these three criteria may be expressed in one or more impersonal and objective, or else personal and subjective forms, thereby enabling many differences of interpretation to be avoided. The attached table contains the terms in which we propose to designate these criteria; many other definitions are possible. Those submitted here have been the subject and are the direct result of a survey carried out in France by the Délégation Générale à la Recherche Scientifique et Technique.

Criterion No. 1. or criterion of the aims of research

The impersonal form of this criterion concerns the course of intellectual action planned for the research operation; this calls for a scale of abstract key-words denoting a sequence of attitudes in man's mastery of phenomena:

Identification of a phenomenon or at least of some of its parameters: this a routine activity research as in the earth sciences, astronomy or archaeology;

Classification - the classification of phenomena is one of the most effective methods of imparting knowledge. The descriptive sciences frequently afford examples of this;

Comprehension - in a restricted sense; i.e. the formal explanation of phenomena. Analogies, as in the physical sciences are often used to this end, but certain aspects of mathematical sciences may also be put forward, in which models provide elements of comprehension.

Anticipation - anticipation logically is a sequel to comprehension, but in an empirical approach may precede it;

Modification of natural phenomena, and often of their development in time; as in an attempt to influence the course of an illness or the trend of an atmospheric disturbance.

To achieve modification local conditions are generally created so that the modified phenomenon can be predicted; chemistry provides numerous examples; (1)

Application of the phenomena, or of the products and processes which induce them. These products and processes ultimately make up the elements of man's well-being and the instruments of human action.

However, these stages of intellectual creation are not absolutely distinct one from another, as can be seen from the overlapping of key-words between columns I, II and III.

In the personal and subjective form of this aim criterion, research or rather organisation of research generally appears to aspire towards the satisfaction of needs: first, the need for knowledge; second, the need to know how to operate, act or produce; and third, the need to know how to proceed under a set of conditions imposed by concrete facts and by the existence of an economic organisation of society.

These few reflections may help to classify the aims of research. It must however, be acknowledged that these aims often elude serious investigation: they are not fixed in time and vary according to the points of view adopted by different persons at different levels of a hierarchy. This criterion, while useful as it stands must be supplemented and cross-checked after the research by the examination a posteriori of other criteria:

Criterion No. 2 or criterion of research findings

The criterion of results, in both its impersonal and personal forms, seeks to apprehend the object together with the value of such creation to the social economy (or at any rate the value it might have had, whether in case of success or failure).

The findings of so-called fundamental research, that is, the knowledge gained, the doctrine established or the general law defined, usually add to a stock of knowledge that can only be used later through new research, such as applied research. From another angle, this means that the knowledge is non-negotiable, and it is therefore freely divulged.

In the category of applied research, the findings as a rule provide a primary element which can be used for a product, operation or method, and which can, although perhaps not universally, be applied to certain types at any rate of particular in unspecified cases. The outcome is that the more clearly the possibilities of application and the field of application emerge, the more research findings will take on a subjective value and become negotiable, the corollary being its control through secrecy and by patents.

The next obvious step is development research, which consists in defining each and every condition - in keeping with the technical progress achieved - of the specific use to which the originally discovered primary element will be put. Those whose task it will be to negotiate such a result must obviously be cognisant of the completeness of the development work and determine whether the invention is in every way prepared for an industrial innovation. Incidentally, the completeness of work already gives it a certain

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(1) It is important to note that, in this instance, the "modifying" aim of research is quite distinct from the experimental method used; very often the art of the experimenter consists in so modifying a phenomenon as to force it into a simple form; this particular modification is therefore a method or device serving to achieve the aim of research.

publicity value, at least from the prestige angle, which should not be confused with the publicising of basic findings; this paves the way for the association of promotional publicity with extra-research activities, which is a function other than that of publicising research.

Criterion No. 3 or criterion of the type of research work

This criterion may be considered from many different angles, some of which come under what has been designated as the impersonal form, and others under the personal form.

Under the impersonal form, we propose special consideration of the following admittedly arbitrary headings;

- Structure of the work:

theoretical and speculative - speculative and constructive - constructive and possibly semi-repetitive (or partially repetitive) would then be the key-words respectively denoting the type of work in the three categories of fundamental research, applied research and development research.

- Organisation of the work;

unrestricted - guided - supervised would similarly denote the degree of freedom enjoyed by the person with research responsibilities in our three categories.

- Time allowed:

unspecified - suggested- specified and imperative would represent the same sequence.

- Cost:

in statistical terms, the overall costs of research in the three categories would respectively be proportionate to such co-efficients as 1, 10, 100 in order of magnitude. Unfortunately these costs represent capital investment and a simple comparison cannot be made with the current operating costs resulting from a research project.

In the personal form, the criterion of the type of work might be designated "quality and experience of the research worker". But the difficulty then is to fix and standardise the personal qualities of the ideal research worker. Tentatively, we propose the consideration that these ideal qualities become increasingly diversified as the work draws nearer to practical industrial application; or again, the more or less openly expressed leanings and desires of research workers and engineers: the natural tendency of the former is to take up basic research, and of the latter to take up development research, or even manufacturing or some aspect of production proper.

In the various aspects of this criterion, care must be taken to avoid any confusion with the earlier criteria or findings and aims; in this instance, the examiner must judge neither the intentions that have directed the research, nor the quality of the findings achieved, but the conditions, taken as a whole, in which the research actually took place. Criterion No. 3 is thus an "a posteriori" criterion, like criterion No. 2.

Without offering any absolute value, these criteria may be extensively applied: they may be used in examining research operations and very often they make it possible to distinguish ancillary activities without recourse to standard definitions. Finally, this present method of definition by separate criteria, if used in conjunction with a questionnaire for a survey of research activities, will guide the replies and shape the findings into a homogeneous whole.

DELEGATION GENERALE
A LA RECHERCHE SCIENTIFIQUE
ET TECHNIQUE

CRITERIA AND CATEGORIES OF RESEARCH

April 1963

CRITERIA	CATEGORIES	I. FUNDAMENTAL RESEARCH	II. APPLIED RESEARCH	III. DEVELOPMENT RESEARCH	IV. NON-RESEARCH
FORM OF CRITERIA	CRITERION No. 1 AIMS				
(a) IMPERSONAL	OBJECTIVES OF INTELLECTUAL APPROACH	- Identification (of: - Classification (a problem - Comprehension (a phenomenon - Anticipation (a method	- Comprehension (of: - Anticipation (a phenomenon - Modification (a method	- Anticipation (- Modification (- Application (	Reproduction of a method in order to make use and ensure the distribution of a product or service
(b) PERSONAL	GOAL OF RESEARCH	- Satisfaction of the need for knowledge	- Satisfaction of the need to know how to operate or produce Guide towards achievement	- Satisfaction of the need to know how to operate under optimum practical (and economic) conditions Guidance towards effective achievement	- Satisfaction of the need to maintain an undertaking by providing services to customers (also valid for public institutions or non-profit-making concerns).
	CRITERION No. 2 RESULTS				
(c) IMPERSONAL	OBJECT CREATED	- Acceptable item of knowledge or theory - Body of doctrine or of coherent method - Abstract general law	- Principle applicable to a number of specific cases - Concrete process or device	- Detailed definition of performance and conditions of specific application of a principle, process or device (this definition includes the factors governing collective distribution: cost, safety, standards, etc.)	- Application, usually repetitive, of a principle, process or device N.B. In the case of performance of certain services (e.g. engineering), a single object can be constructed without thereby coming under the heading of research
(b) PERSONAL	VALUE OF FINDINGS	- Can only be used for research objectives - Non-negotiable (no commercial value) - Published	- Can seldom be practically applied without any definition of specific conditions - Negotiable - subject to secrecy and patents	- Can be used immediately. Prepared for industrial innovation - Negotiable - subject to secrecy and complexity of know-how (publicity value of the overall findings).	- Product or service is negotiable and has a widespread social and economic impact - Publicising of the use and advantages of the product or service
	CRITERION No. 3 TYPE OF WORK				
(a) IMPERSONAL	STRUCTURE	- Theoretical and speculative	- Speculative and constructive	- Constructive and possible semi-repetitive (the latter depending on the quality of results)	- Productive, repetitive and standardised N.B. The supervision and optimisation of production involve no uncertainty and are excluded from research
	ORGANISATION	- Unrestricted - Freedom of research organiser	- Guided - Freedom of research organiser restricted	- Supervised, tendency towards graded programming	- Programmed and supervised
	TIME ALLOWED	- Unspecified (often very long)	- Time suggested	- Specified and imperative	- Checked continuously
	COST	- Co-efficient 1	- Co-efficient 10 (order of magnitude)	- Co-efficient 100 (order of magnitude)	- Current operating costs
(b) PERSONAL	QUALITY AND EXPERIENCE OF PERSONNEL	- Intellectual ability essential	- Intellectual ability and powers of observation important	- Diversified abilities: need for fusion	- Highly diversified abilities

Natural tendency of research worker

Natural tendency of production engineer

Range more especially covered by the engineer

APPENDIX X

Types of Work done by the Research and Development Staffs of 239 Firms

	Type of work	Percentage of firms reporting
1.	Basic and fundamental scientific research	49
2.	Laboratory or small-scale investigation of possible new materials and purchased components	73
3.	Trying out new raw materials and purchased components in the factory or works	65
4.	Establishing specifications for raw materials and purchased components	57
5.	Routine testing of raw materials and purchased components	43
6.	Research on methods of testing raw materials and purchased components	49
7.	Designing modifications to existing machinery for own use	56
8.	Design and development of new machinery for own use	56
9.	Construction of prototypes of new machinery for own use	49
10.	Trying out new machinery in the factory or works	41
11.	Small-scale investigations of new methods of production	74
12.	Testing new methods of production in operation	54
13.	Production control	17
14.	Testing for control purposes	37
15.	Laboratory or small-scale investigation of new processes	75
16.	Testing new processes in operation	60
17.	Routine testing of products	36
18.	Research on methods of testing products	74
19.	Design of new products	74

Type of work	Percentage of firms reporting
20. Development of prototypes of new products	75
21. Testing prototypes	71
22. Development of components	48
23. Production of prototypes	45
24. Running pilot plant	44
25. Work study	10
26. Methods engineering	8
27. Operational research	13
28. Research on industrial health and safety	10
29. Technical services to customers	51
30. Technical sales	17
31. Market or sales research	10
32. Investigation of customers' complaints	54
33. Training of personnel	36
34. Statistical services to production department	16
35. Library services	49
36. Other technical services to manufacturers' departments	28

Source: Dr. E. Rudd op. cit.

APPENDIX XI

Outline for the analysis of State expenditure by financial source

1. General Research

   A. Research connected with higher education (research in Universities, associated institutes and specialised institutes of higher learning)

   B. Special research activity at national level (1) in France: joint research activities of the D.G.R.S.T.; in the United States of America; research activities and subsidies by the N.S.F.

2. Priority Sectors

   C. Nuclear research)
   D. Space research) distinguishing between (non-military research (military research

   E. Military and defence research (excluding nuclear and space research - see C. and D.)

3. Special Activity Sectors

   F. Agriculture, fishing and forestry

   G. Construction, building and town-planning

   H. Transport: roads and bridges, merchant marine, civil aviation, meteorology

   I. Telecommunications

   J. Health, hygiene (excluding medical research in Faculties of Medicine, included under A.)

   K. Industry: (various subsidies and financing of government research bodies where they exist, including mining and quarrying)

   L. Research on behalf of arid or underdeveloped areas

   M. Miscellaneous (to be specified)

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(1) This refers to research activities for which programmes and financial machinery have been established in several countries at national and often at interministerial level.