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MULTI-LEVEL PLANNING IN FUNDAMENTAL RESEARCH

Gabriel Minder

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Summary

The methods of medium-term planning employed in a large fundamental research laboratory are described in this study. They are based on an information system using functional ways of presenting various types of activity and providing the individual components for analytical models. The planning methods used by the research centre are shown to be fully integrated into those of the scientific discipline and make it possible to coordinate research units and their supporting departments. High-energy physics in Europe and the Geneva-Meyrin Laboratory of the European Organization for Nuclear Research (CERN) are used as illustrative examples.

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Introduction and prospects

For some ten years now, an increasingly pressing need has been felt in the field of fundamental research for planning and organization. The causes for this need are the rapid increase in the extent of the equipment and facilities required and the importance of fundamental research to every country's cultural, social, economic and political progress.

The simple, straightforward application of planning methods developed by industry and large administrative bodies for their projects or applied research was clearly unsuitable. Such methods are indeed based on the concept of an accurate assessment of the value of products, a concept as foreign to fundamental scientific research as it is to literature and the arts.

Profound analyses of scientific work(1,2) and discussions at high international level(3,4) have resulted in the formation, within the philosophy of science generally, of a "science of science", by means of which the scientific phenomenon is gradually becoming understood. This study is intended as a contribution toward the methods side of this field by putting forward some bases for planning which the author has developed while working at a large centre for fundamental research: CERN, at Meyrin (Geneva).

There are still very few examples of effective international collaboration in fundamental science. However, particle physics, also referred to as high-energy physics, and the European Organization for Nuclear Research do rank among them. The concerted and considerable effort made by Western Europe (thirteen countries and about 800 million Swiss francs in 1968) makes it possible for three thousand European research workers to operate at the same scientific level as that obtained in the United States and the Soviet Union, and also gives them some assurance that this level will be maintained over a considerable period of time. At world level, this is an essential condition for both cooperation and competition, both of which provide for scientific progress. Because of its general nature, it is hoped that this study may help to extend this experience to other disciplines and other research centres. The basic concepts put forward are also intended to help in the construction of analytical models and the application of modern management methods. The work is likely to encounter many problems, since it has proved difficult to integrate models even in fields into which investigations have been made for a long time, like economics or industrial production(5). Nevertheless, it would be now only right and proper for management to render science the services which it has been receiving from science over the first few decades of this century. The purposes of this study will have largely been fulfilled if it finds a use as a basis for work in this direction.

CHAPTER 1

Context and scope of this study

11. Main features of fundamental research

111. Definition

By fundamental, pure or basic research is meant "work undertaken essentially with the aim of pushing back the limits of scientific knowledge without necessarily having any specific pratical use in view"(6), unlike the case of applied research and technical development. This definition has deliberately been made slightly vague. It is, in fact, becoming ever more difficult to draw a borderline between fundamental and applied research. In physical sciences, for example, it is usually only in those disciplines which explore the infinitely large, like astronomy, or the infinitely small, like elementary particle physics, that the fundamental laws governing space, time, matter and energy and their interrelationships(7) are discovered. The other disciplines apply known fundamental laws to matter and thus come perceptibly closer to the field of practical use. This latter remark also applies to molecular biology and psychology, for example. Over the past few years, something new in science has begun to appear, particularly in the field of space research, namely "oriented" fundamental research aimed at obtaining new basic knowledge required for practical purposes, which thus falls somewhere between fundamental and applied research(8). No longer, therefore, is fundamental research something abstruse and isolated; it is now becoming integrated into modern life.

112. Role of fundamental research

The prime features of fundamental research are recognized as being threefold(9), viz;

1. increasing the extent of knowledge for its own sake, to satisfy man's innate curiosity;

2. the influence upon each other of fundamental research and education;

3. fundamental research as a long-term investment. In this connection, the importance of this development, on the one hand to the economics of peace and war, and on the other to social progress, must be recognized(10).

Finally, the leading part played by international cooperation in fundamental research must be emphasized. It is, in fact, an absolute essential in "mega-science"(11) and is, at the same time, a splendid opportunity(12) for countries to come together in an area beset with relatively few political and economic difficulties.

113. Execution and financing

Research work is carried out by two types of institution:

a) the university, which traditionally gives it a stimulating, inter-disciplinary atmosphere;

b) non-university institutions, set up by the state or by other organizations, either profit-making or not, to make use of facilities not available to the universities ("mega-science"). There has been a considerable increase in research in institutes since the second world war. The data collected by the OECD for the International Statistical Year on Research and Development show that, as early as 1963/64, most of the industrialized countries were devoting more than half of their fundamental research budgets to non-university institutions(13), a feature which coincides with the growth of "mega science" and "oriented" research. This increase in the growth of such institutions will probably not, however, continue at the same rate, in order to preserve the link and balance between research and higher education.

Since science is generally recognized as being of national importance, it is mainly the state which supplies the funds for it, although, especially in the United States, industry and private foundations make a great contribution to its budgets. Here again, as industry has an increasing tendency to enter "oriented" fundamental research and as research workers increasingly call upon industry for the development of their equipment, the old borderlines become blurred and the interests of the public authorities, higher education and private enterprise tend to merge.

114. Scientific policy

In view of the predominance of the state in fundamental research, it is quite understandable that the public authorities have been led to formulate a scientific policy, whatever the economic and political system in force in their country. By this is meant deliberate government action in financing, encouraging and developing the scientific resources of the country, including qualified research workers, laboratories and equipment(14). The main difficulty in deciding the broad lines of such a policy is in finding standards by means of which the total effort can be decided upon and the priorities to be accorded to rival disciplines fixed. Those used, of course, vary from government to government.

The definitions drawn up in 1964 by the OECD in the "Frascati Manual"(15) have recently enabled a comparison to be made between the extent of the national effort in different countries. The table below shows that the United States and the industrialized countries of Western Europe devote between 12 and 27% of the money allocated to research and development to fundamental research, a figure equivalent to 1 to 5‰ of their gross national product(16).

Table 1

Annual expenditure on fundamental research(16)

Country	In absolute terms expressed in $ US	In relation to total expenditure on R and D %	In relation to the GNP ‰	Per inhabitant $ US
United States (1963/64)	2 610	12.4	4.2	13.7
United Kingdom (1964/65)	270	12.5	2.9	5.0
France (1963)	225	17.3	2.8	4.7
Italy (1963)	55	18.6	1.1	1.1
Belgium (1963)	30	20.9	2.1	3.1
Norway (1963)	10	22.2	1.6	2.5
Austria (1963)	5	22.6	0.7	0.7
Netherlands (1964)	90	27.1	5.2	7.4

115. The research workers

The human element does, of course, remain the essential factor in scientific progress. Even in "mega-science", the annual cost of equipment is usually lower than that of the scientific, technical and administrative staff responsible for designing and operating it. The main problem, one which is primarily the responsibility of the universities, is to identify and encourage first-rate research workers; as is well known in the field of research, the best work is considerably more valuable than work which is merely good. Studies of scientific creativity conducted over the past few years have shown that, apart from the essential atmosphere, support and facilities, other factors governed by planning and organization greatly affect the researcher's work. A few conclusions found fully valid by the author are given below:

1. The success achieved by a scientific research worker depends to a considerable degree on his readiness to change his approach to problems and his methods in relation to the cumulative results of both his own work and that of other researchers, often working in places far distant from him(17). He must be convinced, on the one hand, that his programme is as flexible as possible, and on the other, that he is immune from the effects of random alterations in scientific policy.

2. The research worker must not feel weighed down by the administration, neither by the time he has to devote to it, nor, indeed, by a complex system of demarcation lines of administrative channels. He must, however, be prepared to take part in certain important administrative procedures, in accordance with his scientific and hierarchical status.

3. The research worker should not be "feather-bedded". Researchers and engineers whose work has been the subject of a deep investigation in the United States(18) exhibited their greatest effectiveness in conditions which were "not completely comfortable but which, on the contrary, involved creative stresses".

4. Fundamental research should be increasingly looked upon as teamwork, even for theoreticians.

12. The main features of multi-level planning

121. Definitions and concepts

Governmental authorities and managers of private firms regularly announce the targets before them -- growth, stability, achievement, etc. -- and it would be as well to make a distinction between different kinds of targets according to their operational significance(19).

By ends here is meant the final factors, like a rise in the economic, cultural or scientific standard, aimed at by the community as a whole in an organized fashion.

With these ends defined, the next step is to pursue a series of policies framed for the purpose of reaching more specific objectives. An objective is a means to an end, into which research is made not for its own sake, but for the contribution it can make towards achieving a certain end. Objectives tend to be fairly concrete and can often be better defined by the means used rather than by the final products.

They then become quantified objectives identical to the means used and represented by the content of the plans.

There is a certain amount of confusion as to the use of the terms "plan", "programme" and "budget". For the purposes of this study, they will be defined in the following way:

We shall call a suggested course of action:	General	Financial
Tentatively describing the stages towards a given objective:	plan	financial plan
Put forward for approval or already approved:	programme (proposed or approved)	budget (proposed or approved)

Financial approval is not always granted at the same time or as readily as general approval, unfortunately. It is sometimes found, therefore, that long-term programmes are approved, while the budgets for the same period are not.

In an ideal decision-taking process, objectives, especially quantified objectives, should be formulated by means of an object-function. The latter may be defined as the graduated scale by means of which a comparison can be made between the various values of the desired objectives when they vary in quality or quantity. The most serious practical problem lies in obtaining, formulating and communicating the object-function and having it accepted. It becomes even more difficult as the number of people involved in the decision increases. The answer then is to resort to the concensus which expressed the average values accepted by one group of people for the objectives lying within given limits.

The final point to be considered here will be planning in the widest sense of the word, comprising the whole process of drawing up, selecting and revising plans, programmes and budgets.

122. The latest developments in planning procedures

While it is true to say that planning is as old as man himself, it is no less true also to say that progress and expansion in our civilization have given it new significance. The complexity and size of our undertakings and the rate of actual progress have led to three noteworthy developments:

1. the time scales are being extended at all levels;

2. the planning process is tending to become a continuous dialogue between the Centre*) and the Periphery;

3. methods of communication have been developed to facilitate this dialogue and the application of new methods of forecasting and management.

The most striking example of this process of development is, without a doubt, PPBS, a planning-programming-budgeting system adopted by the American administration, first of all by the Department of Defense in 1961 and later, since 1965, in many other federal and local administrations. By the end of 1968, the largest of the roughly 130 departments, agencies and commissions reporting to the Presidency of the United States had either already adapted their methods to PPBS or were in the course of doing so(21). The system clearly reflects the three tendencies listed above:

1. the operational units, constituting the Periphery, are required to make five-year plans, and it is with reference to these that the President of the United States presents his detailed programme to Congress;

2. the programmes put forward and the financial plans (PFP), together with the memos attached to the programmes (PM) are essentially aimed at providing the constructive dialogue between the Periphery and the Centre represented by the Bureau of the Budget;

3. all documents are drafted in functional terms and are thus suitable for various kinds of analysis.

123. <u>Structure and models</u>

The planning process at every level consists basically of three stages:

1. collecting and collating the components (aims, data);

2. determining and assessing the alternatives (plans);

3. selecting and circulating the results (programmes and budgets).

Iterations are normal at every level and stage, requiring a suitable feedback. Thus, decision models have to be produced, and they fall into various classes depending on their time scale:

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*) "Centre" is written with a capital letter when it means the opposite of "Periphery". With a lower-case letter, it refers to a "research laboratory".

- models for day-to-day management;
- models for short-term plans: the short term is a budgetary period, i.e. one or two years;
- models for medium-term plans: the medium term expresses the period required for the principal "conventional" investments to mature, i.e. between three and seven years;
- models for long-term plans which must cover the longest period for which those concerned can make valid forecasts. Such periods may vary widely in length, but usually embrace between ten and twenty years, although in the case of town and country planning, for instance, they may extend up to thirty years. The fields in which there are the need and facilities for planning more than a generation ahead are, however, rare.

One and the same model may, of course, cover different periods of time, and often does for current management and short-term plans, for example.

It would be beyond the scope of this study to give a complete list of all the types of model*) known to industry and economics. At a recent colloquium on the subject(22) the point was raised that so far insufficient work had been done on establishing suitable bases for the use of such models. It is the purpose of this report to draft a few such bases.

13. Definition of the subject of this study

This paper is an attempt to answer the question:

"What are the bases to be used in planning fundamental research?"

This question may be put at three planning levels, viz:

- that of national, international or supranational policy;
- that of the research centres;
- that of the research and supporting units.

This study deals mainly with the research centre level (Chapters 3 and 4) and is restricted to giving the outline of the upper and lower levels (Chapters 2 and 4 respectively). It has, in fact, already been pointed out that national scientific policy is affected by a large number of factors, some of them philosophical, and concerned with culture, social matters, economics and politics. At the other end of the scale, the work done in research units should not be too thoroughly planned since its success does depend on continual and fast changes to problems and methods.

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*) random and deterministic, descriptive and analytical.

In the case of the supporting units, planning involves the age-old problem of sections faced with a fluctuating load of work placed upon them, in this case by the research groups. Experience at large centres has shown the need for an effective planning system at this level, a need which, at CERN-Meyrin at least, it has been found possible to satisfy. The fact that it has so far been impossible in the United States to use the PPBS for fundamental research(23) shows that there are problems, some of which have been solved at CERN.

It is interesting to note that the functional programme presentations (FPP) described later on, which were composed at CERN quite independently of PPBS, exhibit a striking similarity to the documents (PFP) used for PPBS. This fact would indicate that it should be possible to integrate the planning of large fundamental research centres not only vertically within the framework of the scientific discipline but also horizontally in the overall scheme of national plans.

The structure of the models put forward here is still very rudimentary. The models will, therefore, be described only by reference to the main variables and parameters used.

To summarize then, this study is intended to show that medium-term planning for research centres is possible, in order, at one and the same time, to provide a valid basis for integration at high level, operation at lower levels, and the development of analytical models at all levels.

CHAPTER 2

Planning at the level of the scientific discipline and on a Continental scale

21. Planning's part in fundamental research

The theories expressed on the subject of the planning of science may be divided into four classes(24) according to the emphasis laid on one or other of the aspects mentioned in section 112.

1. Science must be planned as an independent activity. This theory, upheld particularly by Polanyi and Price(25), considers that science advances inexorably and autonomously on a universal scale. The only possible method of planning, therefore, consists in directing national efforts towards the prevailing world patterns.

2. Science is an indirect technical price which society must pay to reach its other objectives. Weinberg(26), the eloquent protagonist of this theory, has in view, not a universal scientific programme, but a series of scientific programmes aimed at providing given results.

3. Science must be planned as a social investment, like education. The interaction between research and university is a telling argument in favour of this theory, which is supported by Bell(27) and Ben-David(28).

4. Science is, in effect, a "consumer product", the cost of which is rapidly putting it into the luxury class. Financing it must thus be viewed in the same light as the financial support given to the arts and literature. This viewpoint, expounded by H. Johnson(29), for example, may seem rather out-of-date in this "scientific age", but it is nonetheless shared by many politicians and by a very large number of taxpayers!

Must science, then, be planned strictly or not, as a specific or a general investment? Is it a necessity or a luxury? These questions were recently raised during a colloquium attended by some of the most brilliant advocates of the various theories(30). The general conclusion is that science planning is widely accepted as a national necessity, but there is a long way to go before any model for scientific work within the economy of society can be worked out. In the absence of such a model and in view of the restricted perspectives available, the course to be followed is to observe and analyse existing systems to find out the possible effects of changes.

Thus, depending on the cultural, economic, political and social context of the time and the country, a scientific policy is arrived at which fairly explicitly relates resources to research. However, "the essence is that, within each discipline, the research groups granted considerable facilities should do work of international significance, since it is impossible to accomplish absolutely everything"(31). To this end, each country must make long-term plans regarding the number of scientists available and the facilities which they are to be given. Such is more important than the knowledge of what particular research work is to be done and forms the starting point for planning designed to produce a maximum amount of work of extreme scientific importance with the available means. In order for them to be effective, such plans must be made on a large geographical scale for each discipline.

22. <u>The structure of work put into fundamental research</u>

Research work is conducted by:

- centres on the continental or intercontinental scale;
- regional or national centres;
- the universities.

In particle physics in Europe, nearly all the centres and universities are state-supported. The borderlines between the work of the centres and that of the universities are rather blurred by the close collaboration between them. It is towards clarifying these very boundaries that planning on this level is being directed. Figure 1 gives a diagram of these structures.

The work done in the discipline under investigation is grouped in one of three classes(32):

A) The international effort proper, which includes the work done by the centres on the continental scale.

B_1) The contributions made by national, regional and university work to the international effort (sections R_1 and U_1 in Fig. 1).

B_2) The national, regional and university efforts proper (sections R_2, U_{2R} and U_2 in Fig. 1).

The scientific community expressed its proposals for long-term programmes (fifteen years) in 1967 in these terms, via ECFA (the European Committee for Future Accelerators), in the following way(33):

TABLE 2

European programme 1966-1981 (ECFA model, 1967)

	Number of experimental physicists*)			Annual cost in millions of Swiss francs (1967 prices)		
	1966	1974	1981	1966	1974	1981
Total (1966 = 1.0)	1436* (1.0)	2090 (1.5)	2730 (1.9)	582 (1.0)	1410 (2.4)	1810 (3.1)
Distribution (A 1966 = 1.0)						
A	108 (1.0)	220 (2.1)	380 (3.5)	177 (1.0)	660 (3.8)	780 (4.4)
B_1	685 (6.4)	1120 (10.4)	1500 (13.8)	85 (0.5)	200 (1.1)	380 (2.2)
B_2	643 (6.0)	750 (7.0)	850 (7.9)	320 (1.8)	550 (3.1)	650 (3.7)

*) In 1966, the 1436 experimenters represented half the total number of research workers (including applied physicists and theoreticians).

These proposals are based mainly on plans for new accelerators. They confirm the scientific community's desire to concentrate its efforts on the international plane (A and B_1) without, however, neglecting development at national level (B_2). On this basis, each state decides on the extent to which its scientific policy will permit it to support the proposed work. These decisions may mean that the proposals are modified and fresh long-term programmes drawn up. This constitutes the beginning of the planning cycle.

Figure 1

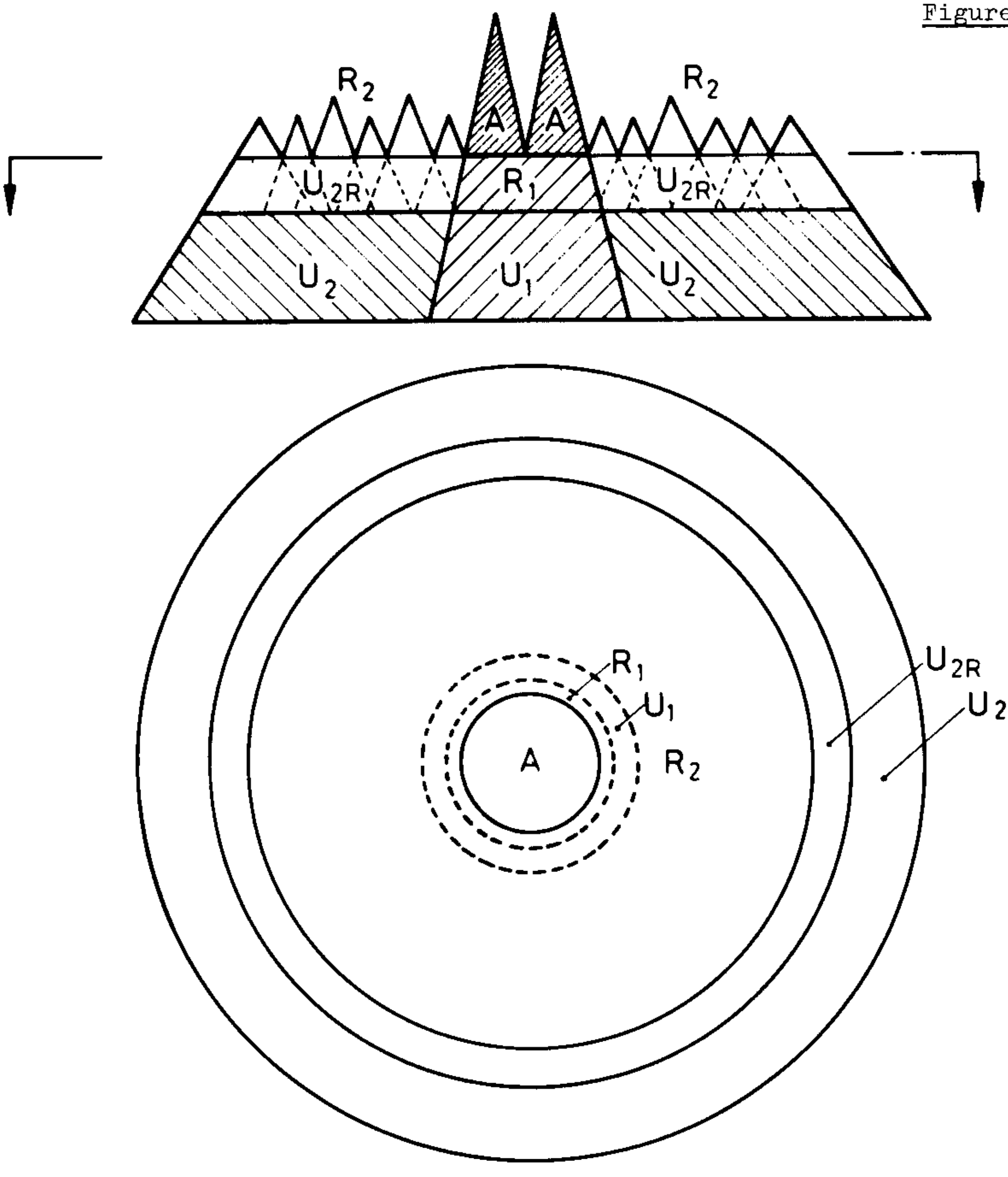

Fig. 1 Structure of total effort in the scientific discipline

A = International effort proper (international centres)

B_1 = (R_1 = Contribution of regional centres to the international effort
(U_1 = Contribution of universities to the international effort

B_2 = (R_2 = Work of regional and national centres
(U_{2R} = Contribution of universities to work of regional centres
(U_2 = Universities' work proper

23. <u>The planning cycle</u>

The diagram in Figure 2 shows five factors (boxed in the diagram), Viz:

- scientific policy;
- considerations of efficiency, giving rise to factors affecting the contruction and operation of long, medium and short-term models and day-to-day management;
- long-term plans;
- medium-term plans;
- the work of the research and supporting units. Such work may itself be oriented towards long- or short-term objectives.

It would be as well, at this juncture, to give an overall idea of the methods of elementary particle physics. The activities will subsequently be described in Chapter 3. The purpose of elementary particle physics is to discover the fundamental laws of nature by studying the elements of which matter is composed. To this end, the energies used are the higher, the smaller the particles and the shorter their lives. Certain objectives, therefore, involve levels of energy from which important discoveries are expected, hence the need to accelerate particle beams at high intensities and energies. Fundamental research work cannot, in fact, really begin until such conditions have been created. It consists in evaluating and explaining the effects of collisions between accelerated particles themselves or between accelerated particles and target-particles. With certain methods (the use of electronic detectors), the experimenters must be near the accelerator. Others (emulsions, bubble chambers) make it possible for universities to take part in experiments without actually having to be present when the data are collected.

Programmes are composed for a varying time scale, about fifteen years ahead for long-term and four for medium-term projects. The fifteen-year period is needed for the full commissioning and operation of the largest accelerator, while four years is the average time required for other large investments to mature and is also the planning period generally accepted by governments. Because of the research equipment needed, planning in high-energy physics has to be over long periods, which is, in effect, both a drawback and an advantage as against other scientific disciplines. It is a drawback, because of the many unknown factors affecting future technology, and an advantage because of the relative security and continuity conferred by the use of such programmes.

Long-term plans are drawn up by the members of ECFA, assisted by national and international study groups. They are submitted to national governments either directly, if national plans are involved, or through the European Organization for Nuclear Research (CERN), when it is a matter of international plans. There is thus coordination at both levels, but there is also a degree of competition because available resources are limited. The governments make use of CERN channels, especially its Scientific Policy Committee, for advice on the priorities to be allocated to different projects. It must be emphasized that long-term programmes involve solely equipment projects and assessments of the appropriate methods and levels of operation. Research proposals are planned only over the short term and, if absolutely necessary, over medium terms. The opinion of the scientific community is sought in the matter of projects concerning large projects. The community itself is guided by the traditional considerations of effectiveness, involving the scientific importance of the project, the number of research workers who will probably be interested in it, the cost, and the time taken to set the project up. The initial operating costs are normally similar to those of the final year of construction.

The diagram in Figure 2 puts medium-term plans at the centre of the planning cycle. Before their composition is described in Chapter 4, the work done at a large research centre will be described in Chapter 3.

Figure 2

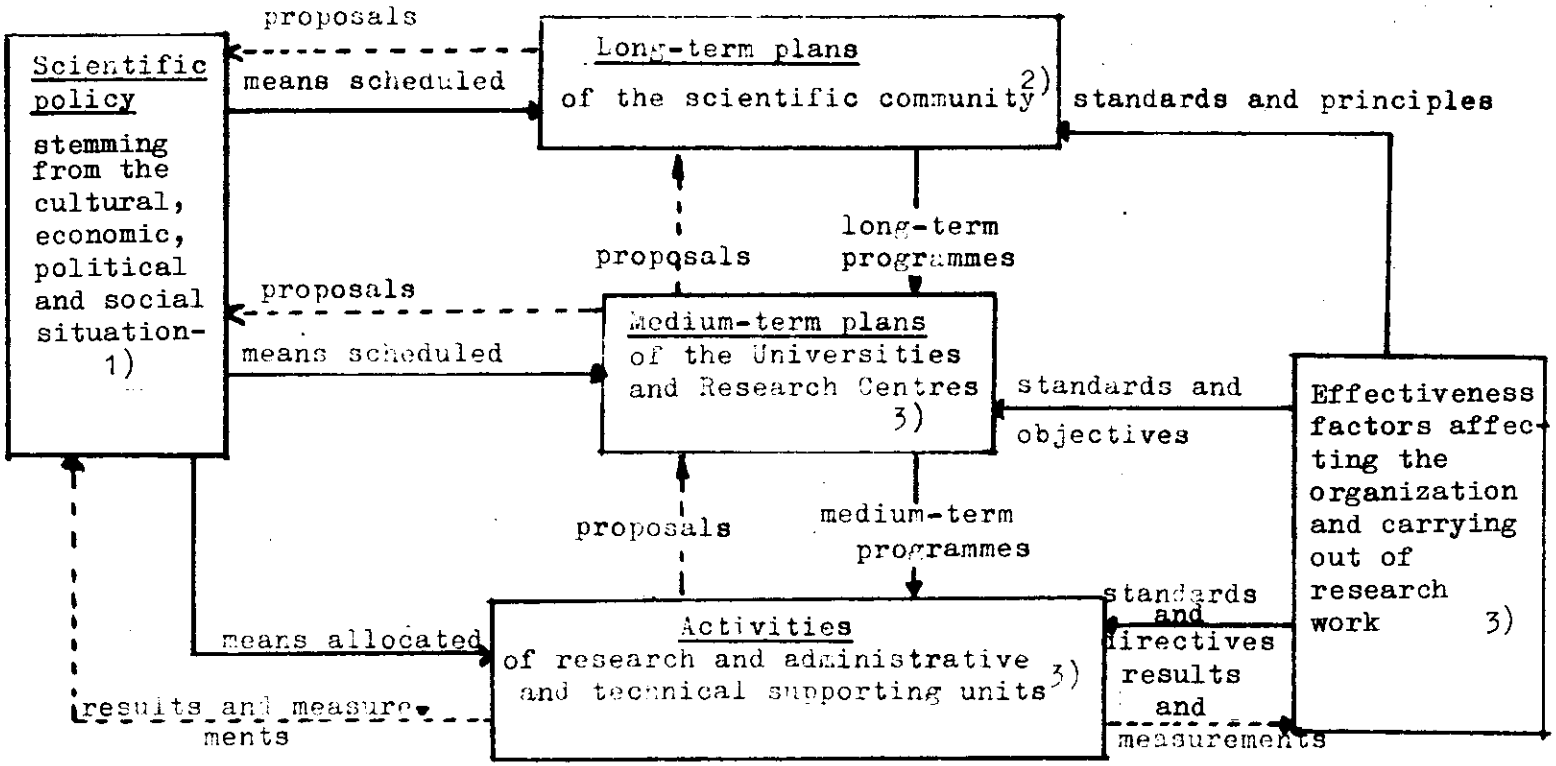

Fig. 2: Diagram of the planning cycle
looked at from the supply (solid lines) and demand (broken lines) viewpoints

Authorities concerned with particle physics in Western Europe:
1) Parliaments and governments, via the Council of the European Organization for Nuclear Research
2) European Committee for Future Accelerators and National Committees
3) Directorates of Centres and Universities, the Faculties, and mixed committees

CHAPTER 3

The work of a large fundamental research centre

31. Brief description of CERN (1969) (cf. Appendix 1)

Whereas most large research centres cover several disciplines, CERN-Meyrin, near Geneva, is entirely devoted to the purposes of high-energy physics. In this field, it has a dual aim:

a) the construction and operation of accelerators and other large pieces of equipment for the use of European experimenters (at present, nearly 60% of them depend on CERN for their research facilities), and the development, if necessary, of the required techniques.

b) undertaking an internal programme of very advanced research, linked to an improvement programme for Fellows and Visiting Scientists.

Only 7% of all European experimental and theoretical physicists are, then, paid directly by CERN, but the Organization welcomes five to six times as many scientists each year, together with a small number of non-European physicists from all over the world. The periods spent by such people at CERN varies between a few weeks and several years.

CERN operates two accelerators, a 600 MeV (million electron volts) synchro-cyclotron (SC), which has been working since 1957, and a 28 GeV (thousand million*) electron volts) proton synchrotron (PS), which was completed in 1959. The Organization is at present building two other machines connected with the PS: a 600 MeV injector (booster) and intersecting storage rings (ISR). These two installations will be taken into service in 1971/2, and will, it is hoped, extend the importance of the PS on the world scale to cover the next ten years. Today, the PS is one of the best and most powerful proton accelerators in the world. The SC is also scheduled for improvement in 1971.

CERN was set up at Meyrin (Geneva) in 1955 and since 1966, has covered an 80-hectare site astride the Franco-Swiss border. The present staff numbers employed by CERN total 3200, to which must be added 1500 people paid by universities or by service and building firms. The number includes 900 physicists and engineers, half of whom are actual research workers. Expenditure in 1968 was almost 280 million Swiss francs, contributed by the thirteen Member States of the European Organization for Nuclear Research, the individual contributions being usually based on the country's GNP. Currently, half of this budget is earmarked for the construction and development of large pieces of research equipment. The other half is used for their scientific operation and the services and general work.

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* In USA: billion

Each Member State is represented by two delegates, all delegates together forming the Council of the Organization. The Council appoints a Director-General, who holds office for five years and sets up the organizational structure which he considers most suitable. The structure at present consists of seven Departments, themselves composed of Divisions (Appendix 2).

The most tangible results of CERN's work, i.e. the results of and reports on research and technical development, are all published and made available, free of charge, to universities and industry.

32. Functional classification of activities

To facilitate the description and planning of the centre, it was considered essential to draw up a functional classification system for its activities, with three aims in view:

1. To present the structure of the work of the Laboratory in a way corresponding to the scheduled aims, i.e. to ensure that there is a correlation between the programme and the available resources.

2. To allow planning, independently of the organizational staff structure or the coding system dictated by budgeting and accounting requirements.

3. To make those plans in collaboration with a large number of scientific, technical and administrative officials at various hierarchical levels.

A CERN activity is a significant effort on the part of the centre of a given type and in a given field. It is the "molecule" of the overall effort. CERN activities are defined in such a way as to preserve their significance, at least over the medium term, and to group together those jobs which have to be jointly analysed at central level.

The main feature of the type of activity is the time at which the projects in view will be completed. The first distinction is made by the answer to the question "Operation or investment?". In order to constitute an investment, an activity must be such that, should it cease, only future research, and not current research, would be affected. Current research itself does include investments like the purchase of spare parts and specific equipment, but these "ad hoc" investments do, in this case, form part of the operating expenses. Conversely, investment activities may include the operation of prototypes for future installations. If these prototypes were to be scrapped, only future installations and hence the future research programme would feel the effects. Such operation is therefore considered as part of the investment. An investment activity is most often equivalent to a project, especially when its objectives can be clearly defined.

The field of activity corresponds to a step towards the essential product of fundamental research, i.e. towards scientific information. Here, an initial distinction can be drawn between the scientific and technical fields, on the one hand, and those constituting general auxiliaries for research on the other.

The very roughest functional classification, then, looks like this:

By field / By type	Scientific and technical	General support
Exploitation	activities R	activities S
Investment	activities E,I,X,Z	activities B

Activities R: Research and operations: operation, maintenance and minor modification connected with research programmes. Single-purpose equipment.

Activities E: Short-term equipment and development (one to two years). Design, construction and major modifications to equipment for research programmes. Development of new techniques.

Activities I and X: Medium-term projects (three to six years).

Activities Z: Long-term projects.

Activities S: Administrative and technical services. Power and water supplies.

Activities B: Construction of buildings, installations and general works. Service equipment.

The fields of scientific and technical activities reflect general sides of fundamental research work:

General side of fundamental research	CERN field of activity	CERN code
Creation and maintenance of typical conditions;	Accelerators, injectors and collision rings;	ACCEL
Adjustment of observation conditions to phenomena studied;	Particle beams and experimental halls;	BEAMS
Acquisition of scientific data;	Detectors;	DETEC
Selection and evaluation of data;	Data handling (analysis and calculation);	DATAH
Theory of the discipline;	Theoretical studies;	THEOR
Circulation of scientific information.	At CERN, this side is included in the field of general support.	

33.. Activity measurement

The activities are evaluated under three types of measurement, viz:

- the parameters (cf. section 432);
- staff (cf. section 433);
- costs (cf. section 434).

By and large, the parameters dictate the production of the activity. They are almost obvious in certain cases, e.g. annual hours of operation, photographs taken, surfaces to be cleaned, value or number of instruments in stock, etc. In other cases, however, the inherent difficulties connected with evaluating scientific productivity are encountered. It is recognized, for example, that the number or weight of publications is seldom a valid parameter in the field of theory!

The staff numbers (CERN symbol N) may be related to the type of contract, the function, or the source from which the personnel are paid. The last-mentioned factor is of great importance at a Laboratory which actually pays only a minority of the researchers working at it. The units used may be the people at the research centre, usually at the end of the year, or man-years.

The costs are related either to the personnel (CERN symbol P) or to equipment and services (CERN symbol M). Annual costs are usually corrected by adjusting price variations according to economic indices.

Objectives may be expressed and the state of progress of the activity measured in relation to the objectives by means of the parameters. Syntheses and analyses of the corresponding effort can be made by means of the staff and costs. The simultaneous use of the various types of measurement gives most of the ratios normally used as indicators. Finally, the time is also used as a factor, firstly for defining the type of activity and secondly in chronological tables using the above measurements.

34. Constitution of the activities

341. CERN activities consist of CERN sub-activities or divisional activities. The latter are themselves made up of divisional sub-activities which represent the "atoms" of the overall effort in functional terms.

CERN activities

CERN sub-activities   divisional activities

divisional
sub-activities

This breakdown may be necessary for one or more of the following reasons:

a) identifying the effort more accurately;

b) finding valid parameters;

c) turning accounting data into functional data.

From top to bottom, the hierarchical structure is:

Department

Division

Group (or Service)

Section (or Office)

and thus the divisional sub-activity represents the work of one or more groups. The group (or service) is the smallest autonomous research (or auxiliary) unit capable of having its own independent programme and its own budget provisions.

342. Accounting data are converted from section level upwards in consultation with the group leader. He gives the correlation between accounting codes and functional sub-activity codes. The correlation is direct in about 80% of all cases, but, in the remaining 20% or so, the group leader states the equivalences, since one accounting code may cover more than one functional code. The conversion keys are revised once or twice a year within each Division. The distribution of personnel numbers may also be given as a general total for the whole of the group or section, or as a ratio to the work done. In such a case, not all the staff are required to fill in a weekly job sheet; this avoids an excessive amount of administrative work. All that need be done is to revise the distribution keys periodically in consultation with the group leader. The 20% mentioned earlier consists mainly of groups responsible at the same time for both the operation and development of large pieces of equipment, and applies particularly to groups dealing with accelerators and large detectors. We shall be returning to this matter in section 363.

35. Synthesis tables

351. Activities or projects with the same aim in view may constitute an activity programme. If only projects are involved, i.e. "investment" type activities, the programme produced may itself be referred to as a "Large Project". Figure 3 shows the way in which programmes are represented according to type and field of activity. Activity measurements may be applied to all these composites in the same way as to the activities themselves.

352. The synthesis tables of the activities provide the bases for planning and the construction of models. An aggregate total should therefore be cast at each planning stage according to the most urgent matters on the time scale in question. The questions "Why?", "By whom?", "Where?" and "When?" relate to the completion of the activities or composites involved and are expressed in the types of measurement given. Their order of importance is:

Figure 3

Measurement of activities and programmes, with the aid of parameters, personnel numbers (N) and costs (P, M, T).

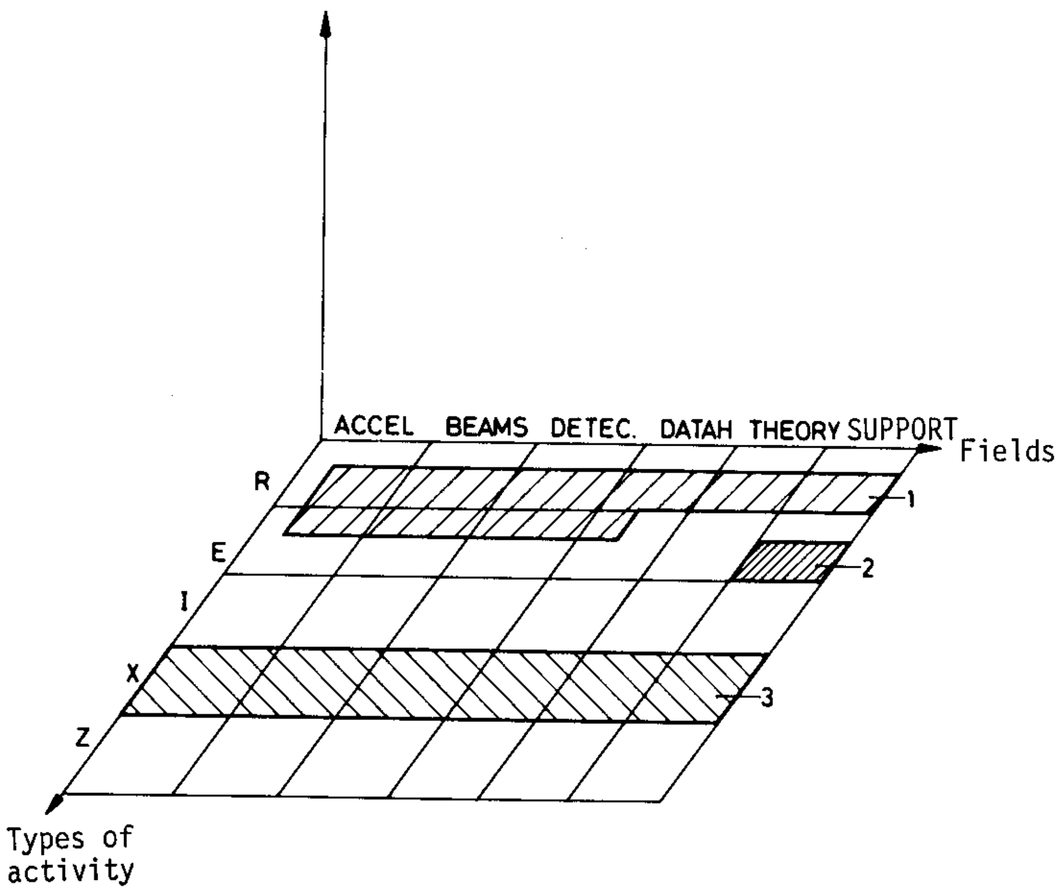


Fig. 3 Programme presentation

Examples: 1. Operation and development programme
2. Construction programme
3. Large project

Questions*) about the work in view	Answers*)	Order of importance	
		Long and medium term	Short term and day-to-day management
For what?	the programme	1st	4th
By when?	the type of activity	2nd	3rd
Where?	the field	3rd	2nd
By whom?	the organizational unit	4th	1st

*) expressed in the same type of measurement.

The essential factors in long-term plans, i.e. the programmes and types, are thus less important in the short term and vice-versa. It is found in practice, therefore, that three activity syntheses are required. They overlap slightly to facilitate conversions from one to another.

A) Long and medium-term tables: Presentation by programmes with activities according to type, the field and finally the organizational unit.

B) Medium and short-term tables: Presentation by organizational units with activities according to field, type and programme concerned.

Figure 4 gives diagrams of these two presentations.

C) Short-term and day-to-day management tables: Normal budgetary and accounting presentation per organizational unit (table 3).

The next section will deal with the relationships between these three presentations.

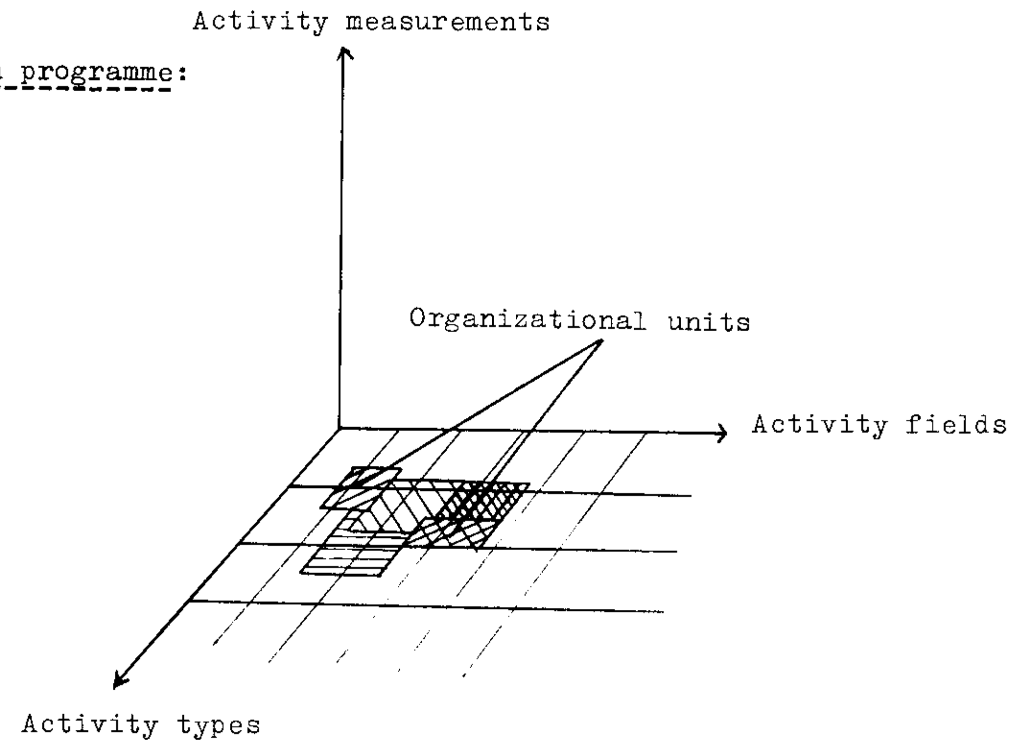
36. Functional and accounting plans

361. It has been said in section 342 that the costs of activities for past years are made up of accounting items listed together with the aid of conversion keys which are periodically revised. It would still be as well to demonstrate the relationship between the functional plan of representations A and B and the budget and accounting plan. The latter looks like this:

Figure 4

A) Long and medium-term representation (by programmes)

For each programme:



B) Medium and short-term activities (per organizational units)

For each Organizational unit:

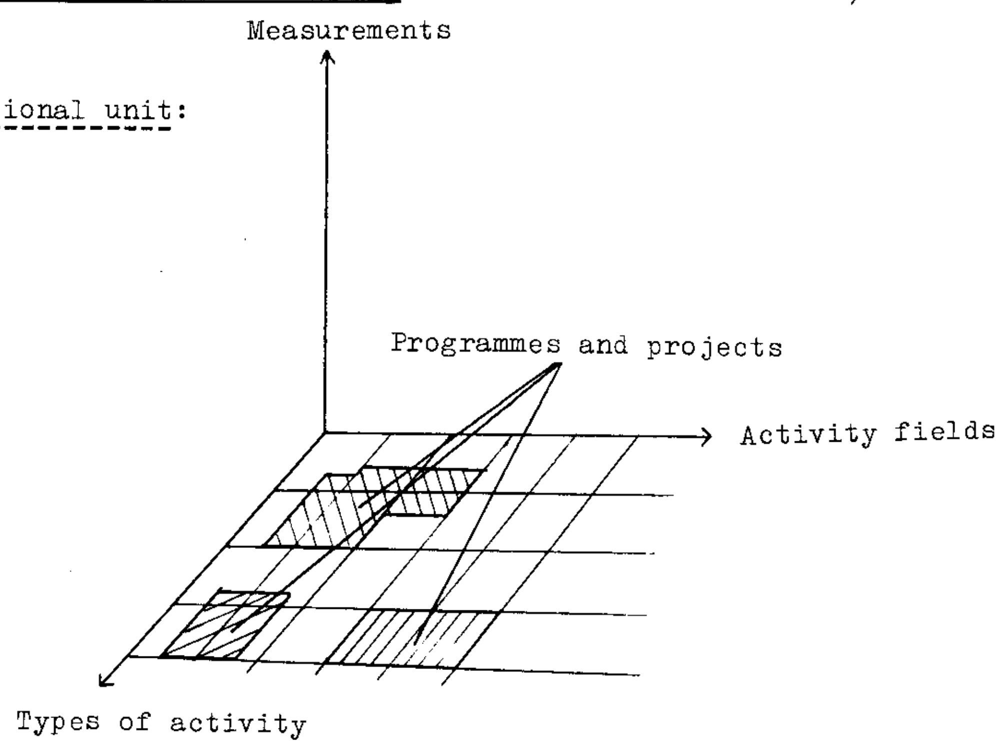


Figure 4 Functional representations of activities

TABLE 3

Accounting representation of expenditure

(representation C)

Budget Headings \ Organizational units	Division	Division	Division
	(by groups and sections)		
1. Personnel (by type of contract)			
2. Operation (by fields)			
3. Capital outlays (by fields)			

The sub-headings under headings 2 and 3 are selected so as to give information on corresponding fields, e.g.:

22 = Accelerator operating costs

32 = Capital outlays per accelerator.

This method of classification by fields makes it easy to convert from the accounting plan to the functional plan. The system of co-ordinates provided by combining these two plans may, in fact, take the form below: (The third plan forms the cost analyses area, generally by fields)

Figure 5

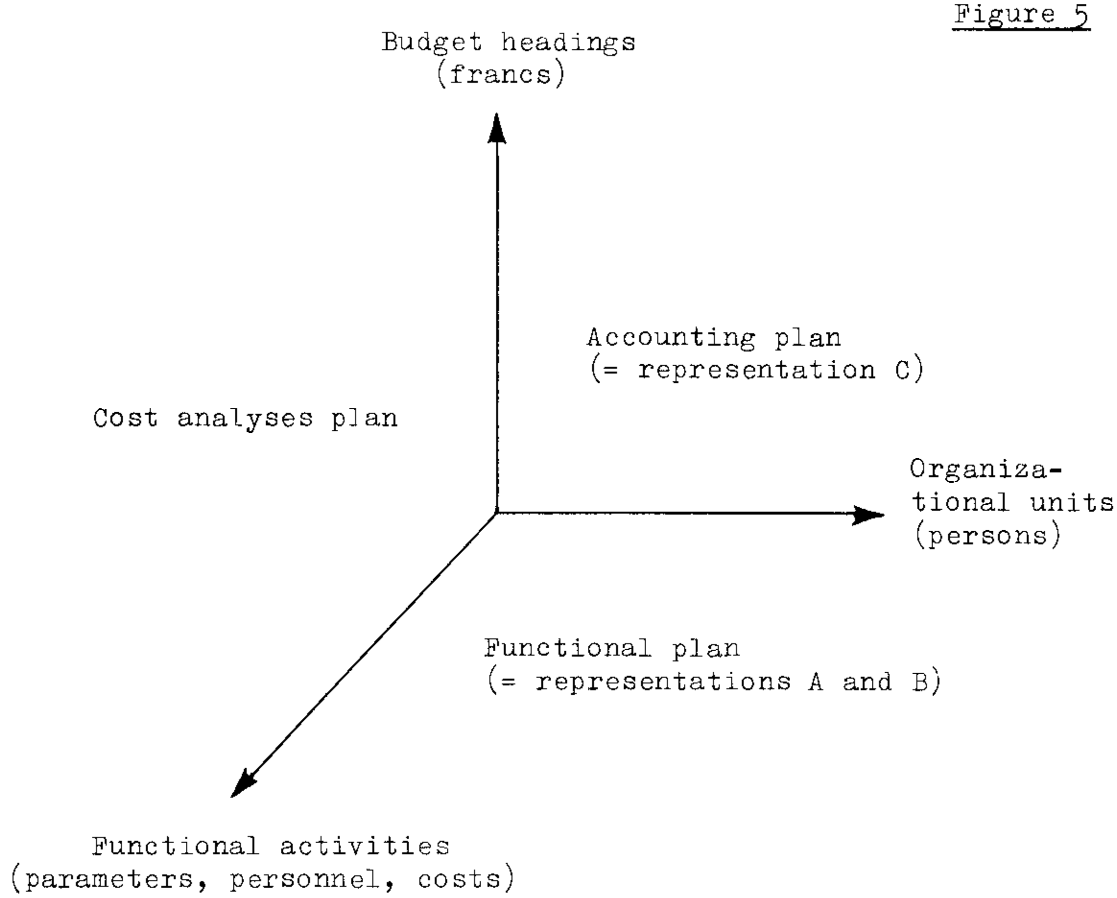


Fig. 5 Functional and accounting plan

362. Let us now try to illustrate this structure by explaining the various meanings of the term "data handling" according to the axis on which it is met.

"data handling" refers:

- on the organizational unit axis:

  to a specialized Division (DD) (Figure 7);

  to various groups in other Divisions;

- on the functional activities axis: (Figure 6)

  to a field containing the operational (R4), (R13b) and (R14b) and investment (E16), (I3b) activities;

- on the budget headings axis: (Figure 7)

  to an operations sub-heading; (25);

  to a capital outlays sub-heading; (35).

Figure 6

Type \ Field	ACCEL	BEAMS	DETEC	DATAH	THEORY	SUPPORT
Day-to-day (R, S)	R11 PS machine operation R21 SC operation	R12 PS area operation	R13a Electronic experiments R14a Track chamber operation R22 SC experiments	R13b Analyses around electronic detectors R14b Analyses around track chambers R4 Central data handling	R3 Theoretical studies	S1 Administration S2 Admin. services S3 Technical services S4 Site operation S5 Power supplies, etc.
Short-term (E, B)	E11 PS development E21 SC development	E12 PS area development E17 Serpukhov development E19 Cryogenic developments, etc.	E13 Development of electronic detectors E14 Track chamber development	E16 Development of central installations		B1 Construction B2 Service equipment
Medium-term (I) (X)	I1 PS improvement (phase I) I5 PS improvement (phase II) X51 ISR machine project	I2a Neutrino beam I6 West area beam X52 ISR areas X54 West area	I3a Omega project I2b Gargamelle project X53 ISR detectors	I3b Omega project (analyses)		(X55) Services for ISR project
Long-term (Z)	Z1 300 GeV design studies					(Z2) Services for 300 GeV design studies

Fig. 6 Functional plan: CERN activities and sub-activities

Figure 7

DATA HANDLING DIVISION (DD)

(in units of 1'000 francs)

Budget 1968	Probable expenditure 1968		Breakdown	Budget 1969	← Organizational units: Direction	Central computers	Data analysis	Scientific information →
21'808	25'770		TOTAL	22'410	695	12'980	5'645	3'090
======	======		=====	======	===	======	=====	=====
8'078	8'180		1. Personnel	9'730	350	4'480	3'030	1'870
7'750	7'805		10) Staff members	9'300	345	4'325	2'830	1'800
17	70		11) Auxiliaries	90	5	-	15	70
213	195		12) Laboratory staff	230	-	100	130	-
98	110		14) Consultants and visitors	110	-	55	55	-
5'180	5'810		2. Operation	5'400	290	3'715	535	860
200	215		20) Site and buildings	185	40	90	25	30
560	950		21) Service equipment	925	10	45	60	810
10	5		23) Equipment for experiments	5	-	-	5	-
4'055	4'350		25) Data handling	3'990	-	3'550	440	-
355	290		28) Administration	295	240	30	5	20
8'550	11'780	cf. § 362	3. Capital outlays	7'280	55	4'785	2'080	360
525	550		31) Service equipment	580	55	80	85	360
10	-		33) Equipment for experiments	5	-	-	5	-
8'015	11'230		35) Data handling	6'695	-	4'705	1'990	-

In other words, the accounting plan will show the units and financial means involved specifically in data handling work, while the functional plan will give the cumulative total of all work in this field, both direct and indirect.

363. One of the essentials for the proper management of the research centre is flexibility, which is also provided by this system of differentiation between the accounting and functional sides. The purchase of a large computer, for example, is clearly a capital outlay (budget heading 3), but it may be considered as an exploitation cost (R4) in the functional plan, if it is paid in installments which are similar to an annual rent. Flexibility is even more important in the use of the personnel's time. The work of the groups is charged up, with the aid of coefficients provided by the group leaders themselves (cf. section 342), to "effective" activities and not to the "nominal" activity of the group. This is very important when a "current research" group (type R), is spending a great deal of its time on developing its research tools, and when there is a change in the organizational structure. These changes occur very frequently as a result of the turnover in research workers and the growth of the Laboratory.

364. The conversion keys may, then, affect

- the personnel (budget heading 1, functional measurement P);
- the equipment (headings 2 and 3, functional measurement M).

Examples of such keys are given in Appendix 3.

In addition, breakdown keys are used in the functional plan and within each Division to distribute "general activities" such as:

No. 9: Direction of the Division,

No. 11: Laboratory supernumeraries,

No. 12: Fellows and visitors,

over the "productive activities", Nos. 1 to 8, for the Division. These breakdowns must be made every time a presentation B is converted into a presentation A (Appendix 4).

365. The centre's administrative computer has been programmed to handle the large number of data included in each presentation A, B and C with the conversion and breakdown keys mentioned above. What has to be done, in fact, is to reduce some 2000 expenditure accounts (presentation C) to about 150 Divisional activities (presentation B) and finally to the 30 CERN activities (presentation A). The aggregation ratio C/B is lower for the personnel (200 organizational sections in presentation C).

Examples of aggregate presentations A, detailed presentations A and presentations B are given in Appendices 5, 6 and 7 respectively.

CHAPTER 4

The planning process for a large fundamental research centre

By planning process is meant the development of a system with a logical side, i.e. the planning structure, and a formal one, i.e. the organization of planning. These two sides may be represented roughly by a diagram (Figure 8) and an annual cycle (Figure 9) respectively. These figures will be described in Sections 41 and 42, whereafter a few examples drawn from CERN will be given to supplement the description, and those developments which appear the most promising will be put forward.

41. The planning diagram

411. Figure 8 shows the logical functions, interconnected by the flow of data. The diagram is "jointed" at three levels, viz:

- the upper one, where scientific policy is decided;
- the central one, dealing with the total activities of the Laboratory; and
- the peripheral one, comprising the activities of the organizational units.

The functions may be classed as:

- models and judgments; (cf. Section 413)
- forecasts and checking (cf. Section 414).

412. The main model of the research centre is the linchpin of the planning system.

The input factors are:

- the exogenous variables originating from scientific policy: limitations and requirements like the availability of research workers, scientific progress, the overall financial situation;
- long-term programmes drawn up within the scientific discipline. These are reflected in "mega-science" mainly by requests for large pieces of equipment and by quantified objectives as defined in section 121;
- the parameters and internal requirements based on standards and statistical series;

Figure 8

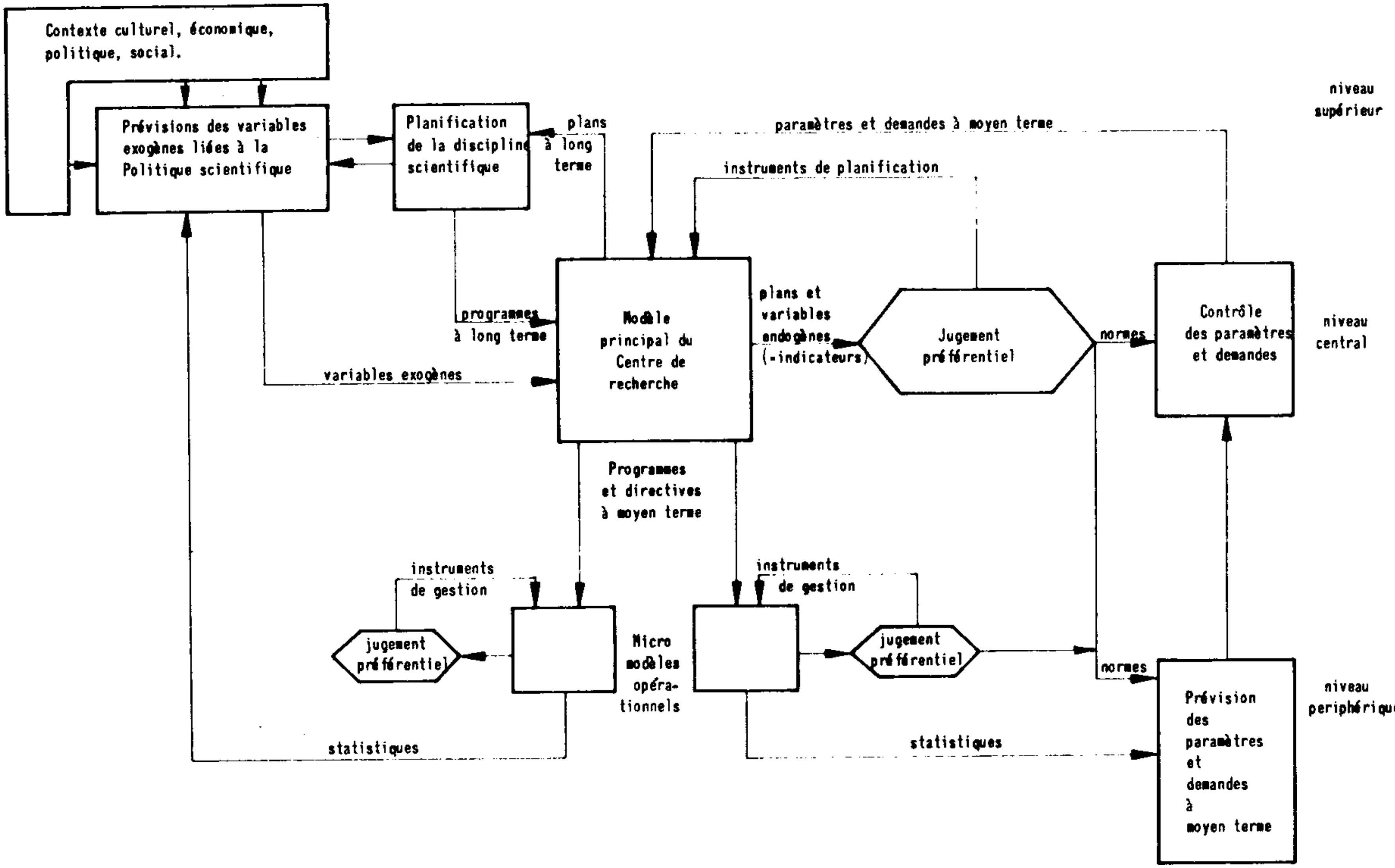


Fig. 8 Schéma de planification du Centre de Recherche

(Planning diagram of the Research Centre)

- the planning instruments used by preferential judgment; they may be direct if they refer explicitly to an activity, or indirect insofar as they affect all the activities with certain features.

The output factors are:

- proposals and justificatory evidence forming long-term plans for the research centre;

- the endogenous variables or indicators submitted preferential judgment for iteration;

- the medium-term programmes and guidelines forming the input for the operational sub-models of the organizational units and those of the planning and coordinating committees.

The statistics provided by these units are used to formulate medium-term forecasts for the research Laboratory and long-term forecasts within the framework of scientific policy. Otherwise, the sub-models work in a similar way to the main model as well as providing a basis for judgment. All data are expressed in activity and sub-activity measurements.

413. The "preferential judgment" models and functions are closely related. In fact, the system is designed to provide the information required by those making decisions. Primarily, it is a matter, in many situations where a function-objective cannot be defined, of filling the gaps with a personal judgment and of integrating these judgments at each level in the planning system. Such a procedure is particularly applicable to fundamental research, where important decisions are largely governed by the bent of scientific thought at the time and the personality of the scientists. The model must, therefore, provide indicators to which the concensus of scientific opinion allocates values. Via the judgments mentioned above, these indicators actuate "planning tools" which can be used immediately on the model and allow standards for forecasts and internal requirements to be laid down.

414. The forecasts and requirements made by the Laboratory units are based on the direction their activities are taking, on specific projects, on the standards and factors originating from the Centre and on the external demands made directly on each unit. The "checking" operation, associated with these forecasts, includes a check on the application of the standards and factors drawn up for the whole Laboratory and, if necessary, the review of the way in which the proposed projects are assessed.

Ideally, there should be correcting coefficients for every person originating a project. These coefficients would be applied to the project estimates. It is well known that, in every laboratory, there are some research workers who, invariably, over-estimate the work in view, and others who always under-estimate it. In actual practice, there are such coefficients at various levels, in the minds of the

Directors and Division Leaders, but it would, of course, be a very delicate matter, if not totally useless, to incorporate them into a planning system as they stand.

415. It must be pointed out that this planning check is superimposed upon the management check which is undertaken at both central (cf. Appendix 2) and peripheral level. The units use the single-estimate critical path method (CPM) to check the state of progress and the cost of projects. CPM/PERT is also employed to level out the use of technical labour. The costs are tracked by extracting the data relating to CPM network sub-systems from accounting reports. Cost forecasts are also made by sub-systems. The sub-systems of large projects are dealt with as divisional sub-activities.

42. The annual planning process

421. Medium-term programmes relate to the coming four years. If A is the current year, the annual process is aimed at:

- extending the existing medium-term programme by one year (A + 4);
- reviewing the programme for A + 3 and A + 2;
- drawing up the short-term programme to which the budget for A + 1 relates.

The following will thus be obtained:

a) A set of plans with financial plans constituting the "estimates" for A + 3 and A + 4;

b) An authorized programme with a "firm" budget (subject, however, to confirmation) for A + 2;

c) An authorized programme with a budget allocation for A + 1.

422. These aims are taken into consideration when the annual planning calendar is drawn up by the central Programme Office. Three phases are usually scheduled (Figure 9);

- the first examines and gives the research centre's plans for A + 1 to A + 4;

- the second sets or confirms the scope of the various programmes for A + 1 to A + 4;

- the third details A + 1. This general case will be described in sections 424 to 426 and Appendix 8 gives an example of it at CERN for 1968.

Where there is a transition from a predominantly capital outlay period to an operating period:

Figure 9

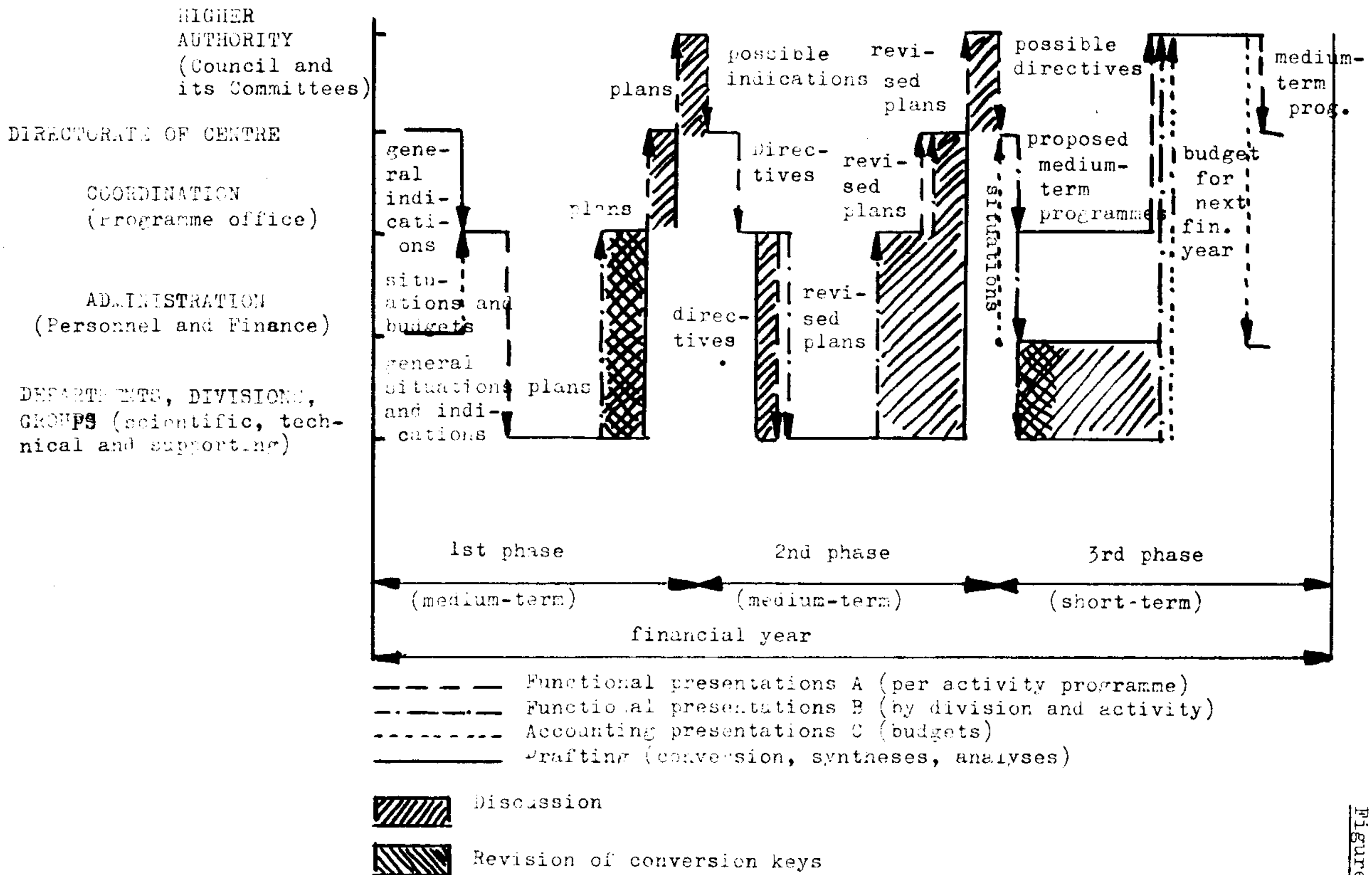


Fig. 9: Annual course of planning

- the first phase will preferably be limited to the investment years, e.g. A + 1 and A + 2;

- the second will provide the schedules for A + 3 and A + 4, after the first has been confirmed;

- the third will detail A + 1, as before. This particular case is illustrated by Appendix 9 for CERN in 1969.

423. It should be possible with these phases to coordinate planning between:

	For CERN
The higher authority	Council, Finance Committee, Scientific Policy Committee
Senior management	Board of Directors
The coordinating body	Programme Office
The administration	Personnel and Finance Divisions
The executives	Departments, Divisions and Groups, standing or ad hoc Committees.

Here, it should not simply be a matter of the higher authorities consulting the lower ones, but rather of a proper conversation, directed initially by the coordinating body for phases I and II, and then by the administration for phase III. This calendar should be drawn up in such a way that everyone knows the contacts to be made, the information to be provided, and the date on which it is required.

424. First phase

The Programme Office asks the Divisions to submit their plans for A + 1 to A + 4. In order to do this, they are given the following information:

- the figures for A - 3 and A - 2; here, the principle of time symmetry (34) is applied, according to which the planner must have at hand back data for the same length of time as that of the period to be planned;

- the provisional results for A - 1 in their functional presentation;

- the authorized figures for the budget for A;

- the figures drawn up in A - 1 for A + 1, A + 2 and A + 3, but corrected by the application of the cost variation indices.

These indices are applied overall to the following four cost areas:

- salaries and allowances;
- buildings and the appropriate installations;
- scientific and technical equipment;
- items unaffected by cost variations, such as certain electricity supply contracts, orders for equipment at fixed prices, lump-sum payments, etc.

Without going into the details of the various indexing methods here, the importance of this price updating, in order to express real prices in the chronological series, must be stressed.

The most important document of the set is formed by the Directorate's general account of the achievements of the past year compared to the programme, the overall objectives and the identifiable problems arising in the years in view, especially those for year A + 4, which is being looked at for the first time. This document must recall the aims already established during the previous financial year and the foreseeable cost factors, e.g. the average salary in each Division. In addition, the problems must be described, while solutions should be merely suggested in order to preserve the scope for initiative and the freedom of action of all those responsible. In fact, the total of the annual amounts suggested should exceed the available totals given by the medium-term schedule by a few percent so as to leave it to the final planning stage to adjust internal requirements to the budget presented for A + 1.

The information is drawn up on the lines of presentation A in Figure 4, i.e. primarily by type and field of activity, and secondarily by Division. Where necessary, therefore, the Divisions themselves have to set up ad hoc working groups to define their respective responsibilities. This is one of the essential features of collaboration, consisting in reducing to a minimum the number of cases where the Directorate has to arbitrate between Divisions, either to bridge gaps, or to avoid duplication. It must nevertheless be emphasized that, unlike the case of industry, it is often permissible in scientific research for groups interested in the same type of work to operate in parallel. The limit to this type of duplication is set by the overall effort allocated to the activity concerned.

The Departments and Divisions utilize a similar procedure with the research groups to define their plans. The plans thus drafted are sent to the Programme Office in the functional form B. They should contain the parameters, personnel and costs per divisional sub-activity, with full and suitable comments.

Before synthesizing them, the Programme Office analyses these plans and checks that the accepted standards have been applied: Fr./man-year, m^2/person, personnel expenditure/expenditure on equipment, etc. It also revises the conversion and breakdown keys in consultation with the Divisions.

The synthesis is discussed in form A with senior management, which then itself submits it to the Council bodies for comment.

425. Second phase

Provided that, in the new plans, the totals for the programmes previously approved for the first three years under consideration are adhered to, the only year which might encounter some opposition at the higher level is A + 4. If such opposition is encountered, however, the whole of the period A + 1 to A + 4 will be discussed and senior management will assemble information to be used in forming its own instructions, which will be distributed after discussion in forms A and B, i.e. in a much more specific form than the initial statements. They will, in fact, contain the framework for all the programmes for A + 1 to A + 4.

After the Divisions have revised the plans, the second phase continues, like the first, with synthesis A. It should, however, be noted that, at this stage, the specific plans B are sent back together with presentation A to allow the Directorate to make a double analysis, from the viewpoints of both the programmes and the organizational units. The financial plans thus submitted to the higher authorities, give amounts which they can accept with a good degree of assurance that they are accurate. The main aim of this procedure is to convince Council that a programme is being drawn up for A + 4 within the framework of the first phase.

426. Third phase

The third phase may begin with Council issuing new guidelines or confirming previous ones. This basis, with the personnel and financial positions for the current year, enables Senior management to make a firm proposal for A + 1. The Administration now uses the information supplied by the Programme Office to solve all detail problems for A + 1 and to draw up the corresponding budgets in consultation with the Divisions. Since these budgets will be presented in forms B and C, the keys must be revised at the very beginning of this phase. At the same time, the Administration will draw up the probable situations for A.

The Research Centre will, then, send the following documents to Council for approval at the same time:

- The probable situation at the end of A (in form C);
- The budget for A + 1 (in forms B and C);
- The medium-term programme giving A - 3 to A + 4 and asking for a "definite" confirmation of A + 2, confirmation of the "estimate" for A + 3 and the recording of A + 4 as a new "estimate".

43. Data flow

The data used in planning are described in the next few sections by reference to CERN examples.

431. The exogenous variables consist mainly of data on higher education and the related population, e.g.:

- the number of physics students or, if this figure is not available, the number of natural sciences students;
- the number of qualified particle physicists;
- the number of universities with a physics faculty and the number of regional high-energy physics centres.

Furthermore, the cost of research per man-year is also given. This ratio may be onsidered as a valid unit of measurement for scientific activity in Europe (35) (36).

These data are forecast at scientific discipline level. In the case of CERN, the work is done by ECFA and CERN itself, which uses the work of OECD, UNESCO and their national correspondents.

432. The physical parameters directly describe the objectives and the results of work. The table below gives the main parameters considered at CERN per field of activity, for types R and S, by way of example (the field and activity codes are given in brackets).

Accelerators (ACCEL: R11, R21)	hours of operation per year; number of targets operating; number of beam ejections; average intensity and energy; repetition rate.
Beams (BEAMS: R12)	number of beams installed; number of beams operating simultaneously; number of magnets available; installed electric power; weight of shielding available.
Detectors (DETEC: R13a, R14a, R22)	number of groups at CERN (internal, external and mixed); number of groups on detectors; number of detectors installed; annual number of hours of operation; triggering, photographs, events per year; average duration of an experiment.

<u>Data handling</u> (DATAH: R13b, R14b, R4)	number of film measuring machines (manual and automatic); number of photographs measured; number of events measured; number of <u>peripheral</u> computers used; capacity of <u>central</u> computers; quantity of work per week; number of users per week; number of cards read; number of pages printed.
<u>Services</u> (SUPPORT: S1, S2, S3, S4, S5)	number of persons employed; number of visiting scientists; number of reports published; number of orders placed; quantity of work done in the workshops; number of withdrawals from stores; areas to be maintained; power consumed, etc.

The divisional activities and sub-activities involve these parameters and give more details about them. The parameters in the case of E and B investment-type activities are usually formed by the annual increases in these values. For projects (I, X, Z), the calandars themselves are generally treated as parameters.

In addition, the <u>value</u> of the available equipment represents an essential parameter. Either the measurements of one single activity, or the activities in a single field, can thereby be interlinked. The value used is the purchase price rather than the market value, so that short-term investments may be expressed in relation to a known original value. Section 445 deals with this matter. There is one difficulty in this connection, that of assessing the cost price of instruments made at the centre itself without having to use industrial accounting methods, which are considered too laborious for the few occasions on which they are used in fundamental research. Nevertheless, electronic data handling will make it possible to obtain such information accurately and in the time required.

433. The staff numbers (N) are viewed in the light of four criteria:

- the type of contract:	Staff Members with medium and long-term contracts; Supernumeraries with short-term contracts; Fellows and Visitors with short-term contracts;
- salaries:	higher grades; medium grades; lower grades; visitors not paid by the centre;

- position: scientists;
  engineers;
  technicians and specialists;
  administrative personnel;
  unspecialized and general-service personnel.

The unit generally used in the models is the man-year. However, requests and directives are also expressed in total personnel employed at the end of the year.

434. All costs (T) are given per budget year. At CERN, this is the same as the calendar year. Personnel costs (P) are given on the basis of man-years and those for equipment (M) are spread out in time according to due payment dates. The cost variation indices are applied according to the classes given in section 424. The staff numbers and costs together determine the activity levels.

435. The endogenous variables or indicators are of prime importance in describing the conduct of the centre. Planning depends to a great degree on how they are selected. According to Stokes (37), the indicators must satisfy the following conditions. They must:

a) be significant over a period of time equal to at least twice the medium term, i.e. over four years past and four to come;

b) be easily derived from the model of the undertaking;

c) be comparable to standards or objectives. There must also be as few of them as possible (this remark is of obvious practical use).

Depending on the way in which they are made up, the indicators may be homogeneous or heterogeneous.

Homogeneous indicators involve a single class of measurement, i.e. the physical parameters, the staff numbers, or the costs.

Heterogeneous indicators use more than one class of measurement.

Examples:

- homogeneous: $\frac{\text{laboratory area}}{\text{total area}}$;

  $\frac{\text{staff numbers in scientific fields}}{\text{supporting personnel}}$;

  $\frac{\text{personnel costs}}{\text{total costs}}$;

- heterogeneous: $\frac{\text{areas}}{\text{personnel}}$; $\frac{\text{total expenditure}}{\text{personnel}}$;

$\frac{\text{cost of analysis}}{\text{event recorded}}$.

The indicators may also express either performance, when the product of activities can be measured, or degrees of satisfaction where they are essentially governed by the appreciation of the scientific community.

Finally, the indicators refer either to a single full activity (type, field or programme), or to several activities, either as an accumulation or compared one to another.

The indicators must be sought among the following alternatives:

Object of comparison	Homogeneous indicators			Heterogeneous indicators		
	param.	N	T	$\frac{N}{\text{param.}}$	$\frac{T}{\text{param.}}$	$\frac{T}{N}$
Activities within one field	x	x	x	x	x	x
Activities of the same type	x	x	x			x
Activities within one programme		x	x			x
Fields among themselves		x	x			x
Types among themselves		x	x			x
Programmes among themselves	x	x	x	x	x	x

*) The activities compared may be inside or outside the Centre.

The following list is representative of the indicators used at centre level:

Objectives of the Laboratory:	Indicators showing: (p = actual performance) (ds = only some "degree of satisfaction")
a) To provide a service for European physicists.	Number of European physicists depending on CERN (ds) in particular for doctorate theses.

b) To guarantee a high level of research work within the centre.	CERN's participation in large international conferences, as a fraction of the number of communications accepted (sub-divided into theoretical and experimental) (p); Number of important experiments made at CERN in relation to those made at American laboratories (p).
c) To proportion out the efforts made in the directions of objectives a) and b)	Number of research workers at CERN paid by the Organization (ds); Ratios between internal, external and mixed groups (ds); Number of CERN photographs sent outside CERN for evaluation (p);
d) To ensure the centre's future	Short-term: $\frac{T_{(E+B)}}{T_{TOT}}$ (ds) Medium-term: $\frac{T_I}{T_{TOT}}$ (ds) Long-term: $\frac{T_{(X+Z)}}{T_{TOT}}$ (ds)
e) To operate the installations efficiently (trends and comparisons with a large American centre)	$\frac{\text{Central computer hours}}{\text{Millions of photos or events handled}}$ (p) $\frac{\text{Hours down-time}}{\text{Hours of operation}}$ (p) for accelerators, detectors and central computers.
f) To provide proper support and adequate facilities for research workers (trends and comparisons with a large American centre)	$\frac{\text{N technicians}}{\text{N research workers}}$ (ds) $\frac{\text{Office + laboratory area}}{\text{Research group}}$ (ds) $\frac{N_s}{N_R}$ (ds) $\frac{M_R}{P_R}$ (ds)

g) In addition, the main activity measurements in each field may be considered as indicators of production or the level of activity in the field concerned. The cost ratios between one field and another thus form important indicators.

436. There are two kinds of planning tools viz: certain endogenous variables to which values have been allocated by the centre's management bodies, and the planning coefficients for the main model. This phase will be mentioned in section 447. These tools are generally the same at peripheral level as those used for day-to-day managment.

437. The standards at central level are presently restricted to the following ratios:

$\frac{P}{N}$: Average progress in grade per Division;

$\frac{M}{P}$: Expenditure on equipment and services in relation to the personnel costs, per type of activity. These ratios may be applied:

- Types X and Z) - Type I)	to the "study" and "construction" stages, depending on the projects
- Type E: 1 to 2	per field
- Type R: 0.1 to 1	depending on whether theoretical studies or theoretical work
- Type S: 0.1 to 1 (except S5)	depending on number and size of external contracts

$\frac{Param}{N}$: Area of laboratories and offices, per occupant. At present, these standards are:

- 9 m^2 net per occupant of an office only;
- 12 m^2 net per occupant of a laboratory only;
- 17 m^2 net per occupant of an office and a laboratory.

These standards are supplemented at peripheral level by similar ones by means of which the parameters may be forecast.

438. The requirements drawn up by the Divisions, the plans stemming from the model and the programmes fixed by the Directorate are represented at various aggregate levels by the measurements:

$$N, P, M, T \text{ (where } T_i = P_i + M_i).$$

Appendices 5, 6 and 7 give a few examples of internal documents obtained from the administrative computer, as described in Chapter 3. The documents submitted to Council usually use only N and T, and, of course, take the most aggregated form.

44. Constructing and using the models

441. The purpose of the main model is to ensure the coherence of plans and programmes with the aid of causal and logical relationships between the exogenous variables, the parameters and instruments, on the one hand, and the activity levels on the other. The model will, thus, use the input data mentioned earlier to dictate these activity levels, as regards both personnel and costs, for every plan drawn up. It has so far been impossible to construct a complete model for the work done at CERN. However, sub-models have been made up. It is still not known for certain, whether the main model will eventually be the equivalent of an aggregation of sub-models or whether it will be possible to draw it up more simply, without recourse to such sub-models. Certainly, the most effective method will be to adopt both, the global and the sub-assembly aggregation approaches at the same time. In addition, the appearance of the model of the Laboratory will be governed by its integration into the overall model of the scientific discipline, sketched out in Figure 1.

442. A general idea of these two versions is given by Figure 10. If the centre is looked at from the point of view of demand, originating from European physicists, the overall version of the model could be arranged to consider the following variables:

N_1 = Number of physicists working at the centre (man-years);

N_2 = Number of physicists drawing their material from the centre (man-years), but actually working in their own universities or institutes;

T_{EXP} = Annual operating expenditure (Types R + S);

T_{INV} = Annual investment expenditure (Types E + B + I + X + Z).

The model could, first of all, be used to find

$T_{EXP} = f\left[\alpha N_1, \beta N_2, t, T_{INV}(T)\right]$ with $(T_{EXP} + T_{INV})$ and $(N_1 + N_2)$ given, while $\alpha(t)$ and $\beta(t)$ represent accepted specific costs. The ranges of T_{EXP} and T_{INV} for any possible N_1, N_2 policy could be obtained.

443. The aggregate version of the model would start from the relationships between parameters, personnel and costs for each activity to define T and N by field and by type. These relationships themselves appear very different, depending on whether they relate to T_{EXP} or T_{INV}.

Figure 10

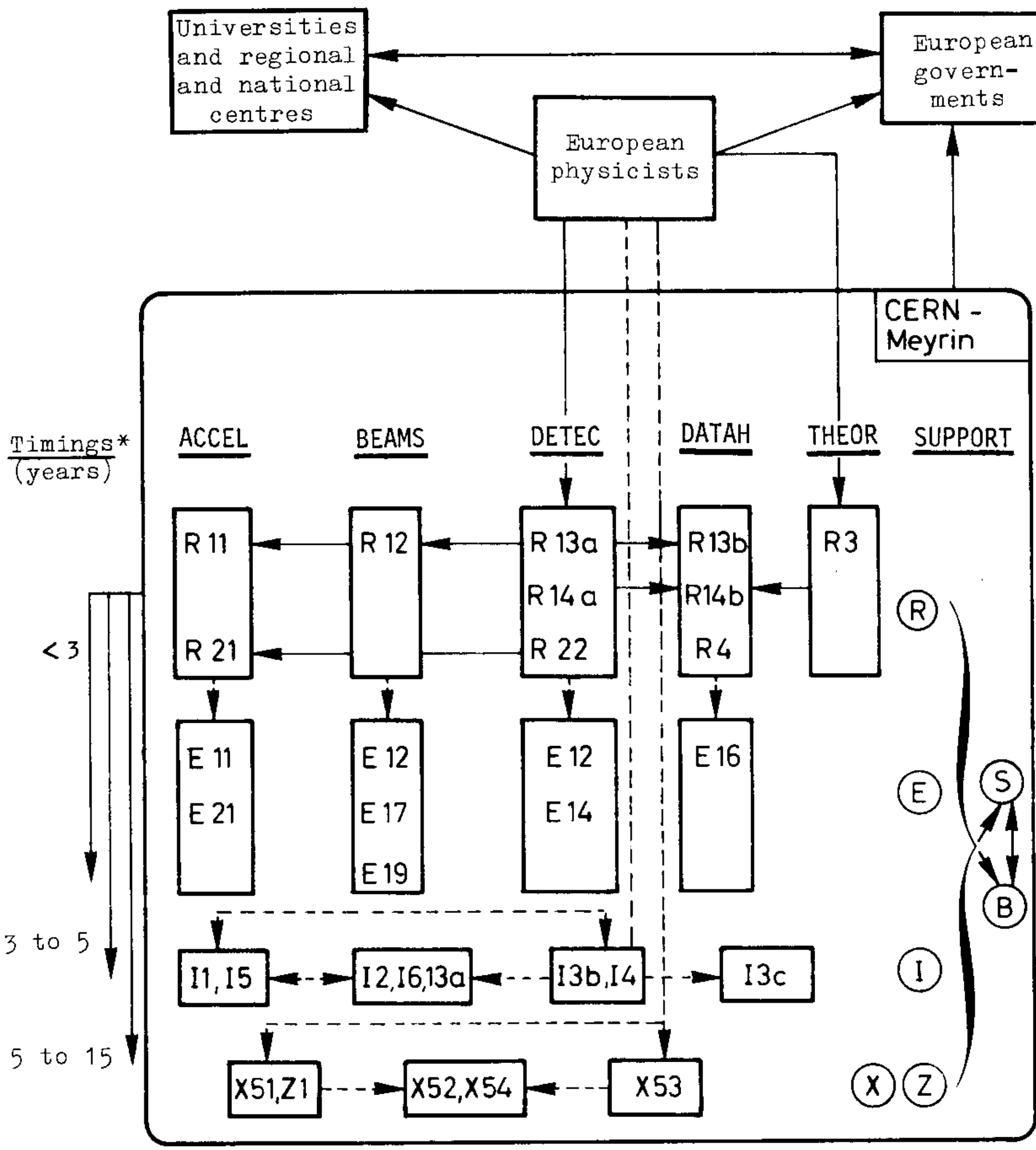


Fig. 10 Model of CERN from the demand viewpoint
(for the meaning of the symbols, cf. Fig. 6, P. 28)

The arrows give the direction in which the demand is made.
The broken lines relate to investment activities.

* The timings referred to are the periods between the presenting of the demands and the completion of the projects.

The relationships between operation activities may, in fact, be expressed by fairly simple approximations in the conventional form:

$$R_i = F_i + \sum_{j=1}^{n} \rho_{ij}\, p_{ij}$$

where:

$\rho_{ij}(t)$ = the linear or differential relationship between parameters and/or costs;

p_{ij} = the demand to be satisfied, generally in the form of parameters j (n = number of such demands);

F_i = fixed part of activity R_i;

R_i = measurement of type R activity.

Examples

- Operation of a track chamber (DETEC, R_{14a}):

Annual cost (R_{14a}) = fixed charges + (cost per hour x the necessary hour operation)
+ (cost per photograph x photographs wanted).

- Operation of an accelerator (ACCEL, R11) (man-years):

Annual personnel numbers (R11) = minimum personnel + (personnel in each team for x teams) + (additional personnel per periodic shut-down x number of periodic shut-downs) + (personnel per beam extraction x number of extractions).

These relationships are affected in time by factors like the level of radioactivity, technical complexity and the ease or difficulty of obtaining spare parts on the industrial market. The latter factor is important when original prototypes can be replaced by standard industrial components.

444. The medium and long-term investment activities (I, X, Z) may also be easily expressed because they are largely unaffected by day-to-day operation and short-term investments. They usually involve large projects which must be physically described and assessed in detail, not by general relationships between parameters, personnel and costs. These projects are planned and followed up with the aid of

graphic networks (CPM) and affect future levels of operation and the services required during their execution. It should also be noted that these activities include a preliminary design study phase, rather like an operational activity, followed by a construction phase proper.

445. There are two main reasons why short-term investment activities are the most difficult to integrate into the model, viz:

1. the fact that it is impossible to predict, three or four years beforehand, what short-term investments will be needed at the time;

2. these investments vary widely depending on their purpose.

The first reason has led to planning by costs rather than by objects. Even in the case of civil engineering work, where it is nevertheless possible to calculate the areas required in four years' time, it can often not be forecast precisely what they will be used for. Therefore, buildings sometimes constitute well-defined "projects", often just "short-term investments". Appendix 10 shows the appropriate sub-model for planning building areas. Concerning the scientific fields, it is usual that nothing more can be done than to request or schedule the availability of equipment to a certain value at a certain date. Since the equipment concerned is unknown, an attempt is made to express its costs in relation to the value of the existing equipment in the field. If the present value V is known according to what is said in section 432, attempts will be made to find the rates corresponding to each class of these investments by a method based on assumptions which can very roughly be the following:

There are four reasons for short-term investments and hence for such classes of investment:

a) Expansion: What is concerned here is the equipment required in each field as the centre expands, e.g. magnets, pumps, power supplies, computers and electronic assemblies. Although the general nature of such equipment is known, it would be useless to attempt to draw up a specification for them a few years in advance, since improved prototypes and models will invariably be used. If the annual rate of expansion is $\underline{a}$, then

$$E_{a_i} = \sum_{j=1}^{n} a_i \frac{dV_{ij}}{dt}$$

where:

E_{a_i} is the cost of expansion in field $\underline{i}$;

a_i is an accepted annual expansion factor for field $\underline{i}$;

V_{ij} is the value of equipment used in stock for class j.

b) Development proper: Most of the equipment used in scientific research must be continually improved and developed in order to remain in the van in the field of instrumentation. It must, for instance, be adapted to the users' needs, new functions must be added to it, etc. These remarks apply particularly to large pieces of equipment like accelerators and detectors, for which the overall development cost distributed over their useful lives, can be assumed to be of the same order of magnitude as their original construction costs.

Thus:

$$E_{b_i} = b_i V_i \ ,$$

where:

$b_i(t)$ is the annual rate of development of equipment i.

This rate, then, may amount to 10% for certain large detectors. Smaller components, like electronic assemblies, are not usually "developed" in this way, but simply replaced by new designs.

c) Replacement: The renewal of components, which is either part of normal maintenance, a day-to-day activity, or part of development as discussed above, if an important improvement is made, is not meant here. What is actually meant is the replacement of an entire assembly or, to cite the above examples, the scrapping of an accelerator after some fifteen years' use, beam components (ten years), computers (five years) or electronic assemblies (three years). All these instruments are replaced primarily as a result of the march of scientific progress, while wear and lower profits are the usual reasons for replacing conventional equipment like machine-tools, vehicles, etc. If the replacement of large equipment is considered as specific medium or long-term projects, and the linear obsolescence of scientific instruments and conventional machinery is accepted, the same formula as for b) can be applied to them:

$$E_{c_i} = c_i V_i$$

where:

c_i = annual rate of replacement of equipment i.

This rate cannot be applied to large projects.

Coefficients b) and c) are the prime components of the overall factor known as the "sophistication" of research. This factor measures the increase in the cost of equipment per research worker. It came, for example, to 2.5%, at updated prices, in the large British centres in the 'sixties(38).

d) Diversification: The fourth reason for short-term investment is justified by the need to make provisions for efforts and means allocated to the development of new instruments and techniques in addition to the existing ones. Here, fundamental research has to invent its own tools; it may, in fact, be said that work on diversifying equipment is to fundamental research what research is to industrial production. It is as hard to work out how much should be put into this aspect as it is to decide, in industry, whether a research programme should be undertaken within the firm or whether patents should be acquired or research contracts awarded to outside bodies.

Diversification may be expressed either as a special activity, i.e. as a project, or as a coefficient (d) affecting all other short-term investments:

$$E_d = d \sum_{i=1}^{n} (E_{a_i} + E_{b_i} + E_{c_i}).$$

The total of the short-term investment activities (E) would thus take the form:

$$E = \left(\sum a_i \frac{dV_i}{dt} + \sum b_i V_i + \sum c_i V_i \right) (1 + d)$$

for constant expansion rates a_i over the period under consideration.

This idea is reasonable in practice. Since the medium and long-term projects have been set apart from the beginning, the rate of expansion of short-term activities may be different from the overall growth of the centre. At CERN, the rate is at present lower than the annual growth rate of the centre, the difference being due to the large projects.

Finally, in attempting to integrate the activities E in the model, one can use V, the value of the equipment, as a starting point, and express E as a function of day-to-day activities R with the aid of a coefficient of use u of the equipment; for each field i,

$$u_i = \frac{R_i}{V_i} \text{ will be obtained.}$$

n this case E_i becomes:

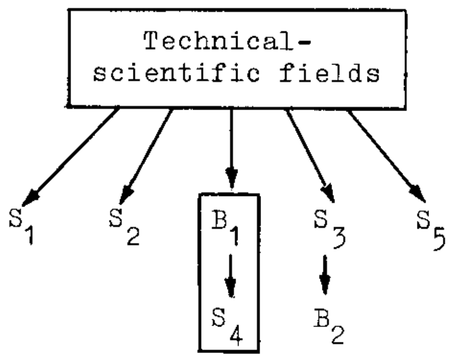
$$E_i = \left[\frac{1+d_i}{u_i}\right]\left[a_i \frac{dR_i}{dt} + (b_i+c_i)\ R_i\right].$$

The total effort in each technical-scientific field could thus be :pressed in annual cost figures via the planning coefficients a, b, d and u, that of the effort R, itself a function of the essential .rameters for the field, and of efforts I, X and Z on large projects.

446. The field of support in a research centre does not differ widely from that in an industrial firm as to justify special at- ntion in a report like this one. Primarily, support activities e governed by the effort scheduled to be made in the technical- ientific fields and by the policy adopted in respect of them. It made up of the following functional activities:

	Administrative support	Technical support
peration	S_1 = Administration S_2 = Administrative services	S_3 = Technical services S_4 = Site services S_5 = Power supplies
ıvestment	(included above)	B_1 = Construction B_2 = Equipment for the technical services

In its simplest approximation, demand for these services is distributed in the following way:



Appendix 10, which has already been mentioned earlier, shows a sub-model $B_1 - S_4$.

A few of the relationships between the technical-scientific fields and the auxiliary activities contain standards of the "m^2/person" type. The levels of these activities are, however, usually still based on the overall indicators discussed in section 437 f).

447. The aggregate model would be finally expressed in the form:

$$f_1 \ (V_i, \text{ large projects}) + f_2 \ (f_1)$$

where:

$$f_1 = \left[R_i \ (u_i V_i), E_i(a_i, b_i, c_i, d_i, V_i), \text{ large projects}\right]$$

and:

$$f_2 = (B, S).$$

It is, then, the purpose of preferential judgment to allocate values, for each field, to the planning coefficients <u>a</u>, <u>b</u>, <u>c</u>, <u>d</u>, <u>u</u> described in Section 445 and to the standards, in such a way that the indicators obtained meet with the approval of the centre's management and consultative bodies.

These coefficients thus constitute some of the best <u>planning tools</u>. The ratios of certain indicators may, moreover, integrate themselves into the model, e.g. the ratios between the proportion of the available resources allocated to neighbouring fields and those relating to external demand. It will therefore be possible for preferential judgment, so far applied empirically, on the one hand to the indicators and on the other to the planning tools and standards, to contribute towards the development of the model by making these values consistent among themselves. The evolutionary mechanism of the system must be seen in these judgment functions at each level. A pragmatic search must be made for new indicators which can be used as planning tools or even standards. This task is the more difficult, the nearer it is to the acquisition of data (DETEC). This kind of work is an integral part of the annual planning process and will probably never be fully completed since new kinds of input data will always appear, in accordance, indeed, with the very spirit of research. This is why the mathematical side of the model will have to be kept as simple as possible to allow for continual adaptation.

448. As has been seen, the two versions of the main model of the Meyrin-Geneva centre are still in the embryonic stage. It is fully recognized that a great deal of planning will be necessary even before the variables and essential relationships can be given a sufficiently strict definition for them to be usable on a model programmed and simulated on a computer. Nevertheless, the planning process already drafted continues to provide pointers in this direction and the vast majority of research and administration workers are making a more or less deliberate contribution to the development of models and submodels. Regression analysis and attempts to predict costs by type and field of activity within a given total envelope of expenditure have not so far been a great deal of help, either because all they have done has been to confirm obvious relationships, or because the data available as a basis (those for the period 1965 to 1968) were too scarce from the start. On the other hand, the functional classification of activities and their practical use has been found extremely effective in extending and supplementing this basis in a continuous and reliable manner.

449. It has already been said that widespread participation in the planning process, particularly for the development of models, was highly desirable. Such participation requires an organization to supplement the hierarchical structure, consisting in a number of coordinating and selection Committees. Those represented on them are:

- those in charge of an activity and taking the decisions concerning it;
- those benefiting from such activity, particularly if they are outside CERN;
- the central management and the Programme Office, as the case may be.

These committees come into being primarily in connection with R and S-type activities. They exercise their judgment with respect to the plans and indicators drawn up by the appropriate section. Table 4 gives a few important examples.

There are also two committees bringing together all those people concerned with the <u>formal</u> side of planning, viz:

- the Working Group on Programme Data, which mainly helps in developing the functional programme presentations (FPP) (about fifteen persons);
- the CPM-PERT committee, which develops critical path methods and their application, mainly to investment activities (about twelve persons).

	Activities	Committee Members: Those in charge	Committee Members: Beneficiaries	Title of Committee
R1+R2	PS and SC research programmes	PS, Physics I and II Departments	European physicists	NPRC (Nuclear Physics Research Committee)*
R13	Research with the aid of electronic detectors	Nuclear Physics Division	European physicists	EEC (Electronics Experiments Committee)*
R14	Research with the aid of the track chambers	Track Chamber Division	European physicists	TCC (Track Chamber Committee)*
R22) E22)	Research with the aid of the SC and nuclear chemistry	Nuclear Physics and MSC Divisions	European physicists	Physics III Committee*
R4) E16)	Central scientific data handling	Data Handling Division	Scientific and technical Divisions	DHPG (Data Handling Policy Group) CUAC (Computer Users Advisory Committee)*
S1	Central administrative data processing	Finance Division	All Divisions	Admin. Data Processing Policy Committee and ADP Users Committee
S3	Scientific information	Data Handling Division	All Divisions	Library Committee
S3	Workshops (central and regional)	Site and Buildings Division and other Divisions	Scientific and technical Divisions	Workshop Users Committee
S3	Central Stores	Site and Buildings Division	All Divisions	Stores Users Committee
B1	Site planning and constructions	SB Division	All Divisions	Committee of Energy and Water Supplies
B1) S5)	Power supplies			

* These committees essentially have the job of setting short-term priorities

TABLE 4

The Centre's main planning committees

CONCLUSIONS

Since there are no quantitative units for measuring the "scientific product", fundamental science planning at all levels must be undertaken with two prime factors in mind.

1. Most decisions contain a considerable proportion of subjective judgment.

2. It is difficult to bring together the components constituting the quantifiable portion of the decision bases.

This is why the author tried to develop a planning system at CERN such that:

1. the judgment function is specifically included at all levels;

2. there is, at all levels, considerable participation in identifying, obtaining, transmitting and assembling significant data.

An attempt has been made in this study to describe this system at the levels of the scientific discipline and of the research centre. The system makes use of a functional language mainly employed between the central bodies and the periphery in order to express, if not scientific productivity, then at least scientific activity.

The construction of models and sub-models is still only in its infancy. Nevertheless, initial work shows that the functional language is useful in formulating significant relationships and that those in charge of research and administration are prepared to use it. Thus, it will be fairly simple to mobilize the outstanding analytical and mathematical potential of a research centre to help in building these models. The problem will mainly be to continue to improve the reliability and coherence of the information.

It has already been possible, through the use of a computer at central level, to reduce considerably the time consumed and errors in transformation between different plan and programme representations. Models should also be designed so as to be able to make use of the same functional data bases. The planning parameters and tools would be introduced at every level to obtain the ratios to be assessed. Such a procedure is by no means a pipe dream, in view of the large number of computers available in a centre like CERN and their continual use by hundreds of research workers. In addition, the absence of any method of measuring scientific productivity means that certain parts of the work can be simplified, while the idea of efficiency consists mainly in distributing the available facilities in the best possible way.

The research centres and, hence, by extension, the scientific disciplines, are thus in a position to learn quickly, on these bases, how to obtain a better knowledge of their own capabilities and to suit modern management and forecasting methods to their needs.

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G. MINDER

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30. cf. (4).

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33. CERN/ECFA, 1967 ECFA Report (CERN/700).

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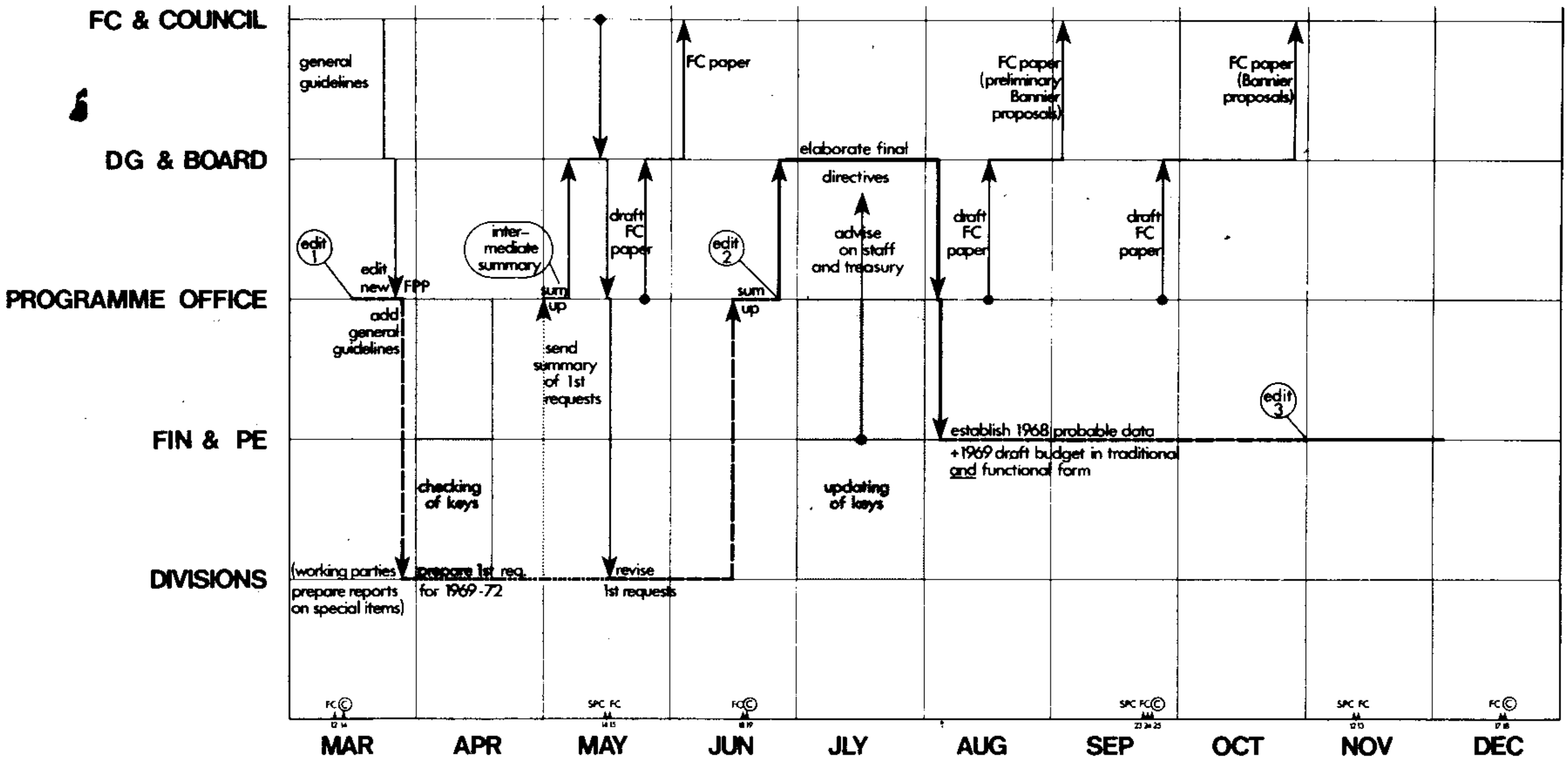
Appendix 8



BUDGET PLANNING PROCEDURE IN 1968

(3 FPP EDITIONS IN MARCH, JUNE & OCTOBER + 1 INTERMEDIATE SUMMARY IN MAY)

PROGRAMME OFFICE
26 3 68

Appendix 1

CERN, Meyrin (1969)

This Appendix consists of a sixteen-page brochure of general interest, describing CERN. It is not shown in CERN Report 70-2, but is obtainable from the Public Information Office, CERN, 1211 Geneva 23.

37. P.M. Stokes, A Total Systems Approach to Management Control, American Management Association, New York 1968, P. 50.

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Appendix 3

TABLE FOR FUNCTIONAL BREAKDOWN OF ACCOUNTS 1967 PAGE 3

SECT.	BUD1	BUD2	ACT. 1	C PER	ACT. 2	C PER	ACT. 3	C PER	ACT. 4	C PER	ACT. 5	C PER	ACT. 6	C PER	ACT. 7	C PER
2201	328		MPS2	M 45	MPS1	M 55										
2201	352		MPS1	M 100												
2201	494	496	MPS2	M 30	MPS1	M 70										
2202	10	11	MPS9	P 3	MPS6	P 11	MPS1	P 26	MPS2	P 26	MPS7	P 34				
2202	212		MPS1	M 100												
2202	223		MPS1	M 100												
2202	225		MPS1	M 100												
2202	236		MPS1	M 50	MPS2	M 50										
2202	237		MPS1	M 100												
2202	312		MPS1	M 50	MPS2	M 50										
2202	323		MPS1	M 40	MPS2	M 60										
2202	325	344	MPS2	M 100												
2202	352		MPS2	M 40	MPS1	M 60										
2202	494	496	MPS2	M 35	MPS1	M 65										
2203	10	11	MPS7	P 2	MPS4K	P 2	MPS9	P 2	MPS3	P 94						
2203	234	235	MPS3	M 100												
2203	236	237	MPS4K	M 10	MPS3	M 90										
2203	238	321	MPS3	M 100												
2203	322		MPS4K	M 100												
2203	323	340	MPS3	M 100												
2203	341		MPS4K	M 100												
2203	342	347	MPS3	M 100												
2203	348		MPS4K	M 100												
2203	494	496	MPS3	M 30	MPS4K	M 70										
2204	10	11	MPS7	P 4	MPS6	P 8	MPS2	P 9	MPS1	P 19	MPS4K	P 25	MPS3	P 35		
2204	211	212	MPS1	M 50	MPS3	M 50										
2204	221		MPS1	M 100												
2204	236	237	MPS1	M 20	MPS3	M 32	MPS4K	M 48								

Organizational unit

Accounting codes

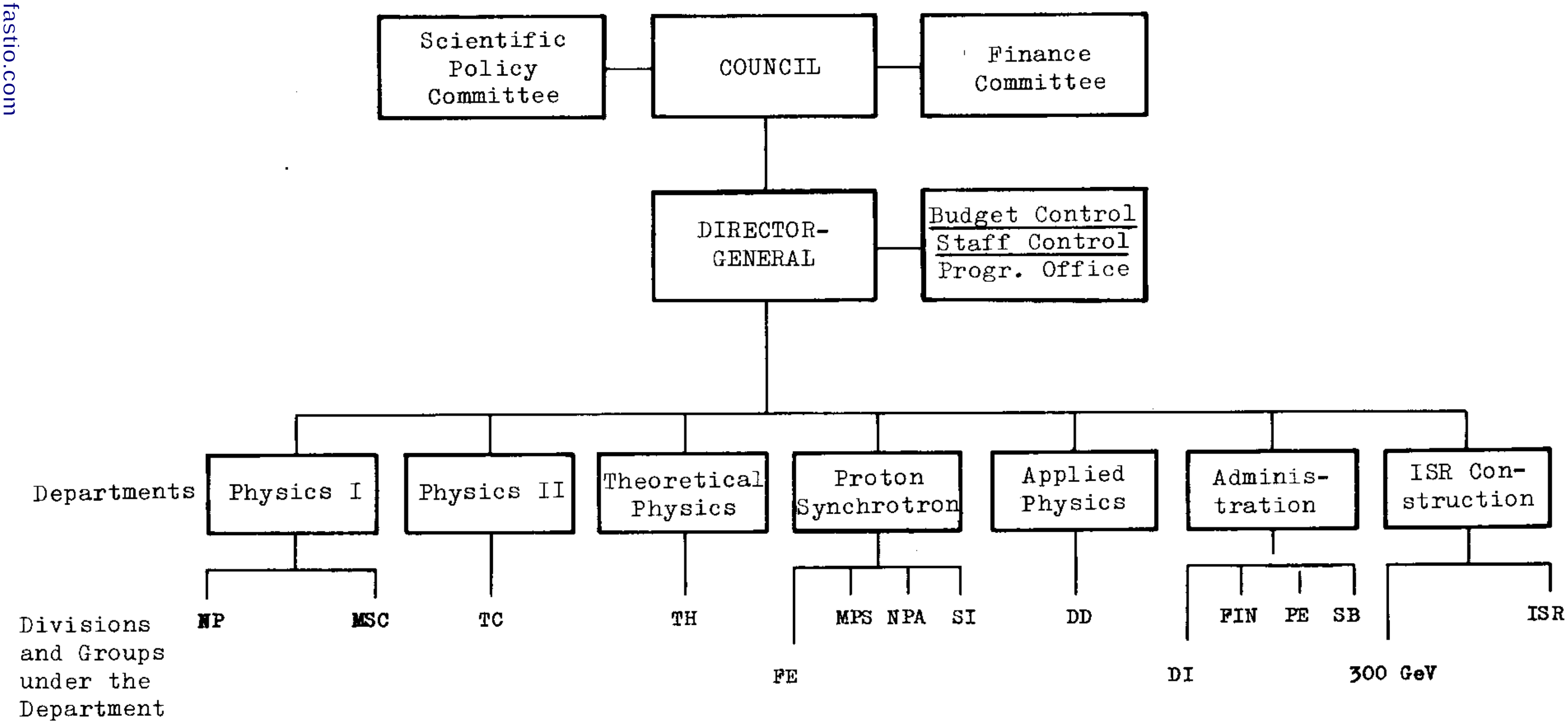
Divisional activities

sub-activity

Breakdown of percentages
(P = Personnel costs)
(M = Equipment costs)

Appendix 3: Table for converting the accounting presentation (C) into a functional presentation (B)

Appendix 2



Appendix 2 Diagram showing the organization of CERN-Meyrin (1969)

FUNCTIONAL PROGRAMME PRESENTATION 17 DECEMBER 1968 REVIEWED AS FOLLOWS- PRICES 1969 NAME PROGR.OFFICE PURPOSE RUN DATE 18/12/68 PAGE 1

CERN SUMMARY - RESEARCH AND OPER

N = PERSONNEL NUMBERS END OF YEAR I
P = PERSONNEL COST PER YEAR II
M = MATERIAL COST PER YEAR III
* = PERSONNEL NUMBER NOT IN TOTAL IV

ALL COSTS EXPRESSED IN UNITS OF 1'000'000 SWISS FRANCS AT 1969 PRICES

YEAR* → A-3 (1965), A-2 (1966), A-1 (1967), A (1968), A+1 (1969), A+2 (1970), A+3 (1971), A+4 (1972)

CERN ACT.	SOURCE → ACTIVITY	1965 ACCOUNTS N /	P	M	TOT	1966 ACCOUNTS N /	P	M	TOT	1967 ACCOUNTS N /	P	M	TOT	1968 * PROBABLE N /	P	M	TOT
CERN Activities	R 11 MACHINE OPERATION		3.59	3.24	6.83	111/	4.00	3.11	7.10	85/	3.13	4.19	7.32	102/	3.76	4.97	8.73
	R 12 EXP AREAS OPERATION		3.50	3.08	6.59	109/	3.69	3.09	6.77	107/	3.76	2.28	6.04	99/	3.76	2.83	6.59
	R 13 ELECTRONICS PHYSICS		7.58	4.62	12.20	213/ (129)	7.79	4.94	12.73	230/ (172)	8.42	5.72	14.15	241/ (188)	8.62	6.62	15.24
	R 14 BUBBLE CHAMB PHYSICS		7.96	4.71	12.67	300/ (32)	8.57	4.73	13.30	316/ (48)	9.44	5.45	14.89	348/ (47)	10.58	6.16	16.74
CERN programme →	R 1 TOTAL PS PROGRAMME		22.63	15.65	38.28	619/ (161)	24.04	15.86	39.90	609/ (220)	24.76	17.63	42.39	645/ (235)	26.72	20.58	47.30
	R 21 MACH & FLOOR OPS		1.25	1.43	2.68	41/ (3)	1.77	2.09	3.86	44/ (3)	1.89	1.76	3.65	51/ (3)	2.07	1.32	3.39
	R 22 PHYSICS EXPERIMENTS		1.12	.74	1.86	27/ (32)	1.19	.99	2.18	28/ (42)	1.29	.88	2.16	30/ (47)	1.25	.77	2.02
	R 2 TOTAL SC PROGRAMME		2.37	2.17	4.54	68/ (35)	2.95	3.08	6.03	72/ (45)	3.17	2.64	5.81	81/ (50)	3.32	2.08	5.40
	R 3 THEORY		1.96	.11	2.06	48/ (13)	2.10	.11	2.21	50/ (13)	2.21	.10	2.30	56/ (19)	2.86	.14	3.00
	R 4 CENTR DH & COMPUTING		2.69	7.59	10.27	93/ (1)	3.17	9.71	12.88	106/ (2)	3.63	10.66	14.29	131/ (3)	4.44	13.95	18.39
	R TOTAL RESEARCH AND OPER		29.65	25.51	55.16	820/ (210)	32.26	28.76	61.02	828/ (280)	33.76	31.03	64.79	902/ (307)	37.34	36.75	74.09

CERN ACT.	ACTIVITY	1969 *BUDGET AT 69 PR.* N /	P	M	TOT	1970 REQUESTS AT 69 PRICES N /	P	M	TOT	1971 CUT 15 JULY N /	P	M	TOT	1972 * N /	P	M	TOT
CERN Activities	R 11 MACHINE OPERATION	109/	4.22	4.11	8.34	116/	4.65	4.60	9.25	119/	5.00	4.66	9.65	134/	5.58	7.28	12.87
	R 12 EXP AREAS OPERATION	106/	4.12	2.72	6.84	109/	4.30	3.06	7.36	142/	5.29	3.08	8.36	157/	6.44	3.44	9.88
	R 13 ELECTRONICS PHYSICS	245/ (204)	9.10	6.58	15.68	260/ (224)	9.83	7.36	17.19	262/ (248)	10.00	7.77	17.77	282/ (280)	10.46	9.29	19.75
	R 14 BUBBLE CHAMB PHYSICS	363/ (51)	11.12	4.98	16.10	403/ (61)	12.47	6.82	19.29	400/ (57)	12.61	6.45	19.07	507/ (65)	17.49	12.43	29.92
CERN programme →	R 1 TOTAL PS PROGRAMME	675/ (255)	28.57	18.39	46.96	713/ (285)	31.25	21.83	53.08	746/ (305)	32.90	21.96	54.86	902/ (345)	39.98	32.43	72.41
	R 21 MACH & FLOOR OPS	51/ (3)	2.25	1.24	3.49	55/ (3)	2.12	.87	2.98	56/ (3)	2.23	1.66	3.89	56/ (3)	2.30	1.90	4.20
	R 22 PHYSICS EXPERIMENTS	31/ (51)	1.33	.82	2.15	32/ (56)	1.45	.85	2.29	33/ (62)	1.51	.89	2.40	33/ (70)	1.53	.89	2.42
	R 2 TOTAL SC PROGRAMME	82/ (54)	3.58	2.06	5.63	87/ (59)	3.56	1.72	5.28	89/ (65)	3.74	2.55	6.29	89/ (73)	3.83	2.79	6.62
	R 3 THEORY	56/ (20)	2.94	.15	3.09	57/ (21)	3.04	.16	3.20	57/ (22)	3.08	.17	3.25	57/ (23)	3.12	.18	3.31
	R 4 CENTR DH & COMPUTING	141/ (3)	4.67	8.35	13.02	167/ (3)	5.64	12.58	18.22	189/ (3)	6.37	15.51	21.88	207/ (3)	6.91	15.96	22.87
	R TOTAL RESEARCH AND OPER	941/ (332)	39.74	28.95	68.69	1010/ (368)	43.48	36.29	79.77	1065/ (395)	46.09	40.19	86.28	1237/ (444)	53.85	51.36	105.21

(Visiting Scientists not paid by CERN)

*

A = Current financial year

A + 1 = Budget year

A + 2 ... A + 4 = Planned financial years

Appendix 5: Aggregate presentation A

Appendix 4

TABLE-2 BREAKDOWN BY CERN ACTIVITY DATE 10/01/69 PAGE 1

ACTIVITY		DESCRIPTION	C.A	O/O	C.A	O/O	C.A	O/O	C.A	O/O	C.A	O/O	C.A	O/O	Y
DG	1	DIRECTION AND SECR	S 1	100											
DG	2	RESERVE	S 1	100											
DG	3	F + V PROGRAMME													
PHI	1	DEPARTMENT DIRECTION	S 1	100											
PHI	2	RESERVE	S 1	100											
NP	1	HIGH ENERGY RES GRPS	R13	100											
NP	2	LOW ENERGY RES GRPS	R22	100											
NP	3	ENGINEERING ASSIST	R13	100											
NP	4A	ENGINEERING DEVELOPM	I 3	100											
NP	4K	ENGINEERING DEVELOPM	E13	100											
NP	5	PROJECT OMEGA	I 3	100											
NP	6	DH & ELECTR ASSIST	R13	100											
NP	7A	DH & ELECTR DEVELOPM	I 3	100											
NP	7K	DH & ELECTR DEVELOPM	E16	100											
NP	9	DIVISIONAL DIRECTION	E16	10	E13	10	R22	20	R13	60					
NP	F+V	F+V PAID BY DG			R22	20	R13	80							2
NP	F+V	F+V PAID BY DG	I 3	10	R22	20	R13	70							8
NP	UV	UNPAID VISITORS	R22	20	R13	80									
NP	11	LAB STAFF (MANYEARS)	R13	100											
NP	12	F+V PAID BY DIVISION	R13	100											
MSC	1	SC MACH & FLOOR OPS	R21	100											
MSC	2	SC MACH & FLOOR DEV	E21	100											
MSC	3	WORKSHOP ETC FOR NP	R13	100											
MSC	9	DIVISIONAL DIRECTION	R21	40	E21	60									
MSC	F+V	F+V PAID BY DG	R21	33	E21	67									
MSC	UV	UNPAID VISITORS	E21	33	R21	67									
MSC	12	F+V PAID BY DIVISION	E21	100											
II	1	DEPARTMENT DIRECTION	S 1	100											
II	2	RESERVE	E17	50	E12	50									
II	3	SERPUKHOV EQUIPMENT	E17	100											
TC	1	BUBBLE CHAMBERS OPS	R14	100											
TC	2	BUBBLE CHAMBERS DEV	E14	100											
TC	3	BEAMS OPERATION	R12	100											
TC	4	BEAMS DEVELOPMENT	E12	100											
TC	5	PICTURE EVAL OPS	R14	100											
TC	6	PICTURE EVAL DEV	E16	100											
TC	7	LOW TEMPERATURE OPS	S 3	100											
TC	8A	LOW TEMPERATURE DEV	I 3	100											
TC	8K	LOW TEMPERATURE DEV	E19	100											
TC	9	DIVISIONAL DIRECTION	R12	5	E14	10	E16	10	E12	20	R14	55			
TC	F+V	F+V PAID BY DG	R14	100											
TC	UV	UNPAID VISITORS	R14	60	I 4	40									
TC	UV	UNPAID VISITORS	R14	45	I 4	55									
TC	UV	UNPAID VISITORS	R14	100											
TC	10	BIG EURO BUBBLE CH	I 4	100											
TC	11	LAB STAFF (MANYEARS)	R14	100											
TC	12	F+V PAID BY DIVISION	R14	100											
III	1	DEPARTMENT DIRECTION	S 1	100											
III	2	RESERVE	S 1	100											
TH	1	THEORETICAL PHYSICS	R3	100											
TH	F+V	F+V PAID BY DG	R3	100											
TH	UV	UNPAID VISITORS	R3	100											
TH	12	F+V PAID BY DIVISION	R3	100											
IV	1	DEPARTMENT DIRECTION	S 1	100											
IV	2	RESERVE	S 1	100											
IV	3	BEAM TRANSFER TO WA	I 6	100											
FE	1	SERPUKHOV EQUIPMENT	E17	100											
FE	2	PS FAST EJECTION OPS	R11	100											
FE	3	PS FAST EJECTION DEV	E11	100											
FE	4	ELECTR DETECTOR DEV	E13	100											

DIVISIONAL ACTIVITY

CERN ACTIVITIES

BREAKDOWN (%)

VALIDITY (IN YEARS)

Appendix 4: Table for converting the functional presentation B into a functional presentation A

Appendix 7

FUNCTIONAL PROGRAMME PRESENTATION 17 DECEMBER 1968 REVIEWED AS FOLLOWS- PRICES NAME PURPOSE RUN DATE PAGE 40

N = PERSONNEL NUMBERS END OF YEAR I 1969 PROGR.OFFICE 18/12/68
P = PERSONNEL COST PER YEAR II
M = MATERIAL COST PER YEAR III
\# = PERSONNEL NUMBER NOT IN TOTALS IV

DIVISIONAL SUMMARY - MPS DIVISION

ACTIVITY CERN ACT.	1965 ACCOUNTS N / P M	TOT	1966 ACCOUNTS N / P M	TOT	1967 ACCOUNTS N / P M	TOT	1968 PROBABLE N / P M	TOT	1969 BUDGET AT 69 PR. N / P M	TOT	1970 REQUESTS AT 69 PRICES N / P M	TOT	1971 N / P M	TOT	1972 CUT 15 JULY N / P M	TOT
MPS 1 R11 PS MACH OPERATION	3.06 2.76	5.82	97/ 3.45 2.76	6.21	80/ 2.90 3.71	6.61	97/ 3.55 4.41	7.95	104/ 4.03 3.67	7.70	111/ 4.42 4.06	8.48	114/ 4.76 4.12	8.89	123/ 5.17 4.70	9.87
MPS 2 E11 PS MACH DEVELOPMENT	2.93 2.55	5.48	69/ 2.54 2.94	5.47	80/ 2.96 3.00	5.95	93/ 3.44 3.84	7.28	105/ 4.00 4.87	8.87	109/ 4.42 4.49	8.91	111/ 4.64 4.76	9.40	121/ 5.17 4.73	9.91
Divisional sub-activity MPS 2A I 5 PS MACH DEVELOPMENT							.71	.71	1.00	1.00	1.16	1.16	1.23	1.23	1.28	1.28
Divisional activity MPS 3 R12 EXP AREAS OPERATION	2.26 1.98	4.24	72/ 2.51 1.87	4.38	76/ 2.75 1.50	4.26	72/ 2.77 1.72	4.49	72/ 2.93 1.56	4.49	75/ 3.01 1.73	4.74	101/ 3.71 1.72	5.43	110/ 4.61 2.05	6.66
MPS 4A I 6 (CERN activity) EXP AREAS DEVELOPM							1.01	1.01								
MPS 4K E12 EXP AREAS DEVELOPM	.66 6.06	6.72	23/ .76 6.79	7.55	36/ 1.24 4.80	6.04	46/ 1.56 4.45	6.01	46/ 1.84 3.89	5.73	48/ 1.90 4.51	6.41	48/ 2.02 14.28	16.30	54/ 2.16 12.13	14.29

Appendix 7: Presentation B

Appendix 6

FUNCTIONAL PROGRAMME PRESENTATION 17 DECEMBER 1968 REVIEWED AS FOLLOWS- PRICES NAME PURPOSE RUN DATE PAGE 1

N = PERSONNEL NUMBERS END OF YEAR I 1969 PROGR.OFFICE 18/12/68

P = PERSONNEL COST PER YEAR II

M = MATERIAL COST PER YEAR III

* = PERSONNEL NUMBER NOT IN TOTAL IV

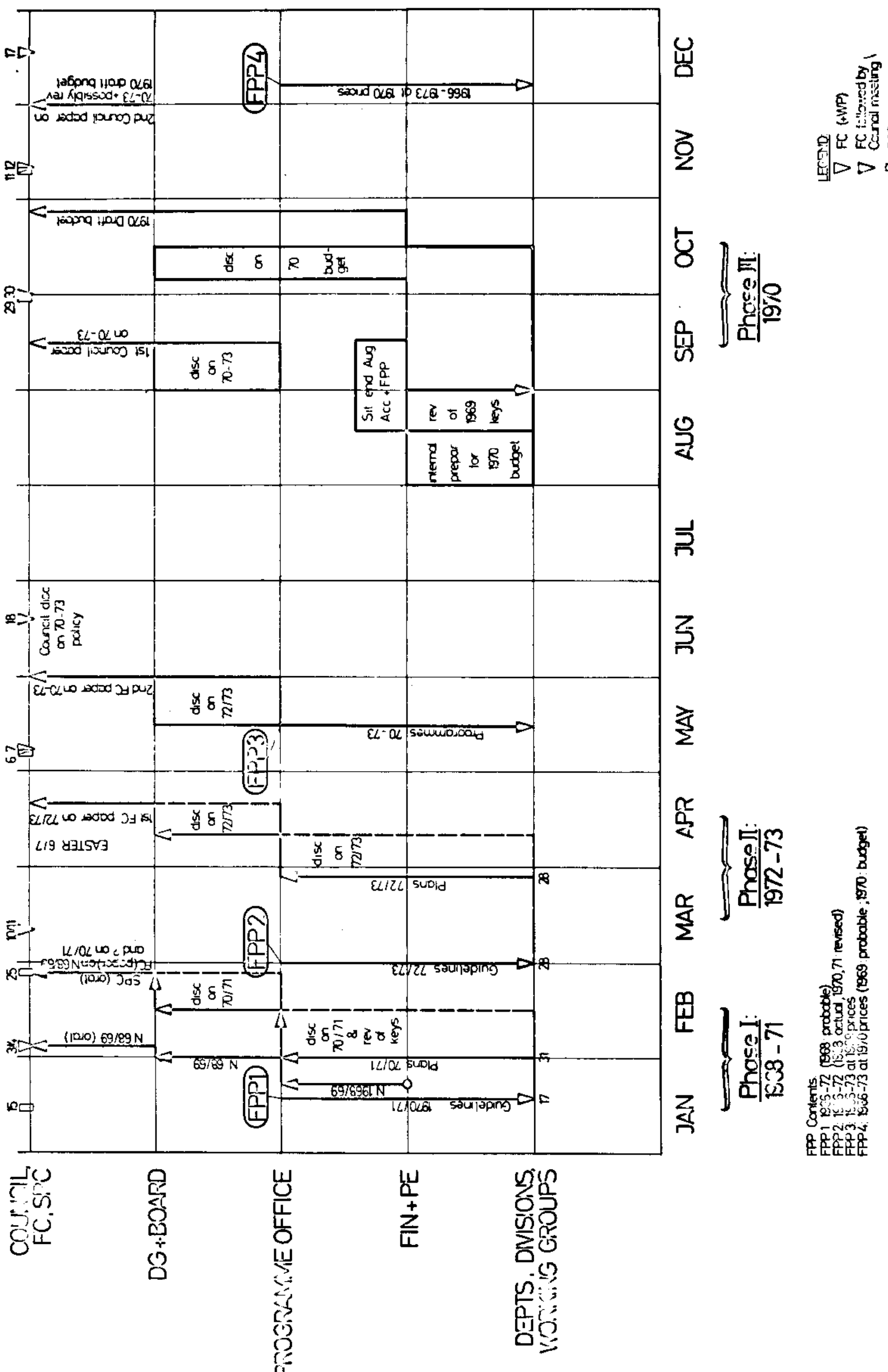
CERN SUMMARY - RESEARCH AND OPER

CERN ACT.	ACTIVITY	1965 ACCOUNTS N	P	M	TOT	1966 ACCOUNTS N	P	M	TOT	1967 ACCOUNTS N	P	M	TOT	* 1968 PROBABLE N	P	M	TOT
R 11	FE 2 MACHINE OPERATION					2/	.05		.05	2/	.08	.03	.11	2/	.08	.15	.24
R 11	MPS 1 MACHINE OPERATION		3.06	2.76	5.82	97/	3.45	2.76	6.21	80/	2.90	3.71	6.61	97/	3.55	4.41	7.95
R 11	MPS 9 MACHINE OPERATION		.53	.48	1.01	12/	.50	.34	.84	3/	.15	.45	.59	3/	.13	.42	.54
R 11	SI 1 MACHINE OPERATION — Division and divisional activity																
R 11	SI 5 MACHINE OPERATION — CERN activity																
R 12	MPS 3 EXP AREAS OPERATION		2.26	1.98	4.24	72/	2.51	1.87	4.38	76/	2.75	1.50	4.26	72/	2.77	1.72	4.49
R 12	MPS 9 EXP AREAS OPERATION		.53	.48	1.01	14/	.50	.34	.84	5/	.15	.45	.59	4/	.13	.42	.54
R 12	NPA 3 EXP AREAS OPERATION		.24	.52	.75	8/	.21	.13	.34	10/	.34	.15	.50	7/	.23	.29	.52
R 12	SI 3 EXP AREAS OPERATION													1/	.04		.04
R 12	TC 3 EXP AREAS OPERATION		.44	.06	.50	14/	.42	.71	1.12	14/	.45	.14	.59	14/	.52	.37	.89
R 12	TC 9 EXP AREAS OPERATION		.05	.04	.09	1/	.05	.03	.09	2/	.07	.04	.11	1/	.07	.04	.10
R 13	MSC 3 ELECTRONICS PHYSICS		.76	.15	.91	21/	.70	.11	.82	21/	.69	.09	.78	20/	.67	.17	.84
R 13	NP 1 ELECTRONICS PHYSICS		3.65	3.45	7.10	78/	3.58	3.75	7.33	82/	3.78	4.27	8.05	82/	3.83	4.04	7.87
R 13	NP 3 ELECTRONICS PHYSICS		.44	.31	.75	13/	.45	.35	.80	14/	.50	.39	.89	15/	.54	.86	1.40
R 13	NP 6 ELECTRONICS PHYSICS		1.06	.37	1.42	33/	1.05	.41	1.46	41/	1.28	.63	1.91	43/	1.34	1.21	2.55
R 13	NP 9 ELECTRONICS PHYSICS		.34	.34	.68	10/	.35	.32	.66	12/	.42	.35	.76	13/	.40	.33	.73
R 13	NP F+V ELECTRONICS PHYSICS		.79		.79	27/	1.03		1.03	24/	1.09		1.09	29/	.94		.94
R 13	NP UV ELECTRONICS PHYSICS					(129)				(172)				(188)			

CERN ACT.	ACTIVITY	*1969 BUDGET AT 69 PR.* N	P	M	TOT	1970 REQUESTS AT 69 N	P	M	TOT	1971 PRICES CUT N	P	M	TOT	1972 15 JULY N	P	M	* TOT
R 11	FE 2 MACHINE OPERATION																
R 11	MPS 1 MACHINE OPERATION	104/	4.03	3.67	7.70	111/	4.42	4.06	8.48	114/	4.76	4.12	8.89	123/	5.17	4.70	9.87
R 11	MPS 9 MACHINE OPERATION	3/	.13	.45	.58	3/	.14	.54	.68	3/	.14	.54	.68	3/	.16	.57	.72
R 11	SI 1 MACHINE OPERATION — Division and divisional activity	2/	.06		.06	2/	.09		.09	2/	.09		.09	2/	.09		.09
R 11	SI 5 MACHINE OPERATION — CERN activity													6/	.17	2.02	2.19
R 12	MPS 3 EXP AREAS OPERATION	72/	2.93	1.56	4.49	75/	3.01	1.73	4.74	101/	3.71	1.72	5.43	110/	4.61	2.05	6.66
R 12	MPS 9 EXP AREAS OPERATION	4/	.13	.45	.58	4/	.14	.54	.68	4/	.14	.54	.68	5/	.16	.57	.72
R 12	NPA 3 EXP AREAS OPERATION	10/	.37	.28	.65	11/	.45	.32	.78	13/	.55	.35	.90	16/	.70	.35	1.05
R 12	SI 3 EXP AREAS OPERATION	1/	.04		.04	1/	.05		.05	1/	.05		.05	1/	.05		.05
R 12	TC 3 EXP AREAS OPERATION	17/	.59	.38	.96	16/	.59	.40	.99	21/	.77	.40	1.18	23/	.86	.40	1.26
R 12	TC 9 EXP AREAS OPERATION	2/	.07	.06	.13	2/	.07	.06	.13	2/	.07	.06	.13	2/	.08	.06	.14
R 13	MSC 3 ELECTRONICS PHYSICS	20/	.75	.22	.97	20/	.84	.20	1.04	22/	.94	.30	1.24	22/	.97	.30	1.28
R 13	NP 1 ELECTRONICS PHYSICS	83/	3.97	4.10	8.07	85/	4.15	4.75	8.90	77/	3.81	4.75	8.56	91/	3.95	5.86	9.81
R 13	NP 3 ELECTRONICS PHYSICS	16/	.59	.90	1.49	17/	.65	.91	1.56	20/	.75	.96	1.71	20/	.77	1.01	1.78
R 13	NP 6 ELECTRONICS PHYSICS	44/	1.47	1.00	2.47	47/	1.62	1.13	2.75	49/	1.71	1.36	3.07	53/	1.88	1.72	3.60
R 13	NP 9 ELECTRONICS PHYSICS	13/	.42	.36	.78	13/	.48	.36	.84	12/	.53	.39	.93	12/	.55	.39	.94
R 13	NP F+V ELECTRONICS PHYSICS	31/	1.17		1.17	34/	1.25		1.25	35/	1.32		1.32	35/	1.32		1.32
R 13	NP UV ELECTRONICS PHYSICS	(204)				(224)				(248)				(280)			

Appendix 6: Detailed presentation A

Appendix 9



Planning and budgeting procedure in 1969

GM, 2169

Appendix 10

Sub-model in the supporting field

1. Activities concerned:

	Construction (Investments)	Operation Maintenance Cleaning
CERN level:	B1	S4
Division level:	SB1	SB2

2. Activities measurement:

	Construction (Investments)	Operation Maintenance Cleaning
Parameters:	CERN population Areas (12 types) Electric powers	Areas and age of buildings Age and value of installations
Personnel:	Of design bureaux and workshop supervision staff	Operating and maintenance staff
Costs:	By type of construction: A) Buildings in general B) Service buildings C) Site work D) Accelerators and tunnels	Maintenance of buildings and appropriate installations; Cleaning; Technical modifications; Maintenance workshops

3. Standards:

Construction (Investments)	Operation Maintenance Cleaning
Occupation density of offices and laboratories; Specific costs by types of area (building standards); Power installed/ power required ratio.	Hours/year maintenance by type of installation and age, and by age of buildings; Alterations to buildings in relation to increases in area.

4. Planning tools:

Construction (Investments)	Operation Maintenance Cleaning
Site development; Rate of building.	CERN maintenance teams or outside contracts.

5. Indicators:

Construction	Operation
$\frac{SB1}{E+B}$ (total expenditure)	$\frac{\text{Maintenance costs}}{\text{Capital value}}$
$\frac{SB1}{Areas}$ (specific expenditure)	cleaning costs/m^2

6. Diagram used for "area" parameter

(see next page)

7. A few actual values for the standards and relationships used:

Standard T:	19 m^2 gross per occupant of offices or laboratories. 70% of CERN staff occupy an office and/or a laboratory.
Standard U:	20 m^2 per parking space. There are at present 75 parking spaces for every 100 persons at CERN, and this ratio tends towards 1 : 1.
Factors K and L:	Every square metre actually used for experiments requires almost 3 m^2 of "industrial" areas, divided into 0.7 m^2 workshop space + 0.6 m^2 for storage + 0.8 m^2 for assembly work + 1 m^2 for technical installations and power supplies.
Building costs (1967):	600 to 1,000 fr/m^2 depending on the type of building.
Maintenance hours/year:	20 to 50 hours/year depending on the type of installation and the average age weighted by an empirical factor (1/5).

Appendix 10
Page 3

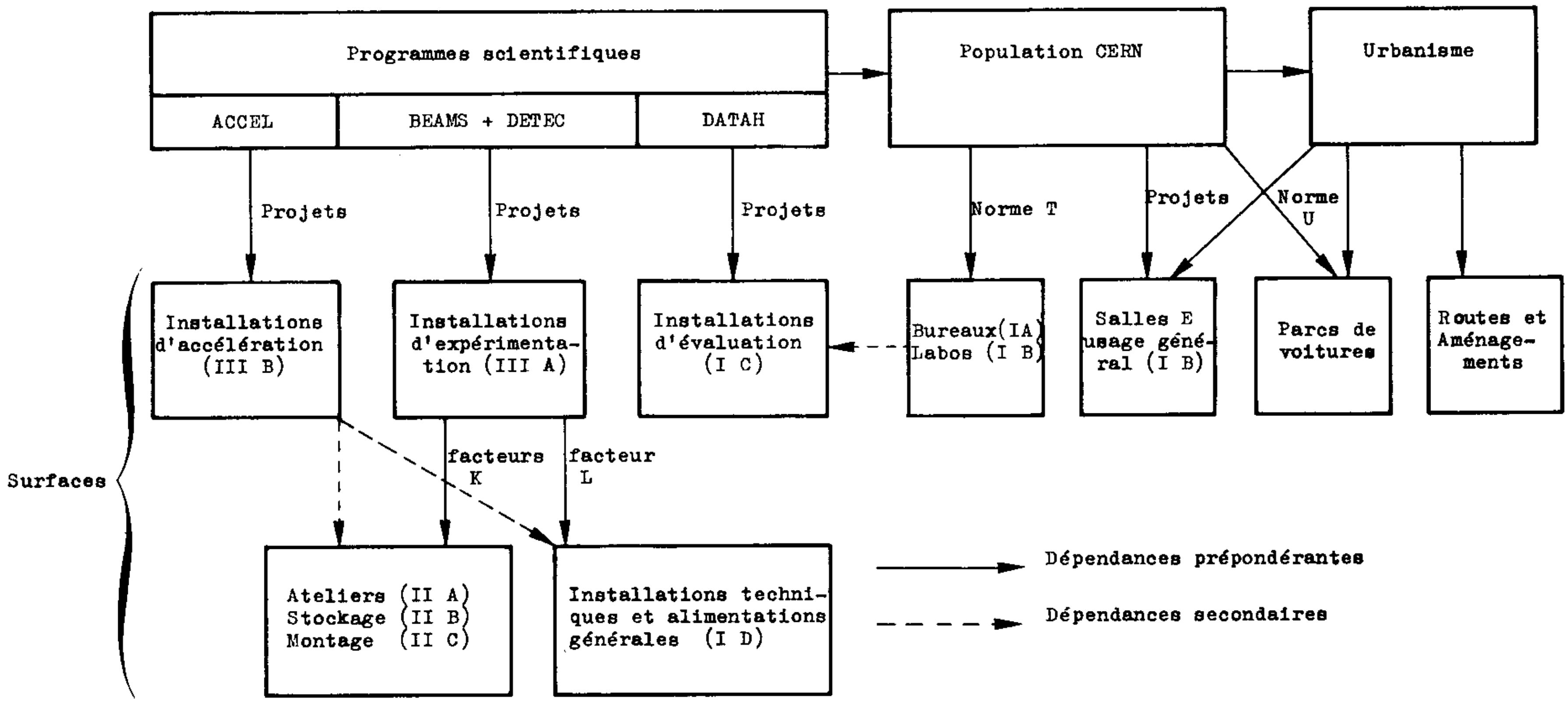


Schéma utilisé pour déterminer le paramètre "surfaces"
(les types de surface sont indiqués entre parenthèses)

Ce schéma concerne le point 6 du modèle considéré aux pages précendentes.

Diagram used to find the "area" parameter (the types of area are given in brackets)

This diagram relates to point 6 of the model discussed in the foregoing pages.