Policy Development and Big Science

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Edited by E.K. Hicks and W. van Rossum

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Preface

After WWII, policy development in 'big science' no longer involved only the scientist and the policy maker in 'intra-national' interaction, but increasingly became a multi-national concern, involving 'international' collaboration. This development has culminated in three primary, albeit mutually inclusive problem areas with respect to big science and related policy planning:

- Multi-national involvement in science projects has generated internal (intra-national) discussions about the nature of the interaction between science research priorities and politically generated policy priorities.
- Stabilized economic growth has generated new policy issues with respect to the limits of developing scientific research. By extension, these issues also involve questions concerning the practical application of scientific research.
- Growing public interest about the nature of science and technology research and its costs has generated questions about the place of scientific research within the realm of the public good.

Research into issues surrounding scientific development and concomitant policy decisions in a period of worldwide economic declivity can greatly contribute to generating an interface between research and policy priorities.

Instrumental to developing such research is the dialogue between science policy researchers, scientists and policy-makers. The primary goal of this colloquium was to stimulate just such a dialogue.

The four themes, constituting the structure of the colloquium were intended to outline some of the major issues involved in the creation of an interface between scientific research and policy development. These included the assessment of projects; resource needs; the macro allocation of resources; the management requirements of big science; organizational characteristics of big science; and big science, politics and the public.

The papers of the contributors to this volume, together with the introductory essay consider the various aspects of these themes.

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The Editors

E.K. Hicks and W. van Rossum

Policy Development and Big Science

Introduction

The notion of a policy for fundamental science appears to be a contradiction in terms. The common perception is that a clear distinction can be made between the *scientific community and its objectives* and the *policy context and its objectives*. In the case of fundamental science, decisions about the financing of research topics should be made by the scientists themselves. This decision-making process, characterized by bottom-up procedures, is one in which policy makers have no place. In this context, *science policy* would be qualified as laisser-faire.

In point of fact, however - and especially with respect to *big* fundamental science, a complex interaction exists between researchers, research organizations and government. Moreover, decision-making in this context involves *scientific questions* (such as the nature of the instruments to be developed) and *political and organizational questions* (e.g., the location and management of big science facilities). The nature of this decision-making process is in contradistinction to a laissez-faire approach to science policy.

In our view, the traditional laissez-faire policy structure has never been able to contend with this complex interaction of actors; a fact which is illustrated by the policy developed for big science. It has also inhibited the adequate development of an integrated policy structure for big science. To date, neither the relationship between the various actors involved in developing a policy for science, nor the goals of science policy with respect to fundamental science have been delineated.

The common policy approach to fundamental science, i.e., laissez-faire, is only commensurate with the concept of *subsidiary* policy, whereby the sole responsibility of external funding agencies should be to endow (subsidize) - rather than to allocate, capital. The laissez-faire policy structure of the post WWII period, which concretized an endowment structure for the funding of science projects, was facilitated by the exponential economic growth of the same period.

This policy structure was based on an organizational distinction between *funding* agencies (government and scientific *decision-making* organizations, i.e., research councils). In the post WWII period, this organizational distinction not only circumscribed political and scientific interests, but simultaneously legitimized them.

Big science fields illustrate the delimitations of this approach. Those fields of research included in the category 'big' science (e.g., high-energy physics) are so expensive that they cannot be conducted without large scale, consecutive funding.

It should be remembered that big science was a relatively new phenomenon after WWII. At that time, governments were prepared to support new scientific developments with what appeared to be unlimited funds. In most nations this is supplied by governments directly to the scientists, and outside the research council context. The reasons for this varied from nation to nation and included the role science had played during WWII, the acquisition of prestige on an international scale (national chauvinism), and defense related activities, to name but a few.

Thus, scientists engaged in fundamental research in the early post-war period were in the unprecedented position of having their every financial request granted. This was fostered by the belief on the part of government - and promoted by the scientific community, that all fundamental research was inherently important.

Hence, at a time when fundamental research was generally being supported by government (through the medium of the research councils which had, in most countries, been established immediately after WWII), it is not surprising that *big* fundamental science activities were being especially stimulated and subsidized.[1]

This triggered the development of an entirely new situation in which both the scale of big fundamental science activities, and the role of government therein, was permanently transformed. In subsequent years, this was to have a snow-ball effect on the scale and aspirations of other scientific fields.

It hardly needs saying that these developments ensued without the benefit of a planned science policy.

The expanding scale of some big science fields (initially, especially with respect to high energy physics), increasingly delimited the potential many nations had to independently engage in these fields. This implied the need for international collaboration in order to finance and organize big science activities. This need did not, however, mitigate (nationalistic) competition between these same nations.

It was in this multifaceted context that multinational scientists, represented by their national research councils, were required to collaborate on big science projects. Moreover, because the funding for such projects was multi-national, the extensive negotiations requisite to establishing big science facilities took on a political as well as a scientific character. Thus, the establishment of big science activities - to include facilities, was no longer based primarily on scientific criteria.

In sum, the distinction between science and government characteristic of the laissez-faire policy approach could not account for developments in big science for two primary reasons:

- The transformation of fundamental science in the post war period involved an increase in the scale of scientific research. This implied, by definition, the need for continuous and increasing funding. The extent of the necessary costs was such that government had to become structurally involved in financing such research. This engendered a relationship from which science can no longer extricate itself. This was especially the case with big science fields.
- While the scientific community has been prepared to accept this relationship on the basis of unconditional and unlimited funding, it has simultaneously attempted to conduct itself as an autonomous community on a political island. This is, however, only possible when a single national scientific community must deal with a single benevolent dictator (government). But even this creates dependency.

Such a scenario is not possible in an international context requiring political negotiation for the acquisition of funding (even when individual governments are willing to extend such funding). Thus, the political context in which international collaboration in big science occurs implies that the manner in which scientific activities are planned, organized and operationalized can become highly politicized (Elzinga, this volume, provides an excellent example).

Those issues inherent to the scientific and managerial development and maintainance of big science activities in the political context are outlined below and are further developed in the contributions contained in this volume.

The Scale and Definition of Big Science

In recent decades, a diverse array of scientific fields have been aggregated according to the scale of their activities, and currently are distinguished as *big* or *little* science. The common denominator for those fields involved in big science remains the fact that they all expend large amounts of money for experimentation.[2]

Big science, which has traditionally been heavily concentrated in the nuclear field, continues to expand in range and investment (e.g., in the 1970s and 1980s in Europe the range of facilities in the nuclear field included proton accelerators, electron accelerators, storage rings, electron positron colliders, proton proton colliders, electron proton colliders, heavy iron facilities). Big science involves fixed site large facilities, broad spectrum facilities such the Antarctic research programme, or even general facilities spanning a broad range of research.

There are many different types of big science projects and facilities, ranging from full scale intergovernmental collaboration to smaller scale arrangements involving a central organization and central funding. These projects and facilities can occur at the national level with local or national usufruct privileges, at the national level with extra-national usufruct privileges and agreements, in the context of bi-lateral or multi-lateral agreements, and in consortia agreements.

Unfortunately, because the range of spending for big science continues to be variable, it has not been possible to precisely qualify the financial boundaries of such big science activities.[3] Interestingly, however, the current scale of big science expenditure - associated with the exigencies of increasingly complex instrumentation has long exceeded that of the post-war period (ever larger accelerators and telescopes, satellites, etc.).

As a result, requisite to a more precise definition of 'big science' is *1)* a consideration of the specific problems involved in the financing and organization of scientific research in large expenditure fields, and *2)* a delineation of the objectives of policy with respect to fundamental big science. In addition, it should not be forgotten that the qualification of an activity as 'big' science is contingent upon the amount of funding allocated to other scientific fields. Moreover, that the boundary between those areas which have until now been qualified as 'big', and those which have come to be called 'little' science is becoming increasingly fuzzy.

Science Policy

While the activities of the scientists engaged in big science fields are regulated by science internal criteria - rather than by political decision-making, the amount of money involved in conducting experiments in such fields precipitates the need for organizational and policy structures. The result is an interaction between political, managerial and scientific considerations. This is especially evident in discussions concerned with scientific development in big science fields, which is often correlated with the generation of new, and larger instruments. This developmental process can be more specifically characterized as follows:

- The realization of new scientific developments is dependent upon long term planned projects during which the requisite instrument(s) has been designed and built. Such preparations can take as much as a decade and involve large scale and complex logistics. A major consequence is that discussions about a new instrument must begin even before its predecessor has been inaugurated. For example, astronomers had begun discussions about the successor of the Hubble satellite telescope before the Hubble had even been launched.
- As indicated above, the acquisition of such instruments also implies subsidies well outside the range of the funds normally allocated for the field in question. This leads to long term discussions with policy makers regarding both the amount of funds necessary for the establishment of a new instrument, and its location. This is true intra-nationally (e.g., in the U.S.), and inter-nationally (among nations which are unable to finance such instruments independently).

Establishing a large scale facility thus involves other than only scientific considerations. In order to justify the additional expenditure, policy-makers often wield the arguments of national chauvinism and employment potential. For example, it is no coincidence, and there are certainly no scientific reasons which account for the diffusion of high energy physics laboratories to specific U.S. states. It is entirely feasible that such non-scientific arguments played an important role in the designation of Texas as the location for the new Superconducting Supercollider.

This complex process has generated negotiations at both the national and international levels; concerned with such issues as site location for big science facilities, the relative contribution of participating nations, scientific access to the facilities, etc. Collaboration and competition are equally important, yet opposing forces in each issue. The developmental process has also generated the need for 'science politicians', the majority of whom continue to be recruited from the higher echelons of the national research councils. The combination of collaboration and competition at the national and international level, and science politicians acting as negotiators results in an inability to distinguish between political and scientific interests. It is this interrelationship which is the basis of the specific political nature of big science activities.

While the coordination of research activities on an international scale facilitates the participation in fundamental research of nations not able to independently support such research, it simultaneously engenders competition between these same nations. Their need to internationalize is only commensurate with their perceived need to participate in fundamental research.

This situation is exacerbated by a decision-making process containing both scientific and political elements; competition between different scientific pressure groups trying to sway a government which has its own political motivations and priorities. This problem is compounded by the utilization of national evaluation procedures which are hopelessly inadequate in judging international programmes. Moreover, because decisions about such programmes are made at the international level, conflicts of interest (both scientific and political) may occur between this and the national level.

A consequence of the complex development outlined above is that the decision-making of 'big science elites' - although exclusively comprising scientists - has also acquired a distinctively political character. Scientists have become negotiators for funding, establish and determine the location of facilities, determine research priorities, etc. Such decisions involve more than scientific acumen. They are part and parcel of a political process, with political objectives. In this context fundamental science, too, becomes a political objective: political prowess can be expressed in terms of competition within fundamental science.

The combination of a decision-making process which increasingly contains both scientific and political elements and the stabilization of economic growth during the past decennia, presage the need for developing a *discretionary* policy approach. However, fundamental science was not, and is not now, perceived as being commensurate with discretionary policy. This is illustrated by the problems generated for Great Britain when it experienced a financial crunch in funding its CERN membership (see Krige, this volume). A more recent case in point is the debate on financing the SSC, where there is a lack of political momentum for those politicians *and* scientists stressing the need to impose restrictive measures in the financing of big science. They point out the negative effects such large scale expenditure would have on the financial support of little science.

Paradoxically, while the need for large-scale, consecutive endowment funding precluded attempts to apply discretionary policy to big science, it simultaneously generated the need for international collaboration in order to fund such projects at all. The nature and confines of such collaborations were, of course, influenced by political factors. This was exacerbated by the fact that science policy had never been implemented in accordance with established models, according to which funding such fields would have to be justified in terms of short- or long-term investment returns. Indeed, in the immediate post-war period policy goals for big science at the governmental level were non-existent. International collaboration further complicates the development of science policy goals because not all nations have the same potential for funding big science activities. Moreover, the basis for collaboration was based on national (laissez-faire) policies for funding fundamental research. Compositely, all of these factors have generated a series of long-term problems which continue to complicate the development of science policy with respect to big science fields.

Prioritization

The large scale funding requirements of big science raises the important question of how priorities should be assessed and resources allocated? We might ask if it is even possible to assess projects or to create an adequate basis for assessment, such that resource allocation can be determined? Similarly, we need to ask about the interaction between big and little science on the one hand, and governments and public funders on the other. Should big and little science compete for money from the same source?

Important in this context is a qualification of the relationship between the criteria utilized at the national and international levels for the selection of research and related organizational activities. Internationally 'integrated' policy decision-making may have developmental or adverse effects, both on national institutional science activities and on all other levels of science policy decision making.

The potential fluctuation in organizational structure implied by such developments, e.g., the liquidation, transformation, and/or merging of research institutions, is of especial relevance, particularly in light of the direct consequences of such changes on the action and interaction patterns of the actors involved at all levels of science research and policy making. Indeed, changes in the international complexion of science policy are already giving new impetus to discussions on the organizational aspects of international big science facilities.[4]

Strategic vs. Fundamental Science

Big science organizations can be distinguished as being involved in strategic or fundamental science.[5] The former includes laboratories involved in problem solving (e.g., energy related), whereas high energy physics and nuclear physics are examples of fundamental research areas.

This distinction has generated three major problems:

- who is to have a voice in the decision-making process with respect to funding and priorities;
- what should be the status of problem-solving research in the context of funding priorities and, perhaps more fundamentally;
- in which context are 'problems' defined (this has serious policy and funding consequences);
- how are we to properly define and qualify the importance of 'problem solving' and related solutions, i.e., how and where should defined problems be placed on the priority listing?

The problem is aggravated by the difficulty of precisely qualifying the generic difference between basic and strategic or targeted research. In fact, decisions - both with respect to the nature of research and the direction of science policy decisions, are still made at the level of individual researchers on the basis of their view of the direction science should take. Whether in the U.S. or Europe, it is these individuals who play an important role in the funding and policy decision-making process.

But this has not been the only deterrent to the development of a rationalized system for determining priorities for big science facilities. Additional factors include the political acumen and solidarity prevalent in some scientific fields, and the perception scientists have of their role in what they deem to be a political process. For example, high energy physicists have traditionally done their own lobbying by operating through their own well established political channels and acquaintances. This has successfully prevented their own research priorities from being considered with those of, e.g., oceanographers and astronomers. It would not be to their advantage if the system were rationalized.

In other fields, scientists deem the establishment of priorities for big science facilities to be a political matter, having nothing to do with them. Added to this is the difficulty of reaching consensus about choices within each field (also a political decision).

Organization and Management of Big Science Facilities

The complexity of doing big science is also apparent at the facilities level. Managing a big science facility involves problems more intricate than those encountered in the managing of laboratories in other (little) science fields. Big science facilities generally derive their significance from both scientific developments and technical prowess. However, this often exacts stringent, and even opposing criteria which must be incorporated into a functional organizational structure. For example, an accelerator can be built according to different technical principles enabling a number of scientific possibilities in the field of high energy physics. However, at the organization level this simultaneously generates different sets of objectives, requiring a juxtaposition of scientific and technical goals. This implies an interplay between scientific and technical interests at the decision-making level.

For many big science facilities there is also the problem of the relationship between scientific and administrative management. This is manifest in attuning scientific requests to efficient use of available instruments. In many cases, scientific programmes will only to a certain degree determine whether, and how often, a given instrument can be used. This is especially evident in international big science facilities, where instrument time is determined both by scientific criteria (the quality of the research proposal) and other factors, such as the distribution of instrument time over participants.

Another problem encountered in managing big science facilities is the special role of engineers vis-à-vis scientists. The specific nature of the instrument(s) precludes a solely supportive function for the engineering staff (in contradistinction to 'little science', where the realization of research objectives is directly dependent on the technical possibilities of available instruments). Moreover, the central role of instruments in big science development implies an equally important role for engineers. In some cases engineers play a prominent role in the development of the instrument and subsequent scientific developments (e.g., the Nobel Prize awarded to Van Der Meer for his work on stochastic cooling at CERN).

The innovative accomplishments of engineers are, thus, an objective of big science facilities in their own right. As a result, technicians have a high status in big science institutes. Moreover, it is this staff, more than the scientific staff which plays a significant role in determining institute policies. This is primarily because the scientific staff have primarily transient positions - especially at international facilities. The specific research orientation of engineers will also greatly determine the 'culture' of such institutes.

Managing large facilities (whether internationally jointly owned and run or the shared national facility belonging to one nation with others having usufruct) requires addressing certain pertinent questions with respect to:

- Scientific management: how does one ensure critical access to material resources for scientists?
- Administrative management: different types of facilities require different management, for example, a benevolent dictatorship is fine in a small facility but won't necessarily work in a large one.
- The relationship between the scientific and administrative management in each type of facility?

Managing an international 'big science' institute is further complicated by additional considerations germane to international institutes.

Invariably, however, a conflict of interest arises between the managerial need for the administrative efficiency and scientific effectivity of the institute, and the demands made by the international science policy community.

This problem occurs both because the steering system of such institutes is not attuned to the needs of the system to be managed, and the exigencies of international science policy, which generates the establishment and maintenance of such institutions. Consequently, even though the boards of international big science institutes include scientists from the various participating nations, the directives generated by these boards reflect more the expectations of the participants than the needs of the organization to be managed.

Closure

While the majority of facilities begin as a single organization or a single purpose lab, they usually follow one of two subsequent routes: they become one of a succession of similar facilities which are created at roughly 10 year intervals, or they are transformed into multi-programme facilities, involving a range of areas of concentration (usually without a clear explication of how these have been chosen). In this context, no clear criteria exist for determining the life cycle for big science facilities. In fact, no major big science laboratory (national or international) has been shut down since the second world war. When such facilities have outlived their original purpose, something else is found for them to do (e.g., laser physics or supercomputers). Unclear is whether these laboratories are the best place to do other forms of research, both in terms of facilities and competent staff.

We might well query why it is so difficult to close down such institutions. One reason involves the engineers responsible for building a given facility. Since this group constitutes an enormous lobby in any big facility (see above), they prevent - or at least complicate closure. Conversely, because work at a big science facility involves the construction and use of large, sophisticated and expensive equipment, the viable collaboration between scientists and engineers is requisite to conducting research.

In considering the issue of how a facility should be closed, we must also address the questions of how one should be created; who will make a choice as to the need to diversify, and to what functional end (especially with respect to national facilities); is diversification easier at the national or the international level?

The contributions included in this volume are generally indicative of the complex problems associated with generating and participating in big science activities, particularly with respect to international organizations and projects.

In this context Krige considers the consequences, in historical perspective, of an unanticipated growth in expenditure in the management of CERN. He outlines the policy strategies which were developed in an attempt to cope with this situation, and analyzes the conflicts generated by these strategies.

Elzinga's review of the Antarctic programme illustrates the politicization of science, questioning the possibility of 'coercing' a multinational concensus both with respect to financing and qualifying the nature of the research and the degree of collaboration.

The cost benefit aspect of participation in international organizations is addressed by Ruivo, who intimates an increasing pressure in Portugal to participate in big science research. The issue of participating in such large expenditure research without a big science resource pocketbook is considered in conjunction with an assessment of the degree to which government spending should be invested in applied research.

Edqvist discusses the allocation and long term distibution of funds for expensive equipment in Sweden, and briefly outlines the relationship between big and small science and the degree to which Sweden participates in international big science.

Van der Woude's contribution is a case-specific study on the development of a bi-lateral collaborative big science project (AGOR).

Finally, Krempel addresses the relationship between the German government and big science centers. In this context he considers the interrelationship between the orientations of big science centres and the competition and cooperation between these organizations for funding.

NOTES

1. Great Britain was the exception to this development. In this case, big science fields were financed through research councils which had already been established prior to WWII. This, more than in any other case, led to ultimate confrontations with respect to the funding of big science activities. See the discussion on the U.K. financing of CERN by Krige in this volume.
2. Some of the fields included in this category are radio-astronomy, which uses large scale telescopes; high energy physics, with its enormous accelerators; space research satellites; oceanographic research, with its re-

quisite large vessels and expensive complex instruments; and the costly and extensive research involved in such programmes as Deep Sea Drilling or Antarctic Research.

3. Big science related projects range from 10 to the 7th to 10 to the 9th in units of e.g., Dutch guilders, Deutchmarks, Swiss franks, U.S. dollars.
4. We presume that any organizational analysis of big science research facilities (extant and more recently established) should address the most important scientific aspects of such facilities in the science policy context. Specifically, such an analysis should:
   - elucidate those factors requisite to the creation of highly successful facilities (on the short and long terms);
   - facilitate the development of criteria for the establishment of common facilities;
   - generate procedures for determining which (type of) facilities warrant internationalization, and what should be the context of such facilities, e.g., shared national, restricted international (e.g., European), or global. Important questions which should be addressed in order to determine the direction development should take in the future include:
   - what is the current raison d'être of existing facilities (national and international);
   - how were decisions made with respect to the establishment and development of these facilities, and how were the sites of existing facilities determined.
   - Can we determine how to develop the most successful type of facility on the basis of existing facilities?
   - What should be the criteria for developing common facilities, i.e.,
   - what setting, financing, etc. arrangements are most conducive to the creation of a facility?
   - What should be the range of facilities, e.g., big and small science facilities?
   - Should scientific activity be organized
   - What has been the comparative development of big/small facilities during the last 2 decades with respect to decision making and management (scientific and administrative)?
   - Should scientific activity be organized around a subject rather than a facility?
   - What should be the scientific priorities, e.g., high energy physics, astronomy, applied mathematics, environmental research?
   - Which of the science disciplines lend themselves to the formation of a common facility?
   - Is it more effective to begin as a bi-lateral facility, e.g., ILL or as a multi-lateral facility, e.g., CERN?
   - How should we differentiate facilities and centres of excellence (i.e., non-facilties related laboratories) vis-à-vis funding?; and what effect will the financing and generation of new such research laboratories have on existing large facilities?
   - Should big science facilities even continue to exist in the future, i.e., in a large-scale Europe the idea of large facilities could prove obsolete!
5. Typical examples of fundamental sciences are high energy physics and space related astrophysics. The strategic sciences may involve the construction of synchroton laboratories or the coordinated programme on HTC (high critical temperature superconductivity). Both the latter programme and such technological research projects as the megabit or laser research use fund raising techniques typical of big science projects. In these cases industry attempts to extract considerable funding from government by generating simplified goals geared to catch the imagination and approval of politicians and the public. In all these cases coordination of the project occurs at both the national and the international level. The latter is mandatory for the acquisition of funding. National/international coordination in almost all scientific activities is generally a prerequisite.

John Krige

Changing National Policies on Acceptable Levels of the CERN Budget: An Historical Case Study of Two Turning Points[1]

Preliminary Note

CERN is the *European Organization for Nuclear Research* based just outside Geneva. It is a laboratory essentially devoted to doing basic research in high-energy physics. Established in 1954, it now has a staff of about 3,500 people, and its facilities are used by large numbers of outside visitors. In 1988 over 5000 users were registered at CERN, some 20% of them from non-Member States, including the United States, Japan, the Soviet Union, China, and eastern European countries. CERN's central funding is presently provided by fourteen European governments who share the burden (roughly) proportionally to their Gross National Products. The laboratory's annual budget today is some 850 million Swiss francs ($500 million).

The day-to-day management of CERN is in the hands of scientists, and the head of the laboratory is generally an eminent physicist - ideally a European Nobel prize winner. The executive's scientific programme is discussed by a Scientific Policy Committee composed of members of the European high-energy physics elite. The programme agreed, the CERN management lays its budget estimates before the Finance Committee, which is composed of one science administrator from each Member State. The budget and other major policy issues are settled in the supreme governing body, the CERN Council, in which each Member State is represented by two delegates, one an eminent scientist, the other a high-level science administrator or diplomat. Finally, on the 'legislative' side there is a Committee of Council which meets just before the Council and which tries to iron out any outstanding policy disputes before they come to the Council, and to the vote.

Introduction

When CERN was officially established in 1954 everyone expected that the overall *magnitude* of the construction budget (estimated at 120 MSF) would be exceeded; at the same time it was generally believed that the *shape* of the expenditure curve (assumed to be bell-shaped) would remain essentially the same. If the 120 MSF was treated as a provisional estimate it was because, from past experience, one knew that there were bound to be cost-overruns in a six-year construction venture involving big scientific equipment. It was also because an R&D effort was called for: the main piece of machinery - a 28 GeV proton synchrotron - was based on a novel principle of acceleration which demanded high-precision engineering. It was difficult to make reliable estimates of its cost well in advance. These considerations, however, were felt to have no bearing on how costs would be spread over time: it was thought that they would climb to a peak when the major orders for equipment and buildings were placed (after about three years) and that they would then fall back to a relatively low baseline as the laboratory moved from the phase of construction to that of exploitation of its accelerators.

By 1957 the hope that annual expenditure on CERN would begin to tail off was being seriously undermined: it was becoming clear that it would cost at least as much per year, if not more, to run the laboratory as it had cost to build it. The main reason for this change in expectations was the transformation then taking place in the complexity and scale of the detection equipment in use around high-energy accelerators. As a result, the costs of research and of doing experimental work looked to exceed anything previously imagined.

The aim of this paper is to study the policies evoked or evolved by the Member States' representatives to CERN to cope with this unanticipated growth in expenditure, and the conflicts surrounding their implementation. More specifically this paper will explore two turning points in the debate over how to regulate the level of the CERN budget. The first occurred in 1957 when the British delegation, alarmed by the rising costs of research, suggested that CERN had to accomodate its scientific programme to fixed expenditure limits. The second occurred in 1961 when, after several years of trying to implement this somewhat unpopular policy, the British were forced to abandon it, and to accept the majority view that CERN's budgets grow annually - a policy that effectively remained in force until the mid-1970s.

The 1957 Crisis. The UK's Ceiling Policy

The recognition that the costs of research were going to be far higher than anticipated emerged after the *CERN Symposium on High Energy Accelerators and Pion Physics* held at the laboratory in June 1956. The staff came away from this international meeting convinced that CERN was in grave danger of lagging behind its competitors in the United States and the Soviet Union. The group responsible for the smaller accelerator in the laboratory, which was to be commissioned the following year, immediately increased its estimates of annual expenditure for 1957 to 1960 by 75% or more. At the same time CERN's Director-General made it clear that this was just the tip of the iceberg; that the preliminary discussions then under way were "merely ushering in the problem of experimental research as a whole".[2]

The delegates to the Finance Committee were unanimous in their concern about the rising costs of the research. However, it was the British who tried to seize the bull by the horns. They tried to formulate a new budget policy which was at once "intelligible and statesmanlike", and which would "reassure the financial authorities of the Member States without unduly hampering the healthy existence of the laboratory".[3]

What was the prevailing policy vis-à-vis the CERN budgets followed by the Finance Committee? Essentially one of *laisser-faire*: the management simply told the delegates what it thought was needed for the following year, and the delegates took it upon themselves to raise the money at home. The British delegation felt that this policy had to be changed, that some form of 'external control' had to be imposed on CERN's expenditure. CERN, said the British delegate H.L. Verry, had to realize that funds for the laboratory were limited and that, just like any national laboratory, it had to fit its scientific programme within the bounds of well-defined appropriations. With this consideration uppermost in his mind, he put forward an alternative policy which was accepted by the management in summer 1957. It required that a ceiling be imposed on CERN's expenditure; a global envelope below which research projects were to be accommodated by some scheme of priorities. In practice what this meant was that the administration was expected to make a two- or three-year forward estimate of its needs, that the total allocation for that period was to be negotiated with the Finance Committee, and that the final overall figure then voted in the Council was to be fixed and binding on both parties - the laboratory and the Member States.

Most of Verry's colleagues in the Finance Committee were lukewarm about the idea of a ceiling. For one thing, it went against standing policy in the Committee, the *laisser-faire* approach to the budget, and the unwillingness to impose constraints on CERN's expenditure. For another, the policy was felt to be unworkable, particularly now when the costs of research could not yet be estimated with any reliability. As many of Verry's fellow delegates saw it, if a two- or three-year ceiling was imposed under such conditions, *and adhered to,* it would inevitably hamper the healthy growth of the laboratory. On the other hand, if it was imposed and *then broken* to accomodate 'unexpected' and 'essential' items of experimental equipment, they could not but lose face before their national financial authorities, and their task of raising the necessary funds for CERN would become that much more difficult.

Despite this opposition, the CERN Council imposed ceilings on CERN's budgets at its meetings in December 1957, December 1958, and May 1959. They did so for two reasons. First, the policy had *procedural* advantages. CERN was in the habit of making last-minute requests for funds after national financial authorities had set aside their allocations for the laboratory for the following year. A two- or three-year ceiling promised to put a stop to this practice. They also supported the policy for *political* reasons. The United Kingdom delegation, generally supported by the Scandinavians, made the imposition of a ceiling a *sine qua non* for their voting in favour of a set of agreed budget figures. And, although the Council was empowered to adopt a budget by simple majority, there was a tacit agreement among its members that no major contributor, like Britain, should be outvoted if at all possible. Hence the majority felt that they had no option but to go along with British policy and, despite their misgivings, to accept that ceilings be imposed on the CERN budget.

It is important to appreciate how radical was the British proposal in the context of the day. It may now seem obvious to us that there should be limits imposed on the budget of a laboratory within which it must function as best it may. Put differently, we may be inclined to say that the British were simply trying to 'normalize' an 'exceptional' and 'unusual' situation. However, it must not be forgotten that in the early 1950s governments had an almost boundless faith in the power of science and technology. Nuclear physics, in particular, was laden with strategic importance, and was regarded as a national asset which could be turned to use in peace and in war. Hence, governments were inclined to give physicists what they said they needed, not only to keep them happy, but in the hope and expectation that something of value to the national interest would emerge from their work. The *laisser-faire* policy adopted by the Finance Committee delegates at CERN was of a piece with these attitudes. The British idea that a medium-term ceiling be 'externally' imposed on expenditure was not. It was an early warning that the 'myth of the atom' was beginning to crumble in government circles.[4]

The 1961 Crisis. The Policy of Growth

The ceiling imposed in May, 1959 turned out to be a particularly severe one. At the Council meeting that month the UK accepted that the budget for 1959 be 55 MSF, and reluctantly agreed that that for 1960 be pegged at 65 MSF. At the same time they insisted that the figures for 1961 and 1962 also be set at 65 MSF. In other words the British delegation was prepared to see CERN's expenditure rise by some 18% from 1959 to 1960, but wanted it to remain stable for three years after that.

Within six months it was obvious that the administration would not be able to keep to these figures, even though it was they who had originally suggested them. They only kept to the 65 MSF ceiling for 1960 by absorbing all the reserves put aside in the original three-year plan. They were allowed to exceed the ceiling for 1961 by some 4 or 5 MSF partly because Spain entered the organization at the end of 1960 bringing some additional money with her. And in the spring of 1961 the CERN management, supported by the Scientific Policy Committee, made it clear that anything like a 65 MSF limit for 1962 was totally unacceptable to them and that, in their view, the laboratory needed from 75-78 MSF for the following year.

No member of the Finance Committee openly refused to consider these figures when they were first suggested in April 1961. Indeed most of them, including the UK delegate, seemed to think that they could find 75 MSF for CERN in 1962, even though this was 10 MSF above the ceiling agreed to in 1959. At the same time they asked the administration to estimate the financial implications of the research programme for 1962 to 1964, Britain's intention doubtless being that it would only accept to break one ceiling if a new three-year limit was imposed on CERN's expenditure.

At this point a new and crucially important element entered the debate on the budget. At the Council meeting in June, 1961 the French scientific delegate Francis Perrin, with one eye on the UK's wish to stabilize annual expenditure, introduced the idea that CERN's budget should *grow* from one year to the next. Experience in managing scientific laboratories in France, said Perrin, had shown that if a budget was kept constant it had the effect of reducing activities: stabilization meant stagnation. The CERN administration enthusiastically supported this idea, as one might imagine, and agreed to prepare its estimates for 1962-64 on the assumption that expenditure would increase from year to year.

It fell to the new Director-General, Victor Weisskopf, to present CERN's budget figures for the next three years to the Finance Committee in October, 1961. Weisskopf proposed that CERN's expenditure be seen as growing by 8.5% per annum from 1960 to 1964. With that in mind, he suggested a figure of 79 MSF for 1962, and a total of 260 MSF for 1962-64.

Weisskopf's proposals immediately polarized the FC delegates. One group - the majority - accepted the policy of growth. As the Danish delegate put it, "it was unrealistic to fix a stable budget for a research institute". This group was also prepared to give CERN about 78 MSF for 1962. The other, much smaller group - of which the United Kingdom was the most prominent meber - was at this stage unwilling to see CERN's budget increase steadily. British policy, said the UK delegation, "would be to stabilize expenditure at around 75 MSF" for the next three years.[5]

By the time the Finance Committee met again in November, the British had modified their position somewhat. They were sticking to their figure of 75 MSF for 1962 but were now prepared to give the laboratory some 240 MSF for 1962-64 (against their original 225 MSF). But this 'concession' was coupled with a new threat. The government let it be known that, to put teeth into the overall estimate, they were 'contemplating' negotiating a figure for 1963 and 1964 *with other governments* (i.e., by-passing the Council) and inserting it in "a kind of financial protocol annexed to the Convention". Acting on this threat one week later, the Foreign Office took the unprecedented step of circulating an *Aide Mémoire* to the other Member States in which it suggested that the participating governments "should determine... what sum should be fixed as the firm upper limit, at present price levels, of the resources that can be made available to CERN over the next three years"; leaving it to the Council to lay down the annual budgets within this limit. They proposed "a ceiling figure of not more than 240 million Swiss francs" and insisted "that member Governments should make up their minds and that the Organisation should realise that this total must be adhered to".[6]

The last round of meetings to settle the 1962 budget got under way on the morning of 18 December 1961. During these two days the deep hostility and resentment felt by some members of the CERN Council to the line adopted by the British government burst into the open. Choking with anger at the meeting of the Committee of Council, Dutch delegate Bannier roundly condemned the Foreign Office's suggestion that the upper limit to CERN's expenditure for the next three years be decided by national governments in consultation with one another. This policy, said Bannier, would "diminish the authority of the international body which is the CERN Council", which "should always make the final decision [on the budget] according to the voting procedure laid down in the CERN Convention". To do otherwise, to "by-pass" the Council on important decisions of this kind would, in Bannier's view "demolish... the very foundations of CERN".[7] He was backed up by the French Council President Francois de Rose, who went so far as to threaten political retaliation if the British persisted with their announced policies.[8]

De Rose's main target of attack was the rates of growth implied in the British suggestion that CERN's budgetary ceiling for 1962-1964 be set at 240 MSF. Assuming that the 1962 budget was voted at 78 MSF, this implied that CERN should have 80 MSF for 1963 and 82 MSF for 1964: a growth rate of 2.5% per annum. This figure, said de Rose, was to be compared with annual rates of expansion in big American laboratories of between 15% and 18%, and of something like 12% in France. If CERN "were to fulfill in Europe the duties which it had been given with regard to national laboratories", and to "keep up in the competition with big laboratories in the United States and the Soviet Union...the only suitable rate of expansion would be one comparable to national laboratories".

De Rose backed up his arguments by threatening to advise his government to withdraw from other collaborative ventures if the French delegation did not get its way on CERN. Firstly, he drew attention to the fact that negotiations were then under way to set up two new European organizations for scientific and technical cooperation, viz. ESRO (space research) and ELDO (launcher development). If CERN's budgets were to be kept down to make money available for these other organizations, as the British had implied in their *Aide Mémoire*, if CERN was to be "sacrificed in favour of new organizations" (de Rose), he would propose that France not join them. "I do not know if my advice will be followed", said de Rose, "but I know that it was followed in the case of France joining the "Blue Streak" (here referring to de Gaulle's change of attitude from opposition to support for the use of a British rocket as launcher for ELDO). De Rose's message to the UK government was clear then: if you do not follow my policy on CERN's development, I will tell my government not to support you in the formation of ELDO - and I am likely to be heeded.

De Rose's second threat was intended to put the British in the embarassing position of being seen to wreck the expansion of CERN. In an off-the-record remark to the Committee of Council he pointed out that the French government was then negotiating with the Swiss authorities for an extension of the CERN site into France. Despite the complexity of having an organization straddle the border between two sovereign states, negotiations were proceeding favourably. However, these arrangements were naturally "based on the hypothesis that CERN would develop". If it did not, and if the Council voted a three-year ceiling of

240 MSF the next day, "I could not go back to my government and say I continue this proposition", said de Rose.

Both de Rose's and Bannier's contributions were warmly commended by many delegates to the Committee of Council on 18 December. By special request, both were repeated at the full Council meeting the following day, where they followed immediately after the presentation of farewell gifts by the Council to Verry and to Adams, two CERN pioneers from the UK. Feted for their contributions to the organization in the past, condemned for their policy concerning its future development, threatened with grievous sanctions if they did not fall in line with the majority, the British delegates were at once embarassed, outmanoeuvred, and isolated. When the vote on the 1962 budget was taken it was 10 in favour and 2 against a 78 MSF level of contributions. Only the Swedes supported the British, and even they implied that, had they realized earlier the size of the majority in favour of this figure, they might have joined its ranks. As for the level of expenditure in the subsequent years, a British *Note* suggesting that a three-year ceiling for 1962-64 be formally enshrined, perhaps even in the Convention, was ignored, and the question of the budgetary contributions to be made for 1963 and 1964 was left unresolved. Instead it was agreed to set up a small group whose task it would be to "draw up proposals for exploiting CERN's research potential, [and] to evaluate the financial implications of those proposals, especially in connection with the rate of growth of the budgets...".[9] The expansion of CERN was thus assured.

Some Remarks on the Factors at Work in this Conflict

To conclude this paper we want to try to explain why it was that, at the end of 1961 in particular, the debate over the CERN budget became so acrimonious, threatening to tear apart the very fabric of the organization. To do this, we shall focus on the British position and, by comparing the situation in the United Kingdom with that in France in particular, we shall try to explain why the differences between Britain and her partners at CERN escalated into a head-on conflict.

Let us begin by asking why the Foreign Office tried to bypass the CERN Council, suggesting that CERN's budget levels be agreed between governments. One reason is fairly obvious: the move was symptomatic of the growing impatience inside the government, and notably the Treasury, with the DSIR (Department of Scientific and Industrial Research) and its representatives at CERN, whom they saw as far too willing to protect and defend the interests of the joint European venture. The DSIR and 'its' CERN representatives were deeply hostile to the Treasury's determination to reduce CERN's expenditure - it was "obsessed by [Britain's] economic stagnation" and it "resent[ed] the cost of [CERN's] success" wrote one DSIR official acrimoniously. It was felt that the best way to control CERN's budgets was to agree on an appropriate "machinery for planning" with their fellow delegates to the CERN Council. The Treasury, for its part, was increasingly frustrated by the apparent inability, or unwillingness, of the UK delegation to impose its will at CERN, and determined to find an effective means of 'external' control over CERN's budgets. Hence its efforts to shift the power to decide the overall level of CERN's expenditure out of the hands of the Council (and the DSIR), and into its own.[10] A number of other factors reinforced the Treasury's position. First, there was the relative lack of pressure on the British government from the national physics community, the lack of a scientific statesman in the UK to plead the laboratory's case directly at the highest levels of government. In France there was Perrin (and Leprince-Ringuet), in Germany there was Heisenberg, in Italy there was Amaldi. In Britain there was no scientist of comparable status and influence in political circles who was as dedicated as these men were to the development of the laboratory in Geneva. Thus, whereas in November, 1961 "arduous discussions were in progress [in France] between the scientific and financial authorities on the question of CERN's long-term budget prospects", and in Italy Amaldi could (apparently) get his government to change its mind on CERN's expenditure in just a week, in Britain no comparable lobbying of the Treasury by eminent scientific statesmen seems to have taken place.[11]

Another factor in forming attitudes in Britain was the concern that high-energy physics - and CERN in particular, were absorbing far too large a slice of the national science budget. There is a fundamental difference here between the United Kingdom and some other CERN Member States.

In countries like France, Italy, and (at least at first) Germany, membership of CERN was seen by high state officials as a primarily political gesture, and resources for it were made available by the departments of Foreign Affairs. Money for CERN was thus "independent" of money voted for national science expenditure. In Britain by contrast, there was less enthusiasm for international scientific collaboration, and the main motive for joining CERN was said to be scientific and economic: it was the cheapest way of doing physics at 25 GeV. As a result the DSIR played a dominant role in presenting the case for membership to Ministers in 1952, and the funds for the laboratory were part of its overall (civilian) science budget. In practice this meant that universities and national research institutes competed with CERN for funds from the same source - and generally lost out.

The general economic situation in Britain at the time also played a part. As one commentator has put it, "The postwar performance of Britain's economy has entered the annals of history as a tale of woe, of constant balance of payments crises [of which there was one in 1961 - JK], of overspending and living on credit".[12] Britain's investment in Research and Development was squeezed in parallel: already higher than any other European country (as percentage of GNP) it grew very slowly around this period (from 2.2 to about 2.4%, between 1962 and 1967). In this context it is not surprising that the Treasury baulked at the demands coming from a range of European joint enterprises, some of them entirely new (ESRO and ELDO), some of them well established, but exceeding all previous expectations (CERN).

The situation in France was quite different. On the one hand, after the general recession in Europe in 1957-8, the economy grew extremely rapidly - between 4 and 7% per annum between 1959 and 1963. At the same time the Gaullist government increased its R&D investment enormously - from about 1.5% of GNP in 1962 to over 2.1% in 1967, the steepest rise in this period of any country in the world.[13]

Finally, one cannot overlook the fact that the policies adopted by the British and French delegations at CERN - particularly concerning the relevance of competition with American laboratories - reflected more general perceptions of their place in the world. For the British, there was still that 'special relationship' with the trans-Atlantic superpower, that form of dependence which had been established during the second world war. For the French, and the Gaullists in particular, there was a general dislike of 'Anglo-Saxons', and a determination to be independent of American influence, a firm resolve not to be an American satellite. In this climate it was only 'natural' to find a UK Treasury official wondering whether or not British physicists could get the same benefits they would have at CERN for less cost from the programme at Berkeley, and to see the French diplomat, de Rose, determined to build CERN into a laboratory which could "keep up in the competition with big laboratories in the United States and the Soviet Union".[14]

NOTES AND REFERENCES

1. This paper is based on documents in the CERN archive, Geneva, Switzerland, and in the archives of the (UK) Science and Engineering Research Council, Hayes, Middlesex. It is essentially a highly abridged, and slightly refocused, version of my discussion of the development of finance policy at CERN in chapter 10 of A. Hermann, J. Krige, U. Mersits, and D. Pestre, *History of CERN, Volume II. Building and Running the Laboratory* (Amsterdam: North Holland, 1990). As there is a comprehensive list of sources in this chapter, and as the symposium organizers have stressed the importance of discussion rather than the written word, I shall limit my references here primarily to important quotations.
2. Bakker to the Finance Comittee Working Party meeting on 2-3/10/56, minutes document CERN/FC/162, 18/10/56 (CERN archives).
3. These remarks were made by the British delegate to the Finance Committee H.L. Verry. They, and all the subsequent quotations from this source, are to be found in the minutes of the FC meeting held on 1-2/5/57, document CERN/FC/198, and in a verbatim record of what Verry said which was attached to the letter CERN/3748, 16/5/57 from Eliane Bertrand to Verry of what Verry said which was attached to the letter CERN/3748, 16/5/57 from Eliane Bertrand to Verry. It is in box DG20804 in

the CERN archives.

4. Britain herself provided an example of how, immediately after the war, governments were willing to invest huge amounts of money without question in basic research in the nuclear field. In 1946 the universities were simply asked what accelerators or other big equipment they wanted, and all their requests were satisfied - see J. Krige, "The installation of high-energy accelerators in Britain after the war: Big equipment but not big science", in M. de Maria, M. Grilli, and F. Sebastiani (eds), *The Restructuring of Physical Sciences in Europe and the United States 1945-1960* (Singapore: World Scientific, 1989), pp. 488-501. In fact, it might be argued that just because Britain - and she alone in Europe had had direct experience of the costs of an accelerator programme far exceeding the original estimates, her government was particularly keen to impose limits on CERN's expenditure so as not to repeat the same 'mistake'.
5. These quotations are from the minutes of the FC held on 19/10/61, document CERN/FC/511.
6. The British threats were made at a meeting of the Finance Committee on 14/11/61: minutes document CERN/FC/520. Although we have not actually found the *Aide Mémoire* itself, we do have a confidential memo from the Foreign Office to the Chanceries in the CERN Member States, dated 10/11/61. Our quotations are taken from this memo, which is in box B125, SERC archives (see note 1).
7. The remarks made by Bannier are taken from the minutes of a Committee of Council meeting held on 18/12/61, document CERN/- CC/-435 (my translation from the French). I have also studied the tape recording of this meeting to capture the mood of the meeting. It is available in the CERN archives.
8. The material on de Rose that follows in the next few paragraphs is taken from the sources cited in note 7. Not all quotations are in the official minutes: some can only be found on the tape recordings.
9. The minutes of the Council meeting held on 19/12/61 comprise pp. 27-49 of the bound version of the Council minutes for that year, issued by CERN.
10. The criticisms made inside the DSIR are in memos from G. Hubbard dated 22/10/61 and 3/11/61 (SERC archives, box B125). Hubbard was one of the advisers to the British delegation in the CERN Council.
11. The quotation is from an intervention by French delegate Courtillet at the FC meeting on 18/12/61 (CERN/FC/527).
12. W. Laquer, *Europe Since Hitler* (Penguin, 1982), p. 224.
13. Britain's and France's figures for gross expenditure on R&D as a percentage of GNP are taken from C. Freeman and A. Young, *The Research and Development Effort* (Paris: OECD, 1965), p. 71 (for 1962), and from *OECD Science and Technology Indicators* (Paris: OECD, 1984), 27 (for later years). The growth rates of France's economy are from Laquer (note 12), p. 214.
14. This remark was made by de Rose at the Committee of Council meeting on 18/12/61 - minutes CERN/CC/435. Doubts about whether it was necessary for CERN to compete with the USA constantly plagued British Treasury officials, who were inclined to see it as little more than an attempt to "keep up with the nuclear Jones's".

Aant Elzinga

The Antarctic as Big Science

Introduction

In the Antarctic, science is *big science*, not so much because of the scale of the operations or investments, but rather by virtue of the role scientific research plays as a form of symbolic capital on a global political arena. This means that science is very much a vehicle whereby great power politics becomes sublimated and rivalry between nations translated into international cooperation and competition. This is done within the framework of a regime of international rules and regulations called the Antarctic Treaty System, the core of which is an agreement ratified in 1961. At that time twelve countries were party to the agreement. These were the same countries that participated centrally in Antarctic science as part of the efforts of the International Geophysical Year of 1957. These countries participated in a series of coordinated research programs with different national inputs, and altogether they established about 60 research stations in the area at that time. Some of these remain to this day, others have dissappeared, and during the past thirty years still others have been added. Today there are some 23 members in the inner club of decision-makers, formally referred to as *Consultative Parties*. According to the basic rules of the game a nation can only qualify itself for this role if it displays substantial research activity in Antarctica. In practical terms this usually means placing and maintaining a research station in the area, although the Netherlands recently qualified through marine research from vessels.

Scientific work in the Antarctic consequently reflects more strongly than in many other instances both geopolitical tensions and the evolution of economic and political events in the postwar era. In short it may be said that science in the Antarctic is the continuation of politics by other means. For the politics to succeed the science that is the vehicle also has to succeed qua contribution to the international fund of basic knowledge about our world. This means that there is a complex mediation between scientific and political dimensions. A part of this complex relationship is explored below; a premise being that *big science* is not only a question of bigness in scale or capital intensity, but also a matter of the close integration of science with *big politics*. We see a similar dimension in science used to explore space or the bottom of the oceans, and today we are seeing it in connection with the global politics of trying to maintain an ecological balance and avoiding a world-wide environmental and climatic catastrophy.

In human exploration of the Solar System current discussion involves two models, the extension of scientific stations and colonization or settlement in space. The first model is also referred to as the *Antarctic Model*, since exploration there has first and foremost been based on extending a network of scientific stations rather than human settlement of the kind that occurred after Columbus' 'discovery' of America, now five centuries ago. Seen in this perspective the efforts of various nations to extend scientific stations is the instrument and spearhead for the kinds of political ambitions that earlier and elsewhere were contained in European countries' efforts to settle and colonize non-European parts of the world. In order to lay claim to territories and maintain such claims, a country has to convince other countries of its 'presence' on the map. The rigours of life in Antarctica are such that settlement and colonization have largely been out of the question, even if there have been some fantastic technocratic dreams of setting up large transparent domes which, on a large scale, would provide the kind of artificial life support systems needed for more permanent forms of human habitation on a level comparable to that represented by European colonization in earlier days.

In the following, the current status of research in the Antarctic will be touched upon; some points will be made regarding the historical roots of Big Science in the area, and a number of different tensions will be brought into focus, many of them emerging from the basic tradeoff between science and politics. Currently, pressure to push science into a direction of greater relevance for future resource exploitation as well as environmental concern, are high on the list of Antarctic affairs. This is having an effect on the nature of science in the area. Fundamentally however, because of the peculiar nature of the existing political regime as defined by the

Antarctic Treaty, the icy continent still remains a haven for basic research. The political regime affords a countervailing pressure that still largely facilitates such efforts.

Science in Antarctica Today

Of the twenty-four countries currently classed as *Consultative Parties* only a few do not really carry their weight in research terms. For example, Belgium, a founding member in the ATS, does not have a research station of its own. Newer participants often complain that this is unfair, since it clearly indicates an historical contingency. Many of the newer participants - usually Third World countries, can only claim relatively recent involvement.

In addition to the consultative parties, the twelve original founding nations and the ten or more newer ones, there exists a large number of non-consultative parties. These comprise countries which, while recognizing the ATS, do not qualify for membership in the inner club because they lack scientific clout. Although such countries now have the right to sit in on meetings, they do not have a vote. In the Autumn of 1988 Spain and Sweden moved from this group into the group of 'later consultative parties' to the treaty, and several other countries are attempting a similar move. The table appearing on page 18 gives an overview of the different countries involved in early 1988. It should be noted that there is a distinction between *claimant* and *non-claimant* states among the original twelve. Claimant states are those that have territorial claims; non-claimants do not. The two superpowers have a special position in this regard, i.e., they are not claimants but have declared the right to lay claims in the future, if and when this is to their advantage (e.g., if the regime of the ATS was to break down). This special position of the superpowers reflects their geopolitical prowess, a factor that is also very much reflected in the pyramid of science.

These power relationships and historically dependent involvements reflect different degrees of political commitment, and constitute the larger framework within which science plays the dual role of satisfying the human quest for knowledge, while also displaying national stakeholder interests and prestige.

Within this overriding framework scientists are linked together in many different ways. Some are involved in the joint effort scientific projects that the Scientific Committee on Antarctic Research (SCAR), an international non-governmental body, seeks to coordinate. Others are involved in bi- or multi-lateral ventures related to national programmes, e.g., the New Zealand/West German/ US Geological investigations and petrology on the coast east of McMurdo sound; the joint Swedish/ Finnish development of two research stations on Dronning Maud Land; work in conjunction with the research vessels involved in the European EPOS programme, under the auspices of the European Science Foundation (ESF).

There are also differences between joint efforts oriented to exploring and - eventually, exploiting natural resources and those which are clearly geared to basic research. In the wake of the oil crisis years of 1973-1974 there was a boom in seismic studies and off-shore sounding. Such studies were carried out by various nations in order to determine the ocean bottom profiles below, for example, the Wedell Sea and the Ross Sea. Japan was a major actor in these studies. A third world country, Brazil, also participated alongside the major powers.

A rough estimate of the scale of Antarctic research indicates that its requirements do not, generally, exceed those of any other *single* big science institution. CERN is a case in point. The two rough indicators I have chosen for this purpose include numbers of scientists and related personnel, and monetary commitments. The figures used were based on a perusal of various national reports, interviews, and a diversity of other sources. The latter included international sources, scientific periodicals, and general travelogues. In the following, I will consider both personnel and funding levels.

In the austral summer there are about 2350 persons living in the Antarctic. Most of these are concentrated on the densely crowded King George Island (off the Antarctic peninsula), with its eight bases, or somewhere on the perimeter of the continent; a large piece of ice four kilometers thick and, in some places, close to two hundred thousand years old. A thin band of extruding rock faces the surrounding seas and the steep dropoff of the continental shelf. If one adds the number of people on the supply ships and research vessels which visit the mainland stations during January and February, the number of people in the area can be between 3000-4000.

This is not, however, a large population for a continent having the composite size of the US and Mexico. During the winter, the population size drops to about 800, and the ratio of scientists to other categories of personnel increases. At some of the bases, during the summer, there are many construction workers and logistics personnel; although the ratio of scientists/non-scientists will vary according to programmes and differences in national styles of science. For example, whereas the British and New Zealand Antarctic research programmes emphasize actual science, the US McMurdo base has a much smaller ratio of scientists. This is due to the size of the US McMurdo base, which has 180 winter staff, with numbers swelling to 1100 or more during the summer, when the station's dominant role is logistics center and supply terminal for other US stations. An added ingredient at the Chilean and Argentinian bases are the contingents of military personnel and their families. These two countries are unique in that they follow a policy of settlement and colonization in the peninsula (the settlement model noted above). The Soviet Union - like the US, also uses numerical superiority to display its super-power presence. It has seven permanent bases and six summer camps fannning across the entire Antarctic continent.

It is difficult to obtain an estimate of the current total expenditure on logistics, science, and other activities in the Antarctic. As in the case of the numbers of personnel outlined above, my estimate is largely limited to in situ efforts. There are, of course, many scientists - in as many institutes around the world, working on data from the Antarctic. Similarly, many university budgets around the world help to carry a portion of the cost burden. While the available literature indicates, to some extent, the commitments at the government level, it cannot provide estimates of the broader investment of time, personnel and related funding. On the basis of available information, it can be estimated that official national funding commitments are on the order of $500 million annually. Only about 10% of this actually goes to research, however; the rest is spent on logistics, building costs and maintenance, fuel, etc. Of course, on a national level the logistics portion of the southern polar research budget may vary. While this will depend on national style, logistics costs will always cut very heavily into any budget.

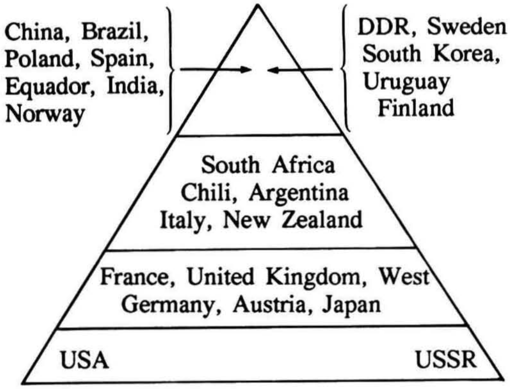
The two big spenders are the US and the USSR. The US lists total programme costs at about $145 million annually; budgeted through the National Science Foundation (NSF). The USSR, with its large number of bases and long supply routes, is planning an air link. This is something the US already has. Consequently, the USSR is in the same class as the US.

Apart from the two super-powers, there is also a set of major powers having historical claims and/or strong and expansive economies in the world market. This group includes Britain, France, Australia, West Germany and Japan. The first two are in the process of building runways for an airlink which, for the moment, involves heavy construction. In France's case, it is a question of a 1100 meter all weather hard tarmac runway for airplanes at its base on Terra Adélie. The Australian program also has a heavy construction component geared to modernize its three bases. This will upgrade its status and power on a very large piece of the Antarctic continent. Australia annually disburses on the order of $35 million for its Antarctic efforts. This order of magnitude is comparable to British (sometimes $20 million p.a.) and French efforts. West Germany has a plan involving expenditure of about $30 million p.a., particularly focussing on research vesssels and the, relatively new and large, Georg von Neumayer base. Japan has a super-modern icebreaker-cum-research vessel and three year-round stations to maintain in the Antarctic. This places the Japanese in the same league as the Germans.

In the next division we have countries boasting smaller, but research intensive, programmes costing in the order of $5-10 million. New Zealand, Argentina and Chile are examples. The latter two not only qualify as research 'spenders', but also as supporting settlements having a strong military contingent; administrative personnel and some scientific leaders may also hold military rank.

Finally, there is the division of small performers. These are countries that sufficiently qualify for membership in the 'club'; some of recent vintage. Sweden, for example, put about $6 million into a national programme leading to the establishment of a summer station (WASA). This programme ran over a three year period. Current funding is now kept at a level sufficient to send scientists there every summer, and to encourage participation in other countries' research projects (e.g., with Germany under the EPOS programme of the ESF).

The foregoing review may be summarized in a 'commitment pyramid' which tallies well with what can be gleaned from other indicators, e.g., numbers of scientists.



Involvement Profile

It would be interesting to review the polar research literature - restricting the search to Antarctic affiliations, to determine which nations are at the top of science citation lists. While the US, the USSR, France and Britain will be found in this category, small countries such as Norway and Sweden - having a tradition of research in the polar north, may also occupy relatively prominent positions. A strong research tradition in the northern polar regions creates disciplinary infrastructures at the university level which may be called upon for Antarctic science. At the epistemic level, the attempt to circumscribe science as 'Antarctic' is rather misleading. This is a result of the globalisation process, both in- and outside science. 'Polar' has increasingly become only one aspect in a science requiring definition in broad disciplinary, and mission-linkeage terms. The latter involves environmental interests or resource exploration associated with future exploitation.

Mission orientation in science is, in part, generated by new functions built into the ATS; more and more conventions have been added to the original treaty of 1961. As noted above, the treaty specifies that any country carrying out substantial scientific activities in Antarctica may become a 'consultative' member of the treaty system. It also holds in abeyance the sovereignty claims of seven countries (freezes territorial claims), and permits equality for states holding claims, states without claims, and those (the two superpowers) having reserved the right to make future territorial claims.

Another part of the basic regime platform is the ban on military activities in Antarctica. The treaty prohibits nuclear weapons or the disposal of nuclear waste materials below the 60th parallel south.

After a period of 30 years (in 1991), the ATS-regime may become the subject of review and modification should any one of its members request such action. This may (but need not) happen in 1991. This could be one reason many countries have geared up their science, i.e., in order to get into the Antarctic 'club' of nations. The ultimate reason is, of course, to influence the future of Antarctica; being, in the eyes of some, the world's last treasure chest of natural resources, marine, hydrocarbons and mineral. During the ensuing years the treaty nations have adopted a number of conventions for resource management and environmental control: the 1972 Convention for the Conservation of Antarctic Seals (CCAS) which went into force in 1978; the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), effective 1982; and the Antarctic Minerals Convention, signed in June 1988 and thereafter opened for signature. This latter convention is perceived as an effective instrument for staving large scale negative environmental impacts in the future. It is also seen as the first step toward exploitation of mineral wealth, which will inevitably get out of hand and disrupt the Antarctic environment; often claimed to be particularly fragile. Serious environmental impact may also contribute further to climatic imbalance, boding global catastrophies of much greater proportions than we can imagine today - despite what is known about the ozone hole and the greenhouse effect.

The global concern with environmental issues has recently split the community of ATS adherents, and there has been some worry about a regime breakdown. The major point of contention today is the minerals convention, which two major actors have refused to sign. For various reasons, e.g., domestic politics, France and Australia have banded together, in partial alliance with Greenpeace, to propose a 'delinking' of mineral resources from environmental issues; giving absolute priority to the latter. They support the adoption of a comprehensive scheme for protecting the Antarctic environment. Those on the other side of the controversy want to link environmental protection to the minerals convention, through a special protocol. They argue that it is easier and more appropriate to build environmental protectionist rules into the existing convention, rather than beginning anew. France and Australia, on the other hand, insist that this would subordinate the environment to the interests of future resource exploitation. In this controversy much hinges on the same contradiction that has emerged in the debate about sustainable development: should prospects for economic development be subordinated to overriding ecological concerns of a global nature, or should we continue to allow the individual interests of various nations to reign supreme, regardless of the danger to the collective interest of humankind. In April 1991 a compromise agreement was reached, banning mining for the next fifty years.

The combination of these various conventions and individual national interest in economic exploitation, environmental and/or political concerns in Antarctica has a direct bearing on the activities of scientists working there. SCAR, the continuation of the expert body created under the International Council of Scientific Unions (ICSU), is often called upon to provide information and scientific results subsequently used as input for Treaty decisions. Indeed, the more the ATS-regime develops regulatory measures, the more science, too, becomes subject to external steering pressures. There is an increasing tendency to drift towards strategic or targeted forms of research. This is especially the case in the areas of environment and potential resource utilization.

In the context of Arctic polar science, strategic research has been defined as "research with a possible long-term (e.g., 25 years) payoff in applications. Most, if not all, of the input arises from research originally geared to improving knowledge". It constitutes efforts to orient "the development in a given discipline toward achieving a predetermined but restricted goal in scientific knowledge".[1] External research motives are translated and internalized into the agendas of basic research programmes. Exploitation and management of renewable resources (e.g., living stocks and, in the future, possibly icebergs) or non-renewable resources (oil, gas and hard rock minerals) calls for multidisciplinary strategic research. This includes foresight regarding possible effects of large-scale exploration and exploitation, as well as more basic research concerning plate techtonics, mineralization processes, sedimentology and stratigraphy. Strict focus on environmental protectionist interests and the international global change programme calls for strategic research of a different nature.

The behaviour of the various actors, party to the ATS, reflects the tension between these two relatively incommensurable values, i.e., economic and environmentalist. Nevertheless, relevance pressures are minimal compared to the push to 'applied' which is taking place in the northern polar hemisphere. The polar north and south are worlds apart. As a consequence, the organisation and 'logic' of the production of scientific knowledge in the two poles follows somewhat different modes. In the Arctic there is a greater fragmentation of knowledge and a greater incorporation into economic and military structures. These are absent in the Antarctic, where science itself is an indicator of extrascientific influence within a unique international regime which has succeeded in immunizing the continent from militarization and armed conflict.

Historical Roots of Big Science

Historically, it would seem that big science was *necessary* in Antarctica if scientists were to be seen as supporting their own countries' interests. After World War II, individual expeditions were no longer enough to uphold these interests, let alone sovereignty claims.

By the late 1920's Antarctic travel was already becoming increasingly mechanized, with airplanes and motorized overland vehicles becoming an important ingredient. In the late 1930's the nature of exploration was intensely politicized; the French, Germans and Norwegians added sovereignty claims to those of imperialist Britain (1908) and its dominians (New Zealand 1925, Australia 1933). The Norwegian claim was consciously made to stave off the German claim and, as such, it directly contradicted Nazi German interests. Tensions over the Antarctic continued during World War II. As Britain was tied up on the European front - and Germany appeared to have a good chance of victory, Chile and Argentina saw a chance to lay territorial claims in the British claimed sector. After Stalingrad the British had to send in a naval force to secure her interests; she subsequently set up bases in and around the Antarctic peninsula. The conflict with Chile and Argentina - to the point of gunfire, continued even after the war. A modus vivendi was finally found in 1948 in the so-called Escudero plan, which suspended national claims without neutralizing them. This formula was the forerunner of the Antarctic Treaty. An alternative to guns, it made science an essential resource which could be used to demonstrate the presence and interests of the various countries in the region. Big Science became the product of this political sublimation. In order for science to be politically useful, it could not be directly fettered to a political master. Hence the emphasis on internationalism; which became a lasting feature of Antarctic Big Science.

A major manifestation of this internationalism came in the IGY. By the mid-1950 many new technologies contributed to making the frozen continent intellectually interesting, for a wide range of scientific disciplines. In addition to biology and natural geography, there was atmospheric physics, glaciology and new developments in geophysics were taking place. At the same time, however, the intense conflict of the cold war days threatened to carry over to the Antarctic. The IGY, and the more permanent continuation of scientific cooperation a few years later, came at a crucial time.

With the IGY, the exploration of the Antarctic was linked to that of space and the ocean floor. Similar institutional forms were also utilized, i.e, large scale, capital-intensive, multidisciplinary, project-oriented, team-related endeavours. "The scale of the IGY focussed national and international planning, funding and organization in a way never seen before".[2] Science had become a cover for power politics; accomplishing that which a show of military strength did elsewhere. Thus, cold war rivalry was transformed into scientific competition, with the two superpowers as the largest and most powerful actors. The US placed a scientific station at the geographic south pole, marking its refusal to recognize any sovereignty claim based on the sectoral principle - the sectors met at this point. The USSR demonstrated its power by putting a station at the highest, and most inaccessible, point.

In sum, it can be said that big science in Antarctica was the product of a combination of two factors; geopolitical tensions before, during and after World War II, and the application of those technologies resulting from the war.

The mapping done in both the north and south poles shortly after the war by the US was a way of descaling the wartime buildup, and testing equipment and personnel in order to combat a new 'enemy'; one that boasted polar lands and experience. A considerable amount of mapping done in Canada's polar regions also took place at this time.

Thus, excursions into the northern and southern polar areas had a clear purpose. For similar reasons, the Antarctic also became an important object for aerial surveys. Operation 'High Jump', in the years 1946-47, was the largest ever expedition to this continent; involving 13 ships, 25 airplanes and over 4000 men. About 60% of the coastline was surveyed by aerial photography (an important new technique). The following season the complementary 'Operation Windmill' was launched - on the ground, to facilitate collating the aerial survey with actual base points on land.

It is possible that these operations were part of a US strategy to get a slice of the Antarctic pie. A large portion of both efforts took place in the, still unclaimed, sector called Marie Byrd land. Soon after these operations, the US suggested that claimant countries formally confer to discuss the possibility of establishing a 'condominium' of powers to rule Antarctica. The objective was to keep the Soviet Union out. The Soviets responded with a protest (June 1950) and threatened to send armed forces. The Escudero plan was invoked as an alternative to the 'condominium' approach, allowing all involved parties to save face. This was the climate in which the IGY was planned and implemented. It layed the groundwork for protecting national interests through an international framework.

Antarctica has since been much more thoroughly mapped. Sufficient mineral riches exist to warrant concern about future conflicts. This potential is already evident in the actions of France and Australia against the minerals convention by their proposal of a comprehensive environmental scheme including a world wilderness preserve. It has been contended that, at least in the Australian case, another motivation lies behind this proposal; i.e., the fear that a future minerals convention may result in a lose of control over claimed territory and its resources.

Globalization and the Cognitive Dissolution of Antarctica

Currently, the ATS is a vehicle having an important influence on the direction of scientific research. Polar research is becoming increasingly globalized, evident both in the global character of scientific projects, and the kind of theoretical work undertaken such as the development of global simulation models of climate systems, oceans, cryosphere-atmospheric interface.

A recent example of this globalization trend is the ICSU International Geosphere-Biosphere Program, commonly referred to as the *Global Change Program*. Here, polar research plays an important role, tying into scientific work which transcends disciplinary boundaries.

In a sense, the Antarctica is becoming less and less an independent object of research. Historically, Antarctica began as a white spot on the map, challenging geographers to fill in the details. Later, biologists and geologists became involved, followed by glaciologists and atmospheric physicists, etc. Scientific specialization within disciplines, together with the possibilities created by new technologies, have made the Antarctic an interesting object of research for an increasing number of specialists. Increasingly, however, the Antarctic is being viewed as one 'aspect' in the research of various disciplines. Of course, on the material level, by virtue of its capital intensive and logistically complicated nature, Antarctica remains very much an object of research in its own right.

In the realm of science policy, Antarctica also exists as a distinct category, both in budgetting and prestige.

Tension Between Internal and External Determinants

A parallel tension exists between internal and external determinants in Antarctic science; evident in the dual structure of research under SCAR. Disciplinary groups in SCAR revolve around specialties such as, e.g., upper atmospheric physics, biology, human biology, medicine, oceanography. There are a total of nine groups, each adhering to the disciplinary boundaries of their respective science. Their problem agendas are internally generated within the international scientific community. In addition, SCAR organizes *ad hoc* groups of specialists. Such groups are interdisciplinary; forming the loci of hybrid communities. The problem agendas of these groups, as their names suggest, include a fair amount of strategic research: Antarctic Climate Research, Environmental Impact, Sea-Studies, Seals and Southern Ocean Ecosystems. The problem areas concerning these groups seem to be prompted by environmental motives, resource management objectives and knowledge requisite to the implementation of conventions.

The division between fundamental and strategic research is reflected in SCAR's committee structure. As a member organization of ICSU, SCAR facilitates information exchange, communication, and encourages cooperation in Antarctic research programmes. Moreover, on its own initiative - or by request, it also interacts with the AT-system, providing important input for its meetings.

Scientists within the community are not always enthusiastic about their role as special advisors at meetings where bureaucrats and politicians dominate. Moreover, the secrecy surrounding diplomatic negotiations runs against the grain of the scientific ethos, with its ideal of free interchange of information. Irritation also exists about the way the ATS consulting parties have come to regard SCAR as *their* scientific secretariat. This has put a strain on the already meager financial resources. The scientists would prefer the organisation to promote fundamental research. At present, consideration is being given to the development of an infrastructural arrangement able to support all of the tasks SCAR is called upon to perform.

In addition to the pressures of mission orientation and external utility, the rhetorical value of research activities may be more important for politicians than the actual scientific value. The image of scientists plotting their own research course is not always accurate, nor is quality automatically predominant. Effecting quality research requires a consciousness of epistemic criteria.

In polar research, the criteria and social control mechanisms whereby internal and external interests interplay are particularly important because of the extreme costs involved. Climatic conditions and logistics, payload costs, unusual modes of transportation, and extreme demands on equipment and maintenance, as well as on the reliability of measuring insturments, all necessitate exceptional care and rigour in the selection, planning and implementation of scientific programmes. This implies that internal rivalries between different scientific schools, and between academic and hybrid research communities may, on occasion, become rather acute.

Even though scientists complain about bureaucratization (the loss of spontaneous individual non-government initiatives), and the fact that administrative or logistics costs increasingly cut into science budgets, the problem is not as great as in other areas of big science. This is due to the basic tradeoff relationship between science and politics, which lies at the heart of the ATS. A new problem in this tradeoff is the environmental degradation caused by science itself. The research stations in Antarctica are pollutors; they pour out toxic chemicals from photographics labs (or have done so); there has been serious spillage from oil drums; many other forms of waste remain intact in the extremely cold environment. These types of pollution are a serious strain on ecosystems which may take centuries to recoup. Pollution from research stations has become a political problem. Environmental activists from Greenpeace have a watchdog station near McMurdo base. They have made regular inspection visits to the scientific stations of different nations, and make their environmental performance a matter of public record. This has influenced home opinion in various countries, and politicians have begun to pressure scientists, whose priorities may lie elsewhere. It is extemely expensive to collect waste and ship it back to the home country. It is easier to stack refuse on the sea ice in the hope that it will sink when the thaw comes. Politically, however, this is unpopular and costly. This constitutes a new tradeoff, with politicians having a hold on scientists.

The Tradeoff Between Science and Politics

Mission orientation and commercial pressures in other fields of science result in a conflation of internal and external criteria for evaluating research results. There tends to be a shift of emphasis toward the latter at the cost of the former. Such a 'drift' in epistemic criteria may, however, be counteracted if researchers are science policy conscious, maintain strong links with international scientific agendas and upholding internal peer review mechanisms.

In Antarctic science there is a natural tendency to counteract "espistemic drift" by virtue of the peculiar tradeoff relationship that casts science in the role of symbolic capital for the nations involved.[3] The international character of the ATS-regime, being based on science, also serves as a counterweight. In other words the specific nature of the political regime is such that it actually can help to reinforce and maintain peer review mechanisms and the predominance of basic research, both of which are international in scope. This helps offset the tendency to epistemic drift in Antarctic big science, a condition that, paradoxically, flows from the very fact that science is a sublimation of politics.

Even though there is a noticeable shift to more resource-related research, such as interest in krill, minerals and hydrocarbons, the predominance of basic research has mitigated a seriously erosive effect on quality control mechanisms. In this respect the situation is quite different from that in the Arctic, where one finds an emphasis on many short-term, applied problems; resulting in a fragmented production of polar knowledge. The difference may be clarified by introducing a distinction in the way in which science generally relates to national interests, and the conditions for cooperation this generates. In functional terms, it is useful to speak of three distinct (but overlapping) forms of research, *1)* practical-instrumental, *2)* symbolic-instrumental, *3)* knowledge-instrumental.

Practical-instrumental research aims at solving current problems for immediate application; be it in a military, economic, administrative, environmental regulative, or other sphere. In such cases research, embodied in, and bearing the stamp of the relevant sphere, is embedded in the structure of the immediate institutional arrangements.[4] Different institutional motives are expressed in mission oriented and applied programmes.

Symbolic-instrumental research serves primarily political ends. "It is initiated in order to demonstrate that the party in question possesses scientific capacity capable, should the need arise, of being used as a basis for influence also in non-scientific fields. Here the client aims to ensure the presence of researchers in a region where he wishes to assert himself. Such presence will signal two things: first, the state's interest in and attachment to the area, and second, the government's political will to play an active part in the development of the area. In the eyes of the government, the scientific component is of secondary importance in relation to the symbolic function".[5] Thus, as long as research is non-threatening, either in content or in organization, researchers will have complete freedom of choice in the selection of topics, collaborators and modes of evaluating results. If, on the other hand, the primary interests of politicians become endangered, the conditions of cooperation will worsen. Whether or not symbolic-instrumental research actually facilitates international scientific cooperation depends on the context, vested interests, and political conjunctures. Freedom is never absolute.

Knowledge-instrumental research is what is usually known as curiosity oriented basic research. There are no promises or mandates for solving pressing problems, or to support political goals. In this sense it is 'pure science'.

It should now be obvious that the knowledge-instrumental interests of scientists and the symbolic-instrumental interests of politicians have been more or less convergent in Antarctica. In the Arctic, on the other hand, especially in the Arctic rim countries, the practical-instrumental research motive dominates. This is the reason for the difference in the structure and conditions for knowledge production as compared to the Antarctic.[6] Only in recent years has some progress been made to create an international forum for coordination and exchange in Arctic science. The immediate basis of this shift is political; Gorbachov's introduction of glasnost into the Arctic arena.

North-South relations also affect research relations. In the case of Antarctic science, some third world country scientists participating in international programmes find themselves at a disadvantage. This is due to the prohibitive cost of linking up with global data systems, and the fact that colleagues from industrial countries can often make more efficient use of the common data base in grinding out scientific papers. This has been a source of some irritation. This is exacerbated by the possible threat of increasing secrecy as research becomes more resource-oriented.

Summary and Conclusion

This paper has reviewed some of the major features of science in Antarctica. The emergence of big science in this case was based upon strong political motives. These motives continue to be relevant and to provide a basic tension and a potential for a tradeoff between scientific and political interests. At the institutional level or as a part of a nation's science policy, the basic research or knowledge-instrumental motive manifests itself in the support extended to a group of specialists defining their problems at some distance from political pressures and economics. Such specialists are frequently part of a broader community extending across national boundaries. This is only possible when the group is sufficiently large to maintain itself as a relatively stable and active community, and is relatively immune to commercial, military, political and other 'external' pressures. Nevertheless, the latter can have a considerable bearing on research, manifested in both the practical-instrumental and the symbolic-instrumental modes.

There is, however, a double contingency; research cannot be reduced to either pure technological application or political behaviour. There is always 'internal' and an 'external' element in institutional motives and embodiments. The latter take their point of departure from quest for economic gain, national prestige, power, the building of a welfare state etc. In the former, the quest is for knowledge; the knowledge-instrumental motive of basic research. It is not the scale of funding or personnel which makes Antarctic science big science. Rather, it is due to the convergence of the knowledge-instrumental with symbolic-instrumental functions of science. This highlights another feature of big science; science as power. Those investing the most also have the greatest scientific and, by extension, political clout. Although the two superpowers dominate, medium size countries with resource interests or actual sovereignty claims also contribute considerably. Some nations participate with a view to protecting global environmentalist interests.

A major theme in this paper has been the role of science in politics. Indeed, science as a continuation of politics. It is this role which qualifies Antarctic research as big science. Added to this is the, albeit of secondary import, transport factor and the use of high technology to maintain artificial life support systems.

This situation enables scientists to profit from the symbolic-instrumental value of their science, provided they can maintain a relative autonomy and a clear understanding of their own goals. This does, however, call for a certain amount of policy awareness and a clear division of responsibilities, both analytically and in committee structures, between internal and external accountability. Failing this, there is a real danger of a drift away from basic scientific norms on at least three levels: the ideological, epistemological and the sociological.

At the ideological level, it is a question of affirmation or dissolution of an internationalist scientific ethos. At the epistemic level, it is a question of upholding some form of the Popperian razor (or failing to do so). Sociologically, this translates into the maintenance of peer review mechanisms - or their potential neglect and/or subversion, for quality control in the production of knowledge.

The lesson to be drawn from this is that a big science regime can only be established if it is able to incorporate the intellectual interest of many scientists. An establishment based on geopolitical decisions to reduce tensions in a region is not enough in itself. Without science, the regime would be of a different nature.

On the other hand, science in its own right is never enough to motivate a mobilisation of resources and effort on the scale seen - and still see, in Antarctica. In order for the symbiotic relationship to function, the symbolic-instrumental role of science must be present. In short, the marriage of science and politics has to be fruitful for both partners.[7]

Characteristic Features of Big Science in Politicized Domains

Some of the essential characteristics (potentially) shared by Antarctic science with other highly politicized domains of big science, such as space and deep oceans, include:

- an intertwining of science and politics; the centrality of nation states (particularly of the two superpowers) generate tension reflected in the scientific arena and in its relationship to the political decision-making arena (in this case the ATS).
- Capital and manpower intensive research programmes wherein logistics consumes a major percentage of budgetary allocations. In this case only the latter is relevant. Moreover, some parts of Antarctic science are little science in a big science power context.
- Development of science and technology in what is essentially an extra-territorial area. There are no clear cut or accepted conventions governing sovereignty or legal structure; these are worked out as needed. Super power interests are reflected in the formulas chosen; in this case the ATS-regime instead of a UN common heritage concept or the world wilderness preserve idea of Greenpeace or, for that matter, France and Australia in their opposition to the minerals convention.
- Using big science as a vehicle wherein the presence of scientists and scientific activities are used to supporting claims of sovereignty and other national interests.
- A symbiotic triangle of government/academe/industry, with balances of power reflected in committee structures and mandates; in this case the balance of symbolic-instrumental and knowledge instrumental motives.
- Roots in past military exploits and the implementation of technologies which have matured under military banners, together with the introduction of operational research and planning methods from the military sphere to the logistical problems involved in big science operations.
- Rational planning and management philosophy associated with the foregoing and an earlier predilection for systems theory and cybernetic modelling. Currently, computer modelling also enters into the cognitive core of science; generating tension related to the differential institutional thrust behind scientific efforts (e.g., in the Arctic, economic vs environmental, or military vs environmental.
- The significance of internationalisation and globalization trends (central in Antarctic science).

NOTES

1. Roederer, J.G." University research. Competition with private industry?" *The Northern Engineer,* 9, 1978, pp. 26-31.
2. Hain, James H. "A Reader's Guide to the Antarctic". *Oceanus,* summer, 1988, p. 4.
3. The concept 'epistemic drift' is developed in A. Elzinga, "Research, bureaucracy and the drift of epistemic criteria". In: Björn Wittrock & Aant Elzinga (eds.), *The University Research System. The Public Policies of the Home of Scientists,* Almqvist & Wiksell International, Stockholm, 1985, pp. 191-220.
4. These distinctions are developed by Willy Ostreng, "Polar Science and Politics: Close twins or opposite poles in international cooperation". In: Andersen & Ostreng (1989). Ostreng bases himself in part on the analysis

in Ingemar Bohlin, "Ett vetenskapsteoretiskt perspektiv på polarforskning", institutionen för vetenskapsteori, Göteborgs universitet, 1988.

5. Ostreng, ibid., p. 89.
6. See Elzinga & Bohlin, 1989.
7. For a recent update see *Nature, p.* 350 (28 March, 1991), which has a 30 page section on Antarctic science as it is pursued in several countries: Britain, France, Australia, the U.S., and New Zealand.

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Beatriz Ruivo

'Big Science' in a Small Country: The Case of Portuguese Participation in High Energy Particle Physics and in CERN

Introduction

Portuguese participation in high energy particle physics, and in the European Organization of Nuclear Research Centre (CERN), illustrates an attempt to take advantage of *big science* to improve national capabilities in both the R&D system and in industry.

One field of big science in which controversy has often arisen about the public allocation of resources is particle physics. Currently, consideration of the allocation of funding by governments occurs primarily on the basis of potential economic benefit. Allocating large funds for big science has often been questioned because of doubts about the economic value of basic research:

> "Governments are considering whether and to what extent a case can be made in present circumstances for spending a substantial part of a nation's wealth on expensive science, which is largely 'basic', i.e., generations away, or even infinitely far removed, from any practical application".[1]

Since its role in the long term development of new technologies began to be perceived, the argument against basic research has been softening; strategic research, in particular, is now being praised. With respect to Portugal, however, the question can be raised whether big science is appropriate for a small, relatively poor country. This question is relevant both from an approach favouring general restraints of R&D expenditure, and one strictly concentrating on *basic needs*.

This paper will attempt to affirmatively answer this question through an analysis of Portuguese participation in High Energy Physics and in CERN. In this context, and based on the above, strong emphasis has been placed on the training of personnel and the potential transfer of technology to the industrial sector.[2] [3]

The CERN-Fund

General Overview

In 1986 - although the agreement had been signed the year before, Portugal became a full member of CERN.[4]

The basis for the agreement had begun in 1981, in Lisbon, at the 'European Conference of High Energy Physics', sponsored by the European Physical Society. Later the same year, an agreement of cooperation was signed between the National Institute of Scientific Research (INIC), of the Ministry of Education, and CERN. This agreement allowed Portuguese researchers access to CERN - with INIC providing their financial support. In this way the CERN stipulation of country membership was circumvented. Moreover, the existence, after 1981, of a Portuguese scientific community at CERN became the basis for the subsequent agreement between Portugal and CERN.

As a result of these negotiations, and on the basis of lower economic and scientific development,[5] more favourable conditions were awarded to Portugal than to Spain[6] - which joined the CERN in 1983.

The agreement with CERN defined a ten year transition period during which the country's financial contribution will remain at a reduced level; a concession allowed by the convention which launched CERN. In the first year, 10% of the normal fee[7] was paid - representing 0.8% of the CERN budget (around 4 million SF); in the second year 20%, and so on until the tenth year of membership, when a full contribution must be paid. In the interim, the Portuguese government is to allocate the remaining amount to strengthening its national scientific and technological capability. The aim is to develop high energy physics and a scientific infra-structure characteristic of national participation in CERN, as well as to support technical and industrial collaboration between national organizations and CERN. The Portuguese financial contribution is provided by the National Board for Scientific and Technological Research (JNICT).[8] During the initial period, CERN agreed, in so far as possible - to grant fellowships, provide facilities for training Portugese technicians, engineers and scientists, and to provide technical assistance to Portuguese research laboratories.

The machinery for setting up the agreement includes a *Portugese Commission for CERN* and a consultative *scientific committee.* The national commission includes five members; one from JNICT, representing the Secretary of State for Science and Technology, one from INIC,[9] representing the Ministry of Education, one from the Ministry of Industry and one from the Ministry of Foreign Affairs. The main tasks of this commission are to run the CERN-Fund and to set up a *liaison* office, maintaining contacts between the national industrial sector and CERN. The CERN Fund, an operating fund based on the amount of the concession and controlled by the Secretary of State for Science and Technology of the Ministry of Planning, was established in 1986.

The scientific committee has thirteen members; eight nationals and five nominated by CERN. It advises on the allocation of resources, and is also in charge of following up on investments. It includes five experts in high energy physics and others in electronics, computing and atomic physics. Each year there is an open competition, advertized by the media. Proposals are selected by peer review followed by open public discussion. In 1988 and 1989, this competition was directed towards obtaining proposals in the following areas:

- research in high energy physics - chiefly experimental research and associated instrumentation, and theoretical research;
- establishing, or developing the national infrastructure requisite to Portuguese participation in CERN in, e.g., scientific computing, experimental research, scientific and technological information;
- technological collaborative research carried out by firms and CERN, with the highest priority given to research capable of promoting the transfer of technology from CERN - or making the CERN market accessible to national industry;
- projects in applied research - to be carried out in co-operation with CERN; the highest priority given to those in the fields of fast electronics, cryogeny and ultravacuum, computer networks, new material sciences, applied optics, superconductors systems, artificial intelligence and dynamic systems.

Up to now, resources have been allocated as follows: 50% to the development of the national scientific and technological infrastructure, 25% to research projects in High Energy Physics, 25% to training of personnel - particularly of technicians in the field of electronics, and to industry.

Infrastructure

The CERN Fund has helped to either set up institutions or launch initiatives such as:

- Laboratory of Instrumentation and Experimental Particle Physics (LIP)
- LIP Lisbon
- LIP Coimbra
- Peripheral countries cooperation
- Foundation for Scientific Computing
- Training
- Research-industry links

Laboratory of Instrumentation and Experimental Particle Physics (LIP): The Laboratory of Instrumentation and Experimental Particle Physics (LIP) was established in 1986. It consists of two units, one in Lisbon and one in Coimbra; a third, in Oporto, is planned for the the near future.[10]
The Laboratory began as a joint venture of JNICT and INIC and is a private non-profit institute. In 1989, membership was expanded to include the National Association of Electric and Electronic Firms (ANIMEE). LIP is now a collaborative research institution of the state (JNICT), the universities (INIC) and private enterprise. It is financed by the 'CERN Fund' and by the three associated institutions. Its aims are:

- to carry out basic research in the field of high energy physics - in particular research aimed at further future applications;
- to carry out applied research and experimental development aimed at technological innovation, to improve existent techniques and to facilitate the transfer of technology from experimental physics and associated instrumentation;
- to promote the transfer of technology to industry;
- to set up specialized instrumentation workshops, develop prototypes and further techniques of quality control;
- to provide training through research for scientists, engineers and technicians in the different sectors, i.e., the industrial sector;
- to provide technical services;
- to promote collaborative research for industrial innovation in cooperation with industry, research institutions and other relevant bodies.

LIP Lisbon:

Scientific and technological activities: The LIP-Lisbon carries out scientific and technological activities related to CERN. It participates in the experiments NA 38 (since 1984/85, through researchers currently linked to LPT), and Delphi. Its other tasks have included the development of Fastbus fast electronics and of general purpose microprocessor software. The scientific areas covered by these projects include the physics of high energy heavy ions collision and of positron-electron collision in the LEP experiment. Technological areas include data acquisition systems, fast optical communications, Fastbus processors, general purpose microprocessor software and graphics software.
Fast Electronics Laboratory: A Fast Electronics Laboratory was established by LIP - Lisbon.
Staff: By the end of 1987, the staff included eight Ph.Ds and twenty post-graduate students, engineers and technicians. The administrative staff included just three employees, all of whom had part-time jobs.

LIP Coimbra: The different units are specialized in order to avoid duplication and to foster efficiency. Apart from its participation in experimental research with CERN, LIP - Coimbra is heavily involved with instrumentation and workshops. It has also contributed to CERN by producing parts of detectors.
Laboratory of Instrumentation: The Laboratory of Instrumentation was set up to build detectors and mechanical devices associated with experiments involving large teams. Its aim is to provide equipment for researchers who had previously only been able to carry out data analysis at their home institutes. Another aim was to render working conditions at the national level similar to those of research groups abroad. In this way the country could become competitive at the international level.
Mechanical Workshop: A workshop for precision mechanics was set up to provide support to researchers involved in CERN projects. It can provide services to universitites and other users.

Peripheral Countries Cooperation

Some activities carried out in conjunction with foreign and international research institutes can be seen as falling within the scope of intra-periphery cooperation.
A project was set up together with the Microprocessing Laboratory of the ICTP in Trieste, Italy, in order to produce a multi-channel processor which works on a microcomputer. The final product was devised to be used both in instrumentation courses given by the Italian institute in Third World countries, and in various other laboratories.
A working programme was launched with the University of Santander (Spain) whereby two engineers from that university were to train at the LIP; learning how the LTD testing systems and the optical communication projects functioned.
These activities can play an important developmental role.

> "Obviously a change in periphery relations would also require a reorientation among the peripheral countries towards each other...[it] would be a major step towards a real definition of the internationality of science".[11]

Foundation for Scientific Computing

A Foundation for Scientific Computing was set up by JNICT, INIC and the National Laboratory of Civil Engineering (LNEC). This national state laboratory already had computing facilities which could be used by the Foundation. The aims of the Foundation are to finance and to coordinate large scale computer facilities. Its main task has been to allow the country to have a fast computer for scientific purposes (IBM 3090 level), and to build a computer network (mainly VAX machines) between several universities and research institutes. The fast computer (a CONVES C200), the first to be introduced into Portugal, was purchased in 1989.

Training

The training activities of LIP have two goals: to consolidate high energy physics in Portugal, and to nationally apply the technological advances of CERN.[12] The two main targets are:
- to increase the number of high energy experimental physicists to about thirty Ph.D's in the next 5-7 years;
- to train high level engineers in fields related to

HEPP; specifically, data acquisition systems and fast electronics.

In 1987, a Technical Training Programme was held for nine senior technicians and two intermediate technicians who were trained in CERN and at LIP. Seven post-graduate students were completing the requirements for the Masters and Ph.D degrees at LIP-Lisbon. Their research was related to the NA 38 and Delphi experiments.

At LIP-Coimbra there were six post-graduate students, three of which were working on the Ph.D degree. Their research was on detector development at Coimbra, and related to the group on Detector Development of the Experimental Physics Division and to PS195 (CP LEAR) at CERN.

LIP has fostered the introduction of post-doctoral positions in Portugal. These are open to foreign researchers. Currently, LIP-Lisbon has two post-doctoral fellows from the UK and one from The Netherlands; all working with the High Energy Theoretical Physics Group.

In 1987, the LIP organized three international schools in the fields of electronics and computing, and an international conference on heavy-ion collision physics.

Research-Industry Links

Links with the industry are planned with the following aims:

- to train skilled technicians by taking advantage of the high-tech training facilities offered both by CERN and by LIP;
- to produce equipment designed by LIP in Portugal for CERN experiments;
- to offer technological and informational guidelines for firms interested in the international competitions promoted by CERN, and prompted by the need for equipment;
- to help set up the technological infra-structure for national industry so that it can compete in the CERN market.

There have been fruitful contacts with the industrial sector, providing a test of the ability of national industry to work within international programmes involving Portuguese and foreign research institutes.

Within the Delphi collaboration, LIP has taken responsibility for producing and testing a batch of 100 Fastbus LEP time digitizers. This has enabled it to establish contacts with the Portuguese electronics industry. On the basis of these contacts, a Portuguese firm (EFACEC) was selected to assemble, solder and electrically test the modules. Acceptance tests are being prepared at LIP. Thereafter the testing routines will be transferred to the Laboratories of the University of Santander.

Another agreement with industry is aimed at producing a short series of the two Fastbus projects related modules designed at LIP-Lisbon. These are to be distributed within CERN. Studies are currently being done on the marketing of LIP developed equipment in the European and US high energy physics market.

A CAD facility was installed at EFACEC with CERN-Fund support. LIP has supplied the firm with scientific and technical aid on the CAD production system. LIP-Coimbra has organized four courses in precision mechanics involving 32 workers from industry.

The Institute of Welding and Quality (ISQ) - a consortium of firms, has studied electron-beam welding at CERN. A firm in the field of metalomechanics (MAGUE has provided mechanical equipment for the LEP tunnel).

During the period 1986-1988, sales of goods and services from Portuguese firms (in metalomechanics, electromechanics, electric and electronic material) to CERN totaled 280 million 'escudos' (Portuguese currency). This exceeded the membership fees paid during this period.

Portuguese Strategy for High Energy Physics and Science Policy

The Portuguese participation in high energy particle physics can be better understood in the context of developments in science and science policy at international level.

Prior to the mid-1980s

During the first phase of science policy - the second world war and thereafter, national security considerations and the evolution of the cold war dominated the formulation of national science policies in advanced countries. The main goals were then related to big science military, space and nuclear energy.

Strong support was given to basic research because of its potential contribution to these major policy endeavours. The development of the field of physics was related to these goals. As the Brooks report put it:

> "The science of physics held the centre of the stage in the development of postwar science as a whole, and the views and style of physicists held sway in the institutions of science and the councils of national science policy".[13]

During this phase in Portugal, research centres related to nuclear physics, theoretical physics and other relevant fields were set up in the 1950s and 1960s within what is now called INIC (a research organization under the Ministry of Education). The National Laboratory of Nuclear Physics and Engineering (LFEN), a large facility related to nuclear research and its applications was established under the Prime Minister in 1958, became an important government research laboratory. Such structures were starting points for the present capabilities in High Energy Physics.

During the second phase of science policies in advanced countries, the role of science and technology in economic growth became a central issue. Science began to be viewed as a means of problem solving.[14] A more rational allocation of resources also became an important concern. In this phase, science was strongly expected to help in meeting social needs. This partly accounts for the relative stagnation in investment in basic research during this period.

At that time, 'policy for science' was superseded by a notion of 'science for policy'.[15] It was in the period from the late 1950s to the mid-1970s that the building up of science policy institutions occurred; specifically, the establishment of high level science policy advisory councils.[16]

In Portugal, the first step toward a national science policy was taken in 1967, with the creation of the National Board for Scientific and Technological Research (JNICT). Its main task was to advise the government on science policy matters and to coordinate scientific and technological research at the national and international levels.

Until the mid-1980s, science policy priorities in Portugal were related, in a very strict sense, to the 'country's economic needs'.

The PMCT (Programme for the Mobilisation of Science and Technology)

A third phase in science policy can be characterized

> "... by the dominance of strategic mobilisation of science for national (or public) interests... The emergence of a separate category of 'strategic science', now linked to fundamental research...is an indicator of the policy need to create an object relevant to the new goals. National programmes, in some countries already introduced during the 1970s, now take on new life. Special funding programmes, innovation stimulation, and community building activities are other tools of the new science policy. In such a relation between science and the state, programming and effectiveness in achieving programme goals become important policy concerns. Priority setting is not the justification of allocation of resources, but one step (and not even always the first step) in a process of implementation of programme goals".[17]

In this last phase, there is a shift from planning to programming. New tools of science policy turn up.

> "Presently countries and companies are jockeying for positions of leadership in various technological niches, and to this end basic research areas are being marked for targeting as strategically important objects for investment. The considerable efforts that go into foresighting (a looser form of technological forecasting) and evaluation must also be understood in this context. They are part of the effort to find an appropriate and potentially lucrative profile for science-based technologies. More than before, advanced technology and technological producets are symbiotically - or rather parasitically - dependent on fundamental research efforts. Hence there is swing 'back to the basics'...".[18]

A better knowledge of how science has evolved, of the relationship science-technology and of technological systems is now also providing new insights into developing science policy. It has had a profound effect on the management of R&D. The new category of *strategic* basic research is now a key factor in the long-term development of new technologies. New tools for targeting strategic research have been explored, e.g., foresighting and the French *prospective*.

On the other hand, research has entered a new phase, the *steady state*, where the main target is the commercialisation of research results. Evaluation and accountability play a key role in the allocation and management of resources. R&D institutions are also changing.

> "Research has become more competitive in quality, more sharply focused on national needs, more responsive to policy, and gives better value for money than it used to.
> Many highly academic institutions have already made considerable progress in marketing their services in the form of commercial research contracts and technical training programmes".[19]

Finally, scientific research is increasingly organized on a multi-national basis, using as tools either international programmes or the sharing of international facilities. It was on the basis of these developments that the JNICT launched a programme of Mobilisation of Science and Technology (PMCT) for the period 1987-1990. The core of the PMCT is the 'Stimulation Programmes'. These programmes are in the areas of Biotechnology, Microelectronics, Computers, Robotics, Sciences and Technologies of New Materials, Sciences and Technologies of the Sea. The general aim of these programmes is the development of scientific/technological areas strategic to national development. They support activities ranging from fundamental research to the utilization of research for industrial applications. Available funding can be used either by existing research teams, to build up new capacities, or applied to the training of personnel and the reinforcement of the infra-structure. Another funding target is the design of strategic R&D projects - involving firms and universities, either to develop existing industrial sectors or to establish new ones.

Programmes directed towards advanced scientific fields in which the country has recognised capabilities, called 'Special Programmes', are another area of the PMCT. The goal of these programmes is to improve the international competitiveness of Portugese teams and to support their participation in multi-national research programmes.

Recent years have witness the introduction of various 'big science' fields into the national science policy realm,[20] and the launching of 'Specific Programmes' in the areas of immunology, artificial intelligence, astrophysics, high energy physics, and applied mathematics. Support has also been given proposals of high scientific quality, regardless of the field. The perceived need to develop a science base generated the conscious attempt to avoid the setting of priorities between scientific fields. This view was related to the first of a two-phase approach for implementing priorities.[21] Phase one has also involved assessing the situation and analyzing the information provided by the proposals.

A primary PMCT goal was the internationalization of science and technology in Portugal. This involved adapting Portuguese science and technology to the standards and criteria of the international community. This necessitated making the Portuguese scientific community open to international scrutiny. In this context, foreign scientists have been invited to participate in the peer review panels set up for each scientific and technological area. A strong concern for more openess in the allocation of resources - and the support of public opinion, led to the launching of public discussion of proposals (except in specific cases where secrecy was required).

Although some new developments occurred in conjunction with the establishment of the CERN-Fund and LIP, the basic orientation of High Energy Physics and current participation in CERN must be seen in the context of the Mobilisation Programme.

Finally, it must be stressed that - in conjunction with overcoming Portugal's backwardness, large investments in R&D were expected; first in the Mobilisation Programme (1987/1990), and then in the Ciencia Programme (1991/1994).[22]

Final Remarks

The Portuguese participation in High Energy Physics, and in CERN, is an interesting case study because its strategy is to improve national capabilities through the appropriation and local diffusion of scientific and technological knowhow. The underlying assumptions of this strategy include:

- that the country should use its own capability within the framework of the appropriate strategy;
- that there is long-term worth in giving support

to basic research, particularly 'strategic' research, in that it helps to develop new science-based technologies;
- that basic research is an important tool for training human resources, e.g., scientists, engineers, technicians, for all sectors, especially the industrial;
- that national participation in international scientific programmes can provide contracts for national firms as well as helping to upgrade and modernise them;[23]
- that, presently, public opinion in Portugal indicates a willingness to support the development of national science and technology capabilities for national needs and/or cultural goals.[24]

Serious consideration has also been given to gathering public support. In this context journalists and secondary education teachers have visited CERN in Geneva, and an exhibition on 'Portugal and CERN' was held in Lisbon in 1988.

It must be stressed that a better understanding of the Portuguese experience in HEPP can be gleaned from the views of the relevant scientific community about basic research and the commercialization of research.

Researchers evolve implicit and explicit strategies, which can be explained when science is 'reconceived analytically as a network of changing socio-cognitive and instrumental [organizational] arrangements'.[25]

Another useful concept has been that of tactical and strategic choices in science policy; the former governed by the logic of scientific inquiry and the latter by budgetary, economic and political considerations.[26]

In the case of Portugal, the trend to commercialize research and to transfer technology through, e.g., training, has been incorporated in the researcher's strategy. In this sense, researchers have shared in the main aims of both the government and CERN. This has enabled them to become mediators, and it is on this basis that the agreement was developed.

LIP has become a collaborative research institution which includes the state, universities and industry. It is interesting to analyze LIP in the context of the framework developed by Blume to explain collaborative research based on 'shared social purposes'.[27] He qualifies three types of common purposes; shared values (e.g., common concern with health care, regional development), shared interests (i.e., perceived mutual benefits), a shared sense of social structure (as in the acceptance of a common authority). Most collaborative research institutions have only industrially related goals. Even when carrying out basic research, they are, in fact, doing strategic research. In contrast, LIP is based on shared mutual interests; combining 'pure' basic research related to the CERN cooperation with work for industry, to include mutual trade-offs. This can be regarded as the influence of the 'steady state' in a field which used to be only concerned with developing basic research.

NOTES

1. Kellerman, E. W. "Big science". In, Goldsmith, M., ed., *UK Science Policy. A critical review of policies for publicly funded research.* London, Longman, 1984.
2. Even in a skeptical view of direct applications, the spin-offs are acknowledged: "Subjects such as high energy particle physics and cosmology can earn some of their keep through their spin-off in sophisticated techniques and skilled personnel, but the direct application of their scientific results is scarcely conceivable". Ziman, J. *Science in a "steady-state". The research system in transition.* SPSG Concept Paper No. 1, London, December 1987.
3. Because of the level of technological development in this case, the aims are mostly the above mentioned spin-off.
4. The suggestion that Portugal become a member was presented to the Portuguese government by Professor Dr. J. Mariano Gago, a Portuguese physicist who had been working at CERN since 1976. He also was instrumental in the preparation of the agreement and the related strategy.
5. In 1986 Portugal had a resident population of 10 million, with US$2915. GDP per head. Gross Domestic Expenditure in R&D (GERD) was about 20 billion 'escudos' (Portuguese currency) (One billion = 10^9); GERD/GDP - 0.5%; total number of researchers numbered about 7,000 of which 2,000 had a doctorate; full time equivalent (fte) researchers numbered about 4,500 with researchers (fte) per thousand economically active population - 1.
6. In the case of Spain, the transition period was six years, during which Spain would pay 20% of the full fee in the first year of membership

and 80% by the sixth year.

7. The CERN fees are based on the GDP of a given country. Portugal will have to pay less than 1% of the CERN budget.
8. JNICT, the most important funding agency, coordinates research at the national level. It falls under the responsibility of the Secretary of State for Science and Technology.
9. It includes 129 research centres and, as such, is an important component of the higher education sector.
10. LIP is already cooperating with the Oporto unit of the Institute of Engineering of Systems and Computers (INESC). This is a private non-profit institution set up in 1980 by an engineering school (IST) of the Technical University of Lisbon (UTL), the Chancellery of the UTL, the University of Oporto (UP) the Post and Telecommunications Corporation (CTT/TLP), and a firm in the field of telecomunications (Marconi). INESC is a multifunctional institution which carries out research and provides training and consultancy services. The work done through this cooperation has been in the field of optical communications.
11. Stolte-Heiskanen, V. "National and international orientations of science of small countries?" *Science Policy Studies from a Small Country Perspective,* 5, 1987, pp. 1-16.
12. Portuguese scientists and students currently directly involved with CERN number about 100, 51 of whom are registered at CERN. In 1989, those registered (including physicists, engineers and students) were connected with the following units of the organization: Experimental Physics Division (EP)-44, Theoretical Physics Division (TH)-1, Experimental Physics Facilities Division (EF)-2, Data Handling Division (DD)-1, others -3.
13. *Science, growth and society. A new perspective.* Report of the Secretary-General's Ad - Hoc Group on New Concepts of Science Policy (Brooks Report). Paris, OECD, 1968.
14. Blume, S. *The development of Dutch science policy in international perspective, 1965-1985.* A report to the RAWB/The Netherlands, December, 1985.
15. Elzinga, A., "From criticism to evaluation". In: Jamison, A., (ed.), *Keeping science straight. A critical look at the assessment of science and technology.* Gothenburg, 1988.
16. Brickman, R. & Rip, A., "Science policy advisory councils in France, The Netherlands and the United States, 1957-77: A comparative analysis. *Social Studies of Science,* Vol. 9, 1979, pp. 167-198.
17. Rip, A. and Hagendijk, R. *Implementation of science policy priorities.* SPSG Concept Paper no. 2, London, March, 1988.
18. Op.cit. 14.
19. Op.cit. 2.
20. It should be noted that, in most cases, heavy financing may not be involved either because international facilities are shared, or due to the nature of the work involved (see OECD): "The publication subfields 'nuclear and particle physics', 'astronomy and astrophysics' and 'oceanography and limmology' bear the closest relationship to big science, but the correspondence is not perfect. Furthermore, the nationality of the author does not necessarily indicate that his or her country possesses a big science facility. Also, researchers may be contributing papers where large equipment was not used (e.g., theoretical work) or, since their subfields are broadly defined, on work in a small science section of the subfield". Organisation for Economic Co-operation and Development. *Science and Technology Policy Outlook - 1988.* Paris, OECD, 1988.
21. A two-step process of implementation of priorities according to Rip, A. and Hagendijk, R. *Implementation of science policy priorities.* SPSG Concept Paper, no. 2. 1988.
22. The Programme 'Ciencia' (Science) is a structural programme for developing science and technology prepared in Portugal, to be funded by the European Regional Development Fund and the European Social Fund. According to its proposal Programme 'Ciencia' will be running from 1990 until 1993, two years after the European Single Market has been achieved. It is aimed at adapting the country to its more scientific and technologically developed European partners. The total cost is expected to be sixty billion 'escudos' (Portuguese currency) during the four year duration, 65% of which financed by the EEC. The total amount will represent about 40% of the Gross Domestic Expenditure in R&D.
23. Studies about the technical and economic utility of CERNlinks with industry include, e.g., Schmied, H., "A study of economic utility resulting from CERN contracts". (US) *Institute of Electrical and Electronic engineers*

(IEEE) *Transactions in Engineering Management,* Vol. 24, 1977, pp. 125-138.

24. An opinion poll carried out in 1987 showed that 76% of people interviewed about science thought that the government should give financial support to R&D; 59% thought that support should be given to R&D aimed at the promotion of knowledge. Dias, A.R.; Goncalves, M. E.; Oliveira, J.V. and Ramos, J. M., 'Ciencia e opiniao publica portuguesa'. *Revista de Ciencia, Tecnologia e Sociedade,* no.2, May-August 1987, pp. 5-27.
25. Op.cit. 14.
26. Brooks, H., "The problem of research priorities". *Daedalus,* Vol. 107, no. 2, 1978, pp. 171-190.
27. Blume, S., "The theoretical significance of cooperative research". In : Blume, S., Bunders, J.; Leydesdorff, L. & Whitley, R. (eds). *The social direction of the public sciences. Causes and consequences of co-operation between scientists and non-scientific groups.* Dordrecht, Holland: D. Reidel, 1987, pp. 3-38.

Olle Edqvist

The Swedish Experience of Funding Big Science

Introduction

This paper will briefly discuss the type of big science which is done in Sweden, how funds for expensive equipment are allocated and distributed, and the relationship between big and small science and how Sweden participates in international big science.

I will somewhat arbitrarily define big science as research carried out with expensive equipment or research installations with a cost exceeding about 10 mill. SEK or 1.5 mill. USD (1 SEK was equivalent to 0.173 USD, Sept. 1990). The lower limit for expensive equipment is set at 300,000 SEK (50,000 USD).

Big Science in Sweden

During the 1980's resources for big science have been expanding. This has enabled Sweden to set up a few national centres, serving research groups from the whole country. Nearly all of these establishments are part of a university and are linked to departments at the university. Their scientific staff takes part in university teaching and young researchers do their doctoral studies at the institutes while being examined at the university. However, the centres have a certain financial independence and are governed by their own boards with representatives from the whole country.

Even though the funds for big science have increased, the same can be said for the costs. It has not been possible for Sweden to continue work at the national level in all areas. Heavy investments have had to be concentrated, particularly in physics and astronomy.

A set of accelerators and storage rings for nuclear physics has been built in Uppsala and Lund. At the Svedberg Laboratory in Uppsala there are three major installations: a tandem accelerator (used mainly for applied medical and biological research), a syncro-cyclotron, dating back to 1950 but reconstructed during the 1970's, and a new, medium energy range storage ring (CELSIUS) for nuclear physics. Construction has begun on the storage ring and the trimming.

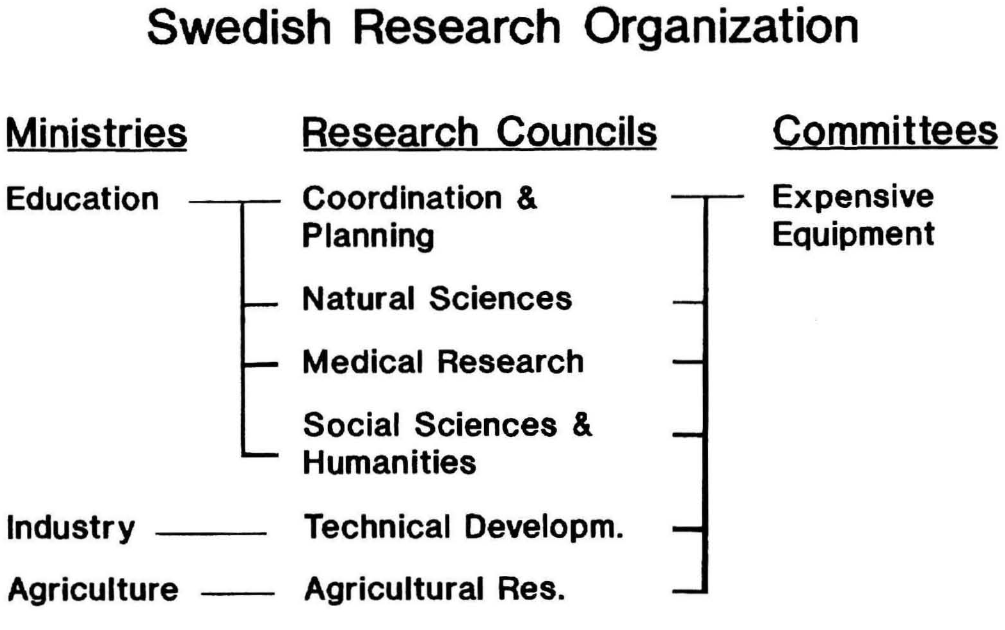


Fig. 1.

An UV syncrotron light source - MAX, has been in operation in Lund for the past three years. MAX II, the next generation light source, will be the major Swedish big science project in the comming years. A storage ring for work on heavy ions is currently under construction at the Manne Siegbahn Institute in Stockholm. A few smaller accelerators for more specialized work are also available. The total investment in these installations (for research equipment; buildings are not included) is currently in the order of 340 mill. SEK (60 mill. USD).

Fusion research in Sweden is closely connected to the fusion research programme of the European Community. The Swedish work is dispersed, with research being conducted in Stockholm, Gothenburg, Studsvik, Uppsala and Lund. The centre for experimental work is the EXTRAP experiment at the Royal Institute of Technology (KTH), where a principle, different from the tokamak, is being tried. A new experimental set-up was decided upon in 1989 and the construction work has begun with partial financial support from the EC. The total cost for this experiment is estimated at 52 mill. SEK.

The second important investment area comprises installations for medical and technological research. In the medical field the distinction between research and clinical work is very difficult to make. Big science equipment which is used for research and development includes, e.g., a human centrifuge at Karolinska Institute in Stockholm (used for testing pilot protective clothing, etc.) and a new positron emission tomograph at Uppsala. The wind tunnel at the Royal Institute of Technology, Stockholm, and high voltage testing and research laboratories in Stockholm and Gothenburg are examples of big science engineering establishments.

Space research is carried out at Kiruna in the far north of Sweden. To a great extent that is done in collaboration with other European countries. This includes work with satellites, rockets and land based equipment.

The third category of big science equipment is made up of telescopes for astronomical research. The radio telescope unit at Onsala, Gothenburg (formerly a part of the Chalmers University of Technology) was made a national centre in 1989. It has two radio telescopes dating back to 1963 and 1975. There is a big optical Schmidt telescope at Uppsala, probably the last big optical telescope in Sweden. Recent investments in optical telescopes, involving Nordic and European collaboration, have been made abroad, where the conditions for astronomical work are more favourable (Canary Islands and Chile). The total investment value for installations in Sweden alone has been estimated at 110 Mill. SEK.

In 1989 and 1990 two new supercomputers were installed in Sweden: a Cray X-MP at Linköping (in collaboration with the Swedish car and airplane company Saab), and an IBM 3090/-600 at Skellefteå. In addition there are a number of mini supercomputers (Alliant, Convex etc.) at various universities and at some research institutes. The investment cost for expensive computers in Sweden amounts to about 300 Mill. SEK (a third of which is invested in the two super-computers).

The total investment in these and other similar big science establishments is estimated at approximately 1,000 Mill. SEK (excluding buildings).

Other Expensive Equipment

Big science does not utilize the largest share of the equipment bill. As defined above, big science comprises about a quarter of the investment in expensive research equipment. Moreover, its share seems to be decreasing; the Natural Science Research Council estimates that between 15-17% of the funds allocated for expensive equipment will be used for big science in the coming three year period. During the 1980s it was about 25%. This tendency reflects the fact that investments in equipment in the medium bracket - 2 to 10 Mill. SEK are rapidly increasing. Examples include equipment for nuclear magnetic resonance, mass spectrometers, electron microscopes, and ultravacuum chambers with experimental equipment for materials research.

In 1989 we reviewed the state of research equipment in Swedish universities and those research institutes related to the universities.[1]
The review was based on a questionnaire sent out to all Swedish research groups and university departments.[2] From this material - complemented with information from other sources (annual reports etc.) - we estimated the total renewal value (cost of replacement) of expensive research equipment at 4,000 Mill. SEK. Most of the equipment was for research in the natural sciences and technology (Fig. 2).

Of particular interest for this discussion is the amount of equipment in the various price brack-

Value of total Swedish research equipment divided among sectors

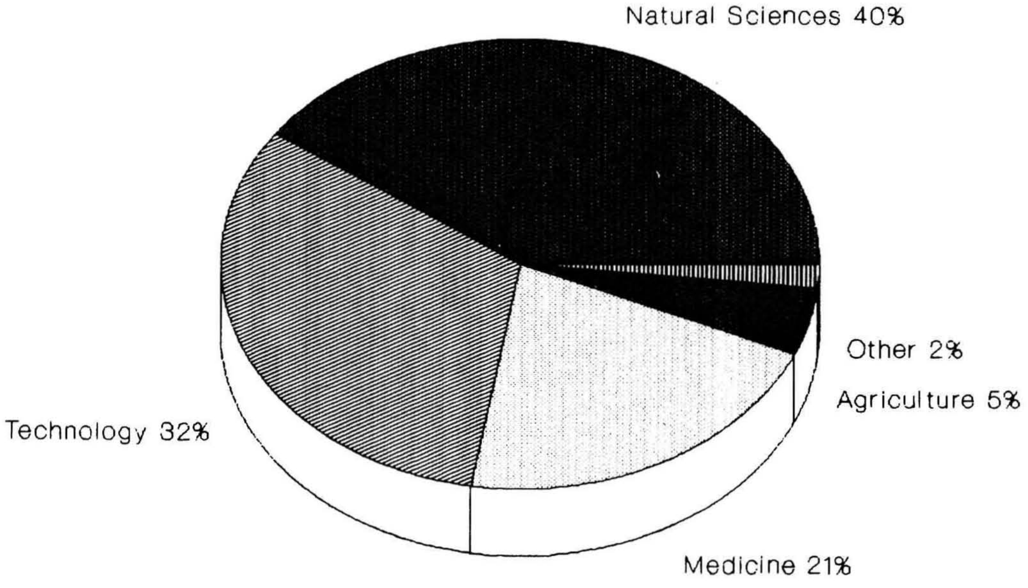


Fig. 2.

ets (Fig. 5). The distribution shows a continuum, with a substantial share - 25% - in the lowest bracket (0.1-0.5 Mill. SEK).

The age distribution of the total available equipment within the different sectors indicated that the average rate of replacement has been relatively slow; about 30% of the equipment was still in use after 10 years (Figs. 3 and 4).

The Funding of Expensive Equipment and Big Science

The costs for research equipment at universities and related research institutes have been rapidly increasing. In some research areas such costs have made it impossible for Sweden to set up independent national research units (e.g., for high energy physics). In other areas, we have only been able to sustain activities at a rather low level (e.g., oceanography).

The main funding sources for research equipment in the 1980s have been the Swedish Council for Planning and Coordination of Research, the other research councils, the universities, industry (to some extent), private foundations, banks and other sponsors.

Private funds have been very important, particularly during the last three years, e.g., the Knut and Alice Wallenberg Foundation allocates about 100 Mill. SEK per year for science. In 1987, the Swedish banks entered an agreement with the government whereby they would donate 600 Mill. SEK for scientific equipment, over a three year period. However, with the decrease in bank donations, the accent has shifted back to public funding. The level of public support channeled through the Swedish Council for Planning and Coordination of Research more than doubled in 1990. In 1987-1989 the annual funds for expensive equipment totaled 103 Mill. SEK. This total increased to 223 Mill. SEK for 1990/91. A further increase - to 253 Mill. SEK has been approved for 1992/93.

The distribution of grants for expensive equipment is handled by the Swedish Council for Planning and Coordination of Research (FRN), in

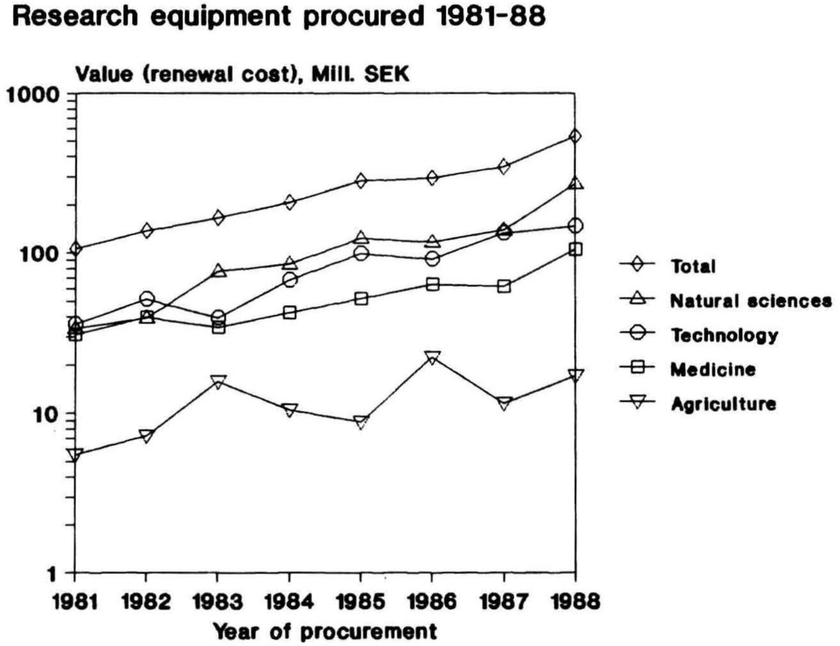


Fig. 3.

close cooperation, both with other research councils (for natural science, medicine, agriculture and engineering) and with similar research funding institutions (Fig. 1). These research councils are represented in the Committee for Expensive Equipment, which advises the council in these matters.

Applications for equipment funding, submitted to FRN by researchers, are reviewed and prioritized by the relevant individual council(s) or authority(ies). On the basis their advice, a final list is negotiated at the annual Committee meeting and a joint funding proposal is submitted to the Council.

The actual procurement of allocated equipment is handled by a separate authority (or sometimes by the researchers themselves when convenient). Big science equipment is, in principle, handled in the same way as the funding of less expensive equipment. As the building of a big accelerator or telescope is spread over a long period of time, the contribution is made available in annual installments.

This system, unique in Europe, has proven very satisfactory; allowing both flexibility and necessary long-term planning, while keeping the important investment decisions at the level of the research councils. The collaboration between the research councils facilitates long term changes in funding allocation; e.g., the social sciences and humanities have received increased support in relation to other fields because of their increasing need for computers. It also provides the possibility to balance the needs of big and small science.

Another useful aspect of this system is that a large investment can be handled without going through the time consuming administrative process at the governmental level. Concomitantly, the fact that Parliamentary allocations are made on a three year basis facilitates planning for several years in advance, and also provides research groups two to three year contracts as needed.

The most important advantage of this system is, however, that it permits cooperation between

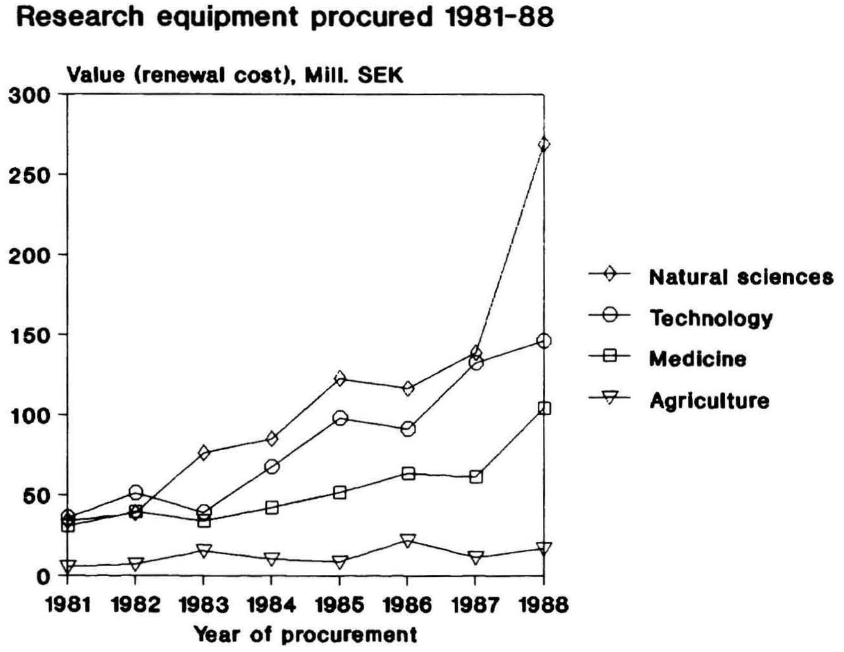


Fig. 4.

the different research councils. Research areas bridging two or more councils (and other public funding bodies) can be funded. One example is the large investment for material sciences which is currently being determined. This involved a joint initiative of the Board of Technical Development (STU) and the Natural Science Research Council. As the principal research councils are represented in the committee handling the proposal for funding distribution, it is easy to reach agreement on issues of common concern.

Participation in Big Science International Cooperation

Participation in international research work has been extremely important for Sweden, and its importance will continue to grow. As Sweden is a small country, our only possibility to uphold high levels of scientific competence and to participate in a wide range of research fields is through international collaboration. Outlined below are a few examples of international collaboration in natural science (excluding technological, medical and social science).

In physics, the traditions of international research date back to the 1950s, beginning with CERN. Currently, Sweden participates in DELPHI (one of the LEP detectors), experiments with heavy ions at the SPS, and works with the LEAR. There is also collaboration with HERA, in Hamburg. Collaboration is requisite, as there are no facilities for high energy particle physics in Sweden.

Although we have our own facilities in nuclear physics (CELSIUS at Uppsala), there is still a need for collaboration within the Nordic project NORDBALL at Risö, Denmark. NORDBALL is a detector system which was put into operation in 1988, and which makes possible studies of very unstable nuclei. Swedish research groups also participate at the isotope separator ISOLDE 3 at CERN.

Research with syncrotron light and neutrons is

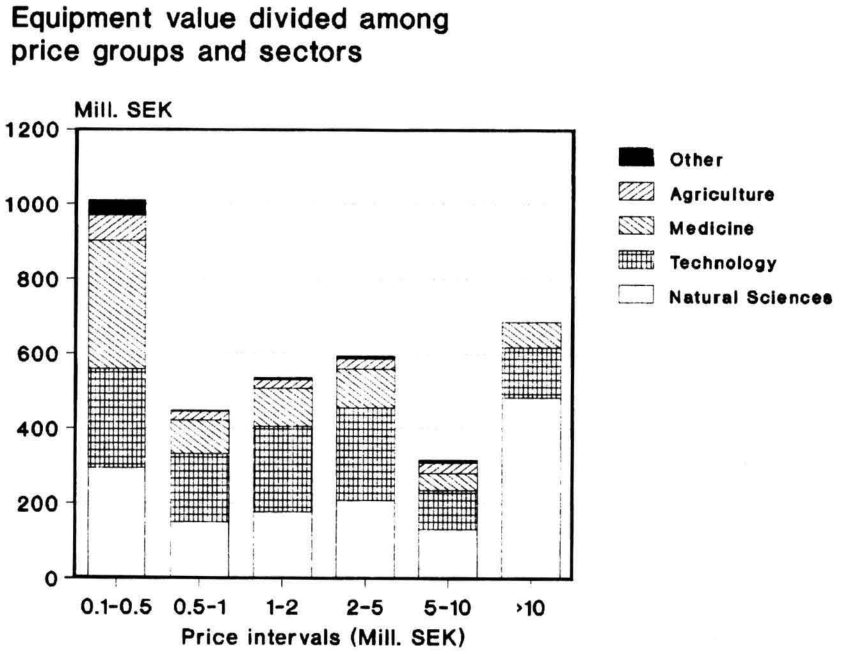


Fig. 5.

done at the national establishments in Lund and Studsvik. These plants are the home base for the heavier work done at ESFR, Grenoble, and at the neutron source (ISIS) of the Rutherford Appleton Laboratory in Great Britain.

Experimental fusion research in Stockholm is a part of the European fusion research programme, JET. Also collaborating are research groups from Gothenburg, Studsvik, Uppsala and Lund.

The dominant working mode for Swedish astronomers is international collaboration. Sweden is an active member of the ESO Observatory in Chile, and has been responsible for the building of the Sub-millimetre telescope (SEST). Sweden is also a member of the Nordic Observatory at La Palma in the Canary Islands.

International collaboration is vital for the geological sciences. Sweden participates in ILP (International Lithosphere Project), the International Geological Correlation Programme (IGCP), the Ocean Drilling Program (ODP), the International Geosphere Biosphere Programme (IGBP), and the Global Geoscience Transects (GGT). The IGCP (Global Change) has its secretariat in Sweden.

Sweden is also a member of the European Molecular Biology Laboratory, EMBL. Swedish participation is currently rather passive in this field, with weaker links to Swedish research groups in molecular chemistry than in some of the programmes mentioned above. Swedish chemistry is also carried out at installations at Daresbury and Hamburg.

The cost for contributing to international programmes is 126 Mill. SEK for CERN (1990), 16 Mill. SEK for ESO, 7 Mill. SEK for EMBL, 9 Mill. SEK for ESRF, and 54 Mill. SEK for JET (via EC direct). The annual total of these contributions is 212 Mill. SEK. This figure can be compared with the total annual budget of the Natural Science Research Council, which was 387 Mill. SEK in 1990.

It is vital for Swedish research that we continue to participate in international science collaboration. Such collaboration must involve active participation if it is to be of full benefit to us and our partners. We need to parallel the research work at home with that done internationally. Ideally, such work should have both a theoretical and an experimental character.

NOTES

1. Hagwall, Kerstin; *Forskningsutrustning inom universitet och högskolor,* FRN, 1989.
2. While the response rate was very good (95%) - with most of the institutions responding, the data may be unreliable to some extent. Equipment in the lowest price brackets is probably under-reported, having - to some extent, been overlooked in institutions with a high proportion of very expensive equipment. Nevertheless, we think that the results are sufficiently satisfactory for planning and policy analysis.

A. van der Woude

AGOR, a Case of Little Big Science

Introduction

AGOR is an acronym for a project designed to build and exploit a new accelerator for fundamental research in Nuclear Physics. It is a collaboration between the Kernfysisch Versneller Instituut (KVI) of the University of Groningen in the Netherlands and the Institut de Physique Nuclaire (IPN) at Orsay, France. The total budget is approximately 48 Mfl (23 M$), which - while a large amount for an university institute, is minimal when compared to that which is customary for laboratories at e.g., CERN in Geneva or the various national laboratories in the U.S. As a consequence, the project can be relegated to the category of little 'Big Science'. Nevertheless, small as it may be, it has had - and continues to have, a profound effect on the KVI and on the entire community of nuclear physicists in the Netherlands.

Various aspects of the project might well be of a more general interest; e.g., the way it was started and approved, how it is managed, and what it implies for the scientists.

The AGOR Project

The Partners

The KVI, although it is an institute of the university of Groningen, is in reality a joint institute of the university of Groningen and the Dutch Organisation of Fundamental Research in Physics, FOM. It was founded in 1965. It has a total annual budget of ca. 9 Mfl which includes the salaries of about 40 academicians (including graduate students and visitors) and ca. 40 technical and administrative employees. Its main facility is a conventional cyclotron which was built by the Philips Company in the Netherlands and which came into operation in 1972. The other partner in this collaboration, the IPN at Orsay, is a much larger institute founded by the famous couple Joliot-Curie in the 1950's. In addition to the scientific staff, it supports a large and highly qualified technical staff with experience in constructing large-scale equipment. It is part of IN2P3, the national French organisation for research in elementary particle and nuclear physics. In the Netherlands, nuclear physics is concentrated in two national institutes: the KVI in Groningen and NIKHEF in Amsterdam. Sizeable groups from the Free University in Amsterdam and the University of Utrecht also use these facilities. The national research in nuclear physics is coordinated by a working group from FOM, comprised of senior nuclear physicists from the various institutes and universities.

How AGOR Got Started

Nuclear physics in the Netherlands has been evaluated by a panel of foreign, internationally well known experts in nuclear physics on several occasions. The 1982/83 panel was delegated to evaluate past performance and to develop plans for the future. At that time, while the KVI had no specific plans, NIKHEF was preparing to submit a proposal requesting an addition to their, rather new, existing machine, which had just become operational. Because the NIKHEF plan was strongly supported by the panel, the Dutch nuclear physics community urged the KVI to immediately submit their prospective plan in order that both plans could be simultaneously evaluated for funding.

The KVI opted to replace the old cyclotron with a new, more powerful one in which the newest developments in the field of superconductivity and high power, high frequency technology would be used. The following considerations led to this decision:

- The proposed accelerator is in keeping with the tendency in nuclear physics to develop larger accelerators which produce more extreme - and new variations of nuclei and nuclear matter.
- The new facility had to be of a size and complexity which could be exploited by an institute having a modest budget and limited staff.
- A university institute should have an in-house facility of moderate size for training graduate students.

An alternative to this would be the formation of visiting groups which would work at larger accelerator locations, e.g., at CERN. The latter approach has the advantage that it guarantees an intensive contact with the international physics community while leaving the physicist - at least in principle - free to select the facility best suited to his/her research interests. The major disadvantage is that it is less effective in training students; the size and complexity of experiments at such facilities makes it very difficult for one individual to understand all aspects of an experiment an essential feature of the educational process. Moreover, the home institute is unattractive for visiting researchers, who prefer to be where the actual experiment is being conducted.

Since the type of accelerator required was not commercially available, our own staff would have had to construct it. The size of our staff was insufficient to perform such a task. We were in a stalemate situation, particularly as we had a short term decision to make.

We were not aware of the fact that similar discussions had been going on for some time at the IPN at Orsay, resulting in a rather detailed proposal for a machine very similar to the one we wanted. By 1984 it had become clear that, although the technical manpower necessary for such a project was available, the funds necessary for construction could not be obtained in France. As a result, there was also a stalemate situation at IPN.

During this time, one of our staff members happened to visit the IPN and mention our dilemma. Subsequent discussions between our two institutions resulted in a joining of forces in order to construct the required machine. The details of a formal proposal were worked out by the respective laboratories. The main points outlined in this proposal were:

- The two institutes, KVI and IPN, would collaborate in the construction of a cyclotron in which the newest technologies were to be incorporated.
- The Dutch partner would provide the funds necessary for construction, while the French partner would provide the bulk of the required manpower.
- The machine would be constructed and tested at the IPN and, after completion, would be moved to the KVI. It will be available to French physicists for their research free of charge.

A total of 45 Mfl was requested by the KVI. Of this total, 33 Mfl was for the construction of the machine; the remainder was to be used for adapting the institutional infrastructure to the new machine.

How AGOR Was Approved

The nuclear physics community now had the task of making a recommendation to FOM (the funding agency) about the two proposals; the KVIIPN proposal for ≅ fl 45 M and the NIKHEF proposal for ≅ fl 20 M. Both proposals were scientifically sound.

An important question was whether the limited annual running budget would permit the satisfactory exploitation of both facilities; it was clear that by recommending only one of the proposals for funding, the other would have only a minimal chance of future funding. In the long run, the result would be the closing of that institute. The decision clearly involved more than simply judging the scientific merits of the two proposals, which implied that the anticipated annual budgets had to be compared to the estimated requisite budgets.

Not surprisingly, the nuclear physics community recommended both projects be funded. The governing board of FOM then had to make a decision. At that point in time it was clear that the requisite extra funding could be obtained from the Govenement if requested. The only remaining question was whether it was reasonable to request ≅ fl 65 M for a single sub-discipline of physics, i.e., nuclear physics.

Undoubtedly, some of the policy-makers responsible for the whole of physics/science questioned the wisdom of maintaining both facilities; closing one facilty would concentrate nuclear physics in a single institute. This would be in keeping with the predicted decrease of 10-20% in the annual budget allotted to nuclear physics in the coming years. Moreover, approving both projects would imply a long range commitment of supporting nuclear physics at the requisite level.

In this same period a committee report was published in which all government supported research in physics was evaluated. In this report it was recommended that the KVI proposal be honoured, and a decision on the NIKHEF proposal be postponed for an additional year and a half. This recommendation was based upon the good scientific record of the KVI facility, whereas NIKHEF was, relatively speaking, operating a new one and still had to develop a track record. This recommendation generated considerable discussion. The major concern at NIKHEF was that it seriously diminished its chances for obtaining the necessary funding. The committee had also suggested that the level of funding for nuclear physics - relative to other physics sub-disciplines should, at best, remain constant; preferably decreasing to some extent. This again raised the question of whether the total annual budget for nuclear physics would be sufficient to run both facilities efficiently.

It took the community half a year to decide to go ahead with the AGOR project, and to simultaneously push for the NIKHEF project. Soon thereafter government funding was made available and the AGOR project could begin.

The NIKHEF proposal was honoured at a slightly later date, on the recommendation of another advisory committee, comprising foreign experts.

The result of approximately two years intensive discussions was the funding of two relatively large-scale projects in nuclear physics. This, in itself, is remarkable given the recommendation of the government evaluation committee that the overall support for this branch of physics should decrease in favour of other new activities. Moreover, of the total funding available over a five year period for investment in large equipment for these two projects, more than half has now already been commited.

Several factors contributed to this course of events.

- It was necessary to update equipment in order to remain competitive and viable, irrespective of the expected general decrease in the annual budget.
- The good scientific record of the KVI at the time the AGOR project was funded.
- The perceived necessity to plan an upgrading of the existing facility coincided with the view at the governmental level that it was necessary to invest in new, big science equipment.
- The fact that AGOR is an international collaboration was certainly important. It should be noted that this collaboration is a special one in that it started, and remains essentially a relationship between institutes. In this sense, it is an excellent example of a 'bottom-up' initiative.

The Management of AGOR

The two funding agencies - the Dutch FOM and the French IN2P3, signed a contract specifying the parameters of the machine, the total budget and manpower available, and the way the project is to be managed.

The project is governed by a board comprising three French and three Dutch officials. On the French side the three are the director and associate director of IN2P3 and the director of IPN; the Dutch are represented by the chairman of FOM, a representative of the University of Groningen and the director of the KVI. The project is managed by a project team consisting of four persons; a French project manager, a Dutch associate manager, and two engineers (one French and one Dutch) responsible for the technical work. A technical advisory committee of three experts, not directly associated with the project, was established in order that the board can receive an independent technical assesment of the way the project is proceeding. This committee meets twice a year with the project group.

The contract also stipulates the requirement of a design phase during which a detailed specification of the technical design is made. Budget revisions are based on this design. Approval to start would only be given if the project proved technically sound and realizable within the financial limits. The plan outlined above clearly defines the various levels of responsibility, as well as assuring the funding agencies that the time, money, and manpower requirements of the project will not get out of hand. It also provides the framework for viable, working floor collaboration between the French and Dutch engineering staff.

The Current Status of the AGOR Project

The project has now (September, 1989) reached the half-way point. All of the main components have been ordered. The first big components have been delivered and testing has begun. As is the case with any project in which new technologies are being applied, some unexpected problems have been encountered. These have, at least on paper, been solved. These problems did, however, result in a one year delay and an approximate 15% budget overrun. Important here is that the initial approved budget was based on a detailed technical design study which include neither the 15% contingency usual in other countries for projects of this type, nor provisions for inflation related adjustments. This has proven a major problem.

Any project using new technologies which have not to date been extensively applied - as is often the case with big scientific equipment, runs a high risk of increased expense and extended duration. Funding agencies should take this factor into account in project approval and budget allocation. The 15% contingency is a well established rule based on long experience. Inflation related price increases should also be taken into account for any long-term project. The main reason these provisions were not included in the budgetting of this project is quite simply that government policy does not, generally speaking, allow it! Perhaps the project management should have raised all budget estimates by 15% as well as including an estimated inflation correction, without explicitly mentioning this to the funding agency. This was not, however, an adequate solution. It would have forced the project management to make statements which cannot be defended, and undermines the specific responsibility of the funding agency. The only sound solution is that funding and/or government agencies allow for a contingency, make provisions for inflation corrections, and realise that time schedules may, of necessity, be exceeded.

The Effect of AGOR on the KVI

An overall budget of about fl 48 M qualifies the AGOR project as 'small' Big Science; for the KVI, however, with an annual budget of about 9 Mfl, it is a very large and risky undertaking. The ≅ 5 ratio of project/annual budget indicates the level of the risk and potential consequences.

Additionally, the long term scientific commitment requisite to this project has far-reaching implications for both the institute and its staff. The duration of this project has been estimated at 10 years. The useful scientific life of the ensuing facility is also estimated at approximately 10 years. Thus, proposing a new facility involves a 20 year commitment! A rather unrealistic situation, given the rapid development of an active research field. This is as applicable to every major big science facility as it is to AGOR. This requires that the proposed facility is either unique, or, as in the case of AGOR, offers a wide range of research possibilities so that it has sufficient built-in flexibility to adjust the research program as needed. The style of research of individuals will be effected by using the increasingly complex equipment associated with large facilities. Research at such facilities can only be conducted by a team of collaborators. The individual scientist having his/her own ideas about the how to conduct research will be replaced by a team of specialists who together determine the scientific goals at hand. This trend to teamwork is a general feature of research at big facilities; the larger the facility the bigger the team. It is even more true in high-energy physics, where teams made up of a hundred scientists are not exceptional.

Also contributing to the change in the style of research has been the establishment of special programme committees to evaluate proposed experiments, thereby guaranteeing optimum use of the facility. Such committees consist of qualified scientists from various countries. Peer review of research proposals can be quite useful in that it forces the proponents to carefully consider, in advance, all facets of the experiment. It can also be dangerous, however, in that an unusual, imaginative and daring new idea might be rejected because it falls outside established lines of research. Moreover, 'politics' can sometime play an important role in the advice given by such committees.

The tendency to bigger facilities with larger teams poses a problem for university associated research institutes such as the KVI. A primary task of such institutes is to educate graduate students. In our present facility we can perform good research at a level of complexity which permits graduate students to take full responsibility for their experiments. We believe this to be an essential feature in the education of students, as well as being a source of inspiration and satisfaction. While this will become more difficult with the AGOR project, we feel that the degree of complexity will yet permit graduate students to understand all of the essential features of the equipment they are using. The AGOR facility will have sufficient new features to perform front-line research. Although the complexity will require more teamwork, it will still be possible for an individual to understand the entire experiment. In our estimation this project strikes a good balance between front-line big science research, and small science research suitable for university education.

Future Developments

The AGOR project was generated by the need for a larger, more powerful in-house facility requisite to performing front-line research. A considerable amount of money and manpower had to be invested in order to realise this project. In fact, the project would not have materialised except for the generous support of our French partner. The annual budget needed to exploit the facility is considerable. The fact that NIKHEF - the other nuclear physics insitute in the Netherlands, has an annual budget of approximately twice that of the KVI, demonstrates that nuclear physics certainly gets its fair share of the total budget for research in the Netherlands. It would be unrealistic to expect either a substantial increase in the annual budget, or another investment involving an even larger amount of money. On the other hand, future research will increasingly demand complex and, by extension, expensive equipment; a situation common to all western European countries.

These developments have resulted in the recent initiative to coordinate nuclear physics research activities in western Europe. Implicit here is that established and new facilities should be exploited on an international scale in order to increase efficiency. Approximately ten such facilities will be available in western Europe. Each will be open to all qualified researchers and will have available the necessary guest facilties. An international programme committee will determine access to these facilities. This network of modern facilities will enable nuclear physics in western Europe to make important contributions to further development of the field. Such a western European collaboration may even facilitiate funding of an even larger research facility in the future, should the need arise.

Lothar Krempel

Big Science and the State in Germany: Networks in the 'IRON CAGE'

Change and Isomorphism of Organizations

Various organizational forms have evolved in the German science sector. In order to ensure high productivity, portions of the German science system has experienced formal organizational independence. In the case of the subsector of big science centres, independence was introduced to promote a balanced influence of state, research and industry.

The objective of research policy is to solve tomorrow's problems today. This involves two successive steps: anticipating the right problems, and generating results designed to solve these problems. While the former is the question of *what to study*, the second is the question of *how to study*. The discussion of both questions has always been accompanied by questions of organization. In this context, the big science system is characterized by the fact that the question *what to study* is decided on the governmental level, while *how to study* falls mainly within the realm of responsibility of the research organizations.

There are two lines of theoretical arguments and empirical results which add to our understanding of the relationship between government and Big Science Centres in Germany. Strong interorganizational dependencies can foster increased similarity among organizations (*structural isomorphism*). In the absence of clear performance criteria, such organizations are forced to spend considerable effort legitimating themselves according to societal norms and values, whereas the factors of *resource dependence* and organizational density in a given environment are strongly related to the long term development of organizations. Growth or decline of organizations depend on their use of interorganizational relations in coping with resource uncertainties.

What makes the study of the big science system especially interesting is that it is characterized by both driving forces. The establishments in the big science sector (in contrast to the other sectors) receive their institutional funding according to their participation in the various research activities of the Federal Ministry of Research and Technology (BMFT). Because there is considerable overlap in research activities, this funding procedure introduces the element of interorganizational competition for funds into this system.

State-sponsored research organizations differ from commercial organizations in various ways:

- Financial supply as input is controlled, more or less monopolistically, by government agencies acting as owners of research organizations.
- Criteria of organizational success are less evident than in market settings. Evaluation of scientific efficiency is vague. Peer evaluation among scientists is a frequently used substitute for other indicators.
- Instead of market success of goods from commercial organizations, scientific results of these institutions must meet government determined standards and procedures. The evaluation of their efficiency is a highly intervowen process of interorganizational and scientific relations in the research sector.

In this article an attempt is made to understand the inherent tendencies of the big science sector; analyzing how organizational growth is related to governmental control as mediated by the internal structure of the research sector (see Figure 1).

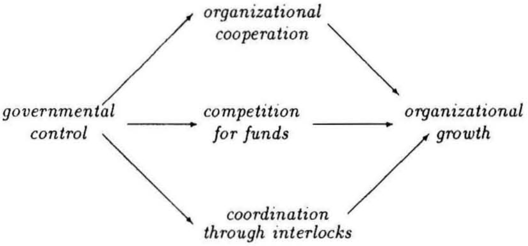


Fig. 1. Structural Covariates of Organizational Growth

Advances in the methodology of studying social structures, together with accessable information about research organizations, their environment and interlocks, are a good starting point for a detailed analysis of the input dependencies of such a system. It may also help to reveal how organizational change occurs in such systems.

While the immediate aim is to understand some of the mechanisms and consequences of government activities in the system under study, the general interest is to fill the gap, on an empirical level, between two lines of ecological organization theory on an empirical level; although this still only draws a coarse picture of organizational development.

To understand change we must take into account the input dependencies of the system, organizational competition and cooperation among the organizations, as well as other sources of coordination external and internal to the environment.

In the following sections an overview is given of the institutional design of the German science system as an outer system to the subsector of Big Science Centers. Subsequently, an analysis will be made of the various structures of this system and their development and dependencies through time. Finally, a multivariate analysis is made, modeling organizational growth over a period of ten years, and evaluating the competing explanatory power of our structural explanations.

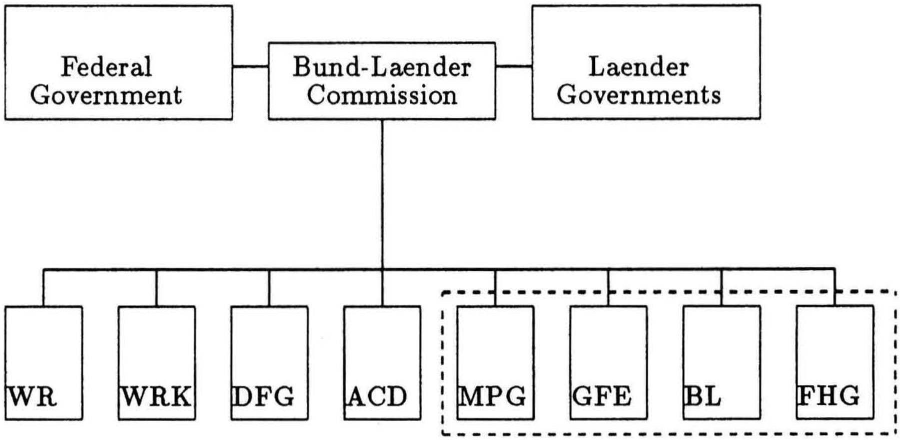
The Outer System: Big Science Centers and Government sponsored Research in Germany

Science promotion in Germany falls within both the responsibility of the Federal Government (Federal Ministry of Research and Technology, Federal Ministry of Education and Science) and the Länder governments. While each has its own research establishments (Bundesforschungsanstalten, Landesforschungsanstalten), all major science organizations fall under the joint responsibility of the federal and the Länder governments. In this respect the *Bund-Länder Commission* (BLK) plays an important role. Of central interest here are four groups of research organizations (dashed box): the Max Planck Society (MPG) conducting basic research, the Big Science Centers (GFE) implementing large-scale technological projects, the Fraunhofer Society (FHG) doing applied industrial research and the Bund-Länder Research Establishments (BL); a group of 48 research institutions with more than regional significance - the so called 'Blue List'.

As is shown in figure 2, there are 8 institutions which report to the 'Bund-Länder' Commission. Two committees are involved in planning for the future: the Science Council (Wissenschaftsrat), the 'West German Conference of University Rectors' (WRK). The German Research Association (DFG) provides project funding mainly for universities. Four large groups of organizations carry out research: the Max Planck Society (MPG), the Big Science Establishments (GFE), the Bund-Länder Research Establishments (BL), and the Fraunhofer Society (FHG).

Science promotion in the Ministry for Research and Technology is oriented to five main objectives:

- safeguarding material resources;
- maintaining and increasing industrial competitiveness;
- improving living and working conditions;



WR	**Science Council**
WRK	**West German Conference of University Rectors**
DFG	**German Research Association**
ACD	**Academies of Science**

Fig. 2. Research Organization and Science Promotion in the FRG

- modernizing and improving public infrastructure and services;
- basic research.

There are fifteen promotion activities subsumed under these main research objectives; all of which are affected by changing priorities at the ministerial level (see Figure 2.).

Different modes of funding exist for each of the research sectors: the MPG receives a complete institutional funding (50% federal, 50% Länder) with full autonomy concerning research topics in basic research. The FHG, conducting applied industrial research, receives project funding for each research contract established with industrial partners (50% from the federal government). Funding for the GFEs is legitimated according to specific priority programmes of the government (90% federal, 10% from the Land in which the establishment is located). It is based on bilateral negotiations between each organization and the governments involved.

The development of funding the 'outer system' of big science establishments is an important constraint to its development and helps us to understand what happens inside this subsystem. It also shows how central the big science sector is and how important any development in this subsector is for different interest groups.

These developmental trends have to be taken into account when explaining differential growth inside the subsystem on the basis of its internal structure. This, of course, reflects the synchronous conditions of the outer system.

Table 1 shows that approximately 50% of the total institutional funds for the science sector are allocated to big science centres; the remainder is divided between the DFG (20%), MPG (17%), the BL institutes (9%) and FHG (4%).

There is growth (in real terms) in all five subsectors (compared to the inflation rate of (1975-1985 ~ 141%). Looking at the growth of the subsectors indicated in Table 2, we find the strongest growth in the FHG (443%), followed by the BL-Institutes (243%) and then the big science establishments (201%). The distribution of shares held by these organizations is fairly stable over time.

Except for the FHG - which despite its strong growth still gets the smallest share of all, the BL-institutes and the big science establishments yield above average growth. Even though big science already is the largest subsector, it has, nevertheless, managed to increase its share of institutional funding. This illustrates that the internal distribution of funds in the big science sector is far from being a zero-sum situation; there is still room for real organizational growth without internal consequences. The characteristics of the internal organizational environment are thus re-

Shares of institutional funding provided by the federal and Länder governments for five sectors of the publicly sponsored research system over time. (abs): absolute terms in million marks; (share): share of total for the year

	MPG		*FHG*		*GFE*		*BL*		*DFG*		*TOTAL*	
	abs	share	abs	share	abs	share	abs	share	abs	share	TOTAL	growth
1975	459.2	17.92	42.7	1.67	1272.7	49.67	192.8	7.52	595.0	23.22	2562.4	100
1976	489.6	17.93	45.3	1.66	1368.4	50.10	207.3	7.59	620.7	22.73	2731.3	106.59
1977	517.3	18.37	51.8	1.84	1362.9	48.40	235.6	8.37	648.3	23.02	2815.9	109.89
1978	548.3	18.06	54.1	1.78	1486.0	48.94	263.9	8.69	684.3	22.54	3036.6	118.51
1979	..	..	..	..	..	..	..	..	..	..	..	..
1980	..	..	..	..	..	..	..	..	..	..	..	..
1981	687.0	19.43	138.2	3.91	1798.8	50.87	360.0	10.18	552.2	15.62	3536.2	138.00
1982	714.2	19.51	149.9	4.09	1823.7	49.82	395.6	10.81	577.4	15.77	3660.8	142.87
1983	737.0	18.64	165.8	4.19	2025.6	51.24	427.2	10.81	597.4	15.11	3953.0	154.27
1984	..	..	..	..	..	..	..	..	..	..	..	..
1985	787.4	17.59	152.7	3.41	2187.7	48.88	401.4	8.97	946.9	21.15	4476.1	174.68
1986	816.4	17.30	155.1	3.29	2355.4	49.91	432.1	9.16	960.0	20.34	4719.0	184.16
1987	863.4	16.93	189.3	3.71	2555.1	50.11	469.6	9.21	1021.6	20.04	5099.0	198.99

based on: Bundesforschungsbericht 1979, 1984, 1989

Table 1. The Outer System: Shares of Funding (1975-1987)

Growth of institutional funding through the Federal and Laender Governments for five sectors of the public sponsored research system.
(abs): absolute terms, (growth): sectoral growthrates (1975 = 100 %).

	MPG		*FHG*		*GFE*		*BL*		*DFG*		*TOTAL*	
	abs	growth	abs	growth	abs	growth	abs	growth	abs	growth	abs	growth
1975	459.2	100	42.7	100	1272.7	100	192.8	100	595.0	100	2562.4	100
1976	489.6	106.62	45.3	106.09	1368.4	107.52	207.3	107.52	620.7	104.32	2731.3	106.59
1977	517.3	112.65	51.8	121.31	1362.9	107.09	235.6	122.20	648.3	108.96	2815.9	109.89
1978	548.3	119.40	54.1	126.70	1486.0	116.76	263.9	136.88	684.3	115.01	3036.6	118.51
1979	..	..	..	..	..	..	..	..	..	..	..	..
1980	..	..	..	..	..	..	..	..	..	..	..	..
1981	687.0	149.61	138.2	323.65	1798.8	141.34	360.0	186.72	552.2	92.81	3536.2	138.00
1982	714.2	155.53	149.9	351.05	1823.7	143.29	395.6	205.19	577.4	97.04	3660.8	142.87
1983	737.0	160.50	165.8	388.29	2025.6	159.16	427.2	221.58	597.4	100.40	3953	154.27
1984	..	..	..	..	..	..	..	..	..	..	..	..
1985	787.4	171.47	152.7	357.61	2187.7	171.89	401.4	208.20	946.9	159.14	4476.1	174.68
1986	816.4	177.79	155.1	363.23	2355.4	185.07	432.1	224.12	960.0	161.34	4719	184.16
1987	863.4	188.02	189.3	443.33	2555.1	200.76	469.6	243.57	1021.6	171.70	5099	198.99

based on: Bundesforschungsbericht 1979, 1984, 1989

Table 2. The Outer System: Growth in five Sectors (1975-1987)

lated more to the maximization of growth than to organizational survival. For the latter one could expect the organizational environment to be of greater relevance than is reported in the latter sections of this paper.

Big Science Centers

There are twelve organizations in the group of big science establishments. These are listed according to the year in which they were established and their main objectives of research. The number of employees in the years 1975, 1980 and 1985 is also provided. Until the end of the sixties there was some variety in the organizational design of the various big science establishments. In 1968 a general organizational layout for the institutes was proposed:

- To guarantee state influence to ensure control of proper spending of funds;
- encourage cooperation between state, science and industry;
- increase responsibility of the research organizations themselves.

Procedures have been established for more effective monitoring of the in- and output of big science establishments; documented by two official reports of the federal government, in 1984 and 1986. Output control uses mainly peer evaluation of scientists as a tool of efficiency control. A typical organizational layout contains at least three boards in addition to the director of the organization:

- A board of trustees in which half of the seats are usually reserved for the Ministry of Research and Technology and the representatives of the Länder-government. The director of the organization reports to this board.
- A scientific advisory board, made up of external scientists, which reports to the director of the organization. A second scientific committee in which scientists of the organization are represented.

Big Science Centers

There are twelve organizations in the group of Big Science establishments. These are listed according to the year in which they were established and their main objectives of research. The number of employees in the years 1975, 1980 and 1985 is also provided.

Organization	**Main Fields of Research**	**Employees**
1956 Kernforschungszentrum Karlsruhe GmbH **(KfK)** (Karlsruhe Nuclear Research Centre) Postfach 3640, 7500 Karlsruhe 1	**Fast breeders**, separation nozzle process, reprocessing and waste disposal of nuclear fuels, nuclear safety, nuclear safeguards, cryogenic engineering, fusion reactor technologies, data processing and Systems analysis, basic research, nuclear test methods for industrial applications, Operation of test facilities in semitechnical size.	3,214 3,336 3,953
1956 Kernforschungsanlage Jülich GmbH **(KFA)** (Jülich Nuclear Research Establishment) Postfach 1913, 5170	**High temperature reactors**, reprocessing, process heat, fusion reactor technologies, plasma physics, solid state research, materials research, basic nuclear research, life sciences, environmental protection and safety research.	3,379 3,497 4,575
1956 GKSS-Forschungszentrum Geesthacht GmbH **(GKSS** Research Centre) Postfach 1160, 2054 Geesthacht-Tesperhude	Desalination and sea water chemistry, ocean technology and environmental research. **Nuclear ship propulsion systems**, engineering materials technology, reactor safety research.	585 593 731
1957 Hahn-Meitner Institut für Kernforschung Berlin GmbH **(HMI)** (Hahn Meitner Institute of Nuclear Research) Glienicker Str. 100, 1000 Berlin 39	**Nuclear, atomic and heavy ion physics,** radiation chemistry and photo chemistry, solid state research, problems of materials in various technological applications, bio-medicine, geochemistry, computer networks and process control applications.	485 496 730
1959 Deutsches Elektronen-Synchrotron **(DESY)** (German Electron Synchrotron) Notkestr. 85, 2000 Hamburg 52	Basic research in subnuclear physics **(elementary particle physics)** by means of an electron accelerator and storage rings. Use of synchrotron radiation in solid state physics and molecular biology. Problems of handling vast amounts of computer data and pattern recognition.	1,041 1,046 1,228
1960 Max-Planck-Institut für Plasmaphysik **(IPP)** (Max Plack Institute	Experimental pasma physics, production heating and confinement of plasma, surface physics, plasma theories, magnetic fields techniques and determination, fusion reactor technology, Systems analysis,	916 915

for Plasmaphysics) 8046 Garching bei München	dataprocessing.	1,050
1960 Gesellschaft f. Strahlen- und Umweltforschungs mbH **(GSF)** (Radiation and Environmental Research Corporation) Ingolstädter Landstr.1, 8042 Neuherberg, Post Oberschleissheim	Environmental research, health prophylaxis development of new technologies in biomedicine, data processing in medicine, **final disposal of radioactive wastes.**	1,179 1,154 1,509
1964 Deutsches Krebsforschungszentrum **(DKFZ)** (German Cancer Res.Centre) Im Neuenheimer Feld 280 6900 Heidelberg	**Cancerogenic factors and environmental carcinogens, mechanisms of cancer genesis,** diagnosis and early diagnosis of cancer diseases, therapy of cancer diseases, biological research on tumor therapy.	754 711 1,170
1968 Gesellschaft für Mathematik und Datenverarbeitung mbh **(GMD)** (Mathematics and Data Processing Research Corporation) Schloss Birlinghoven Postfach 1240, 5205 St. Augustin 1, formerly: 1962: DRZ, Darmstadt	Application-oriented basic research as well as **applied R&D in information technology for** organizations, mainly in the public sector (planning, administration and jurisdiction); analysis and prognostics of technological developments and trends in applications of information technology; research into socioeconomic effects of dp-applications; promotion of standardisation in information technology; socioeconomic models.	611 608 781
1969 Deutsche Forschungs- und Versuchsanstalt für Raumfahrt e.V. (DFVLR) (German Aerospace Res. and Testing Institute) Linder Hhe 5000 Köln 90 (Köln-Porz) formerly: 1907: AV Berlin, 1912: DVL Berlin, 1936: DFL Braunschweig	**Aeronautical and space technology, transport and communications systems.** Remote sensing technology. Energy technology and other advanced technologies. Operation of major test and operations facilities for aeronautical and space technology. Project management.	3,228 3,162 3,694
1969 Gesellschaft für Schwerionenforschung mbH **(GSI)** (Heavy Ion Research Corporation) Postfach 541, 6100 Darmstadt 1	**Research on heavy ions in nuclear physics,** atomic physics, nuclear chemistry, solid state research, radiation biology by means of heavy-ion accelerator UNILAC.	448 458 535

1976 Gesellschaft für Biotechnologische Forschung mbH (**GBF**) (Institute for Biotechnological Research) Mascherode Weg 1 3300 Braunschweig-Stockheim. formerly: 1968: BMBF	**Basic research and development in biotechnology** by means of microorganisms, plant and animal cellular cultures and enzyme Systems, development of new technologies for obtaining basic materials for pharmaceutical, chemical and food products.	210 249 390
	Total	16,207

Based on: Geimer & Geimer (1981),[1] Bundesforschungsbericht 1979, 1984, 1989.

Data

In our study (Krempel, 1989) we discuss the way in which governmental control, competition for funds and organizational cooperation can be measured. Consideration is also given to methodological alternatives to derive interlocks among big science establishments.

The structure of the science administration in the Ministry of Research and Technology allows us to quantify the limits of political control. The amount of actual funding, based on the promotion activities of the ministry, gives us information about competition between the different research establishments for programme funds. The structure of the interlocks between the boards of big science organizations and their links to other organizations in the science and industrial sector are based on reports of those establishments listing individual board members. Each of the big science establishments can thus be characterized according to four structural positions: the potential for control by the Ministry, the amount of competition it faces for programme funding, the position in the interlock structure of the boards of big science as well as its position in the joint cooperation structure.

In the following, a more detailed analysis is given of changes on the basis of complete structures. This shifts the focus to the systems level of big science.

Organizational Control in the Ministry

There is an overall long-term trend to relax interdependent responsibility for individual GFE's. Government decisions concerning a specific research institution are becoming less interdependent. This is consistent with the shift to restrict administrative activities to the principle of global guidance (Globalsteuerung), and to direct only the general orientation of research (see Table 3).

The most significant change happened to those institutions working on nuclear energy: their relative positions in the rank order of governmental control have increased over time. Change in organizational design of the Ministry for Research and Technology has deminished governmental coordination for the GSI, HMI and DESY. These three organizations, working on nuclear particles and operating various kinds of accelerators, function partly as service organizations to university research. Relatively little coordination affects either the DFVLR, which works on traffic and aerospace, or the GMD, which conducts research activities on computer science.

Funds and Competition

Two large, older nuclear energy establishments - the KFA and KFK, conduct research in many areas and face the highest competition; which has increased over time (see Table 4). This indicates that both are generalist, whereas the GMD and DFVLR get almost exclusive funds in their respective domains. A special case is the GKSS, formerly working mainly on nuclear ship-propulsion systems. When this programme ended, the organization had to generate a new orientation; in the context of already crowded budget allocations.

Although rank ordering has remained remarkably stable over time, there is consistent upward mobility in the competition rank order for the GSF and DKFZ. These organizations work, respectively, in nuclear safety and cancer research,

Governmental coordination for different Big Science Establishments.
(high numeric values indicate low coordination)

Rank	1975		1980		1985	
1	HMI	21	GBF	26	GSF	30
2	GSI	21	KFA	30	KFA	30
3	GBF	21	IPP	30	IPP	30
4	DESY	21	GKS	30	GKS	30
5	DKFZ	21	KFK	30	KFK	30
6	GSF	21	GSF	30	GBF	32
7	KFK	23	HMI	38	GSI	36
8	IPP	23	DFV	38	HMI	38
9	GKS	23	DESY	38	DESY	38
10	KFA	23	DKFZ	39	GMD	42
11	GMD	44	GMD	42	DKFZ	42
12	DFV	44	GSI	42	DFV	44

Table 3. Governmental Control 1975-1985

Competition for funds by different Big Science Establishments. Based on the competition matrix, aggregated for the different establishments, rank ordered.

Rank	1975		1980		1985	
1	KFA	3.27	KFA	3.70	KFA	3.94
2	KFK	2.35	KFK	2.77	KFK	3.07
3	IPP	2.28	IPP	2.62	GSF	2.94
4	HMI	2.12	GSF	2.50	HMI	2.72
5	GSF	1.86	HMI	2.35	DKFZ	2.57
6	GSI	1.78	DKFZ	2.00	GBF	2.57
7	GBF	1.70	GBF	2.00	IPP	2.41
8	DKFZ	1.69	GSI	1.83	GSI	2.32
9	DESY	1.67	DESY	1.76	DESY	2.10
10	GKSS	0.68	GKSS	1.57	GKSS	2.00
11	GMD	-0.30	GMD	-0.67	GMD	-0.99
12	DFVLR	-1.00	DFVLR	-1.43	DFVLR	-1.67

Table 4. Competition for Funds 1975-1985

both of which are domains of increasing research activities by other establishments.

There is a general tendency toward a consistent spread over the entire scale in the long term. While competition sharpens at the upper end of the scale, it decreases at the lower end.

Cooperation

In the cooperation structure of 1985 (see Table 5) the GMD, working in computer science, played a central role. Biotechnological research (GBF), plasma physics (IPP) and aerospace (DFVLR), which follow in subsequent ranks show relatively little participation in the overall activities. They reduced their participation, restricting it to work groups and a computer science project in which almost all of the organizations are interested.

The two big (nuclear energy) generalist organizations are found at the lower end of the rank

Centrality in the projects of the AGF

Rank		1985
1	GMD	5.12
2	GBF	4.74
3	IPP	4.35
4	DFVLR	4.27
5	DESY	3.87
6	GSI	3.18
7	HMI	3.05
8	GSF	3.01
9	DKFZ	2.55
10	KfK	2.49
11	KFA	2.22
12	GKSS	0.82

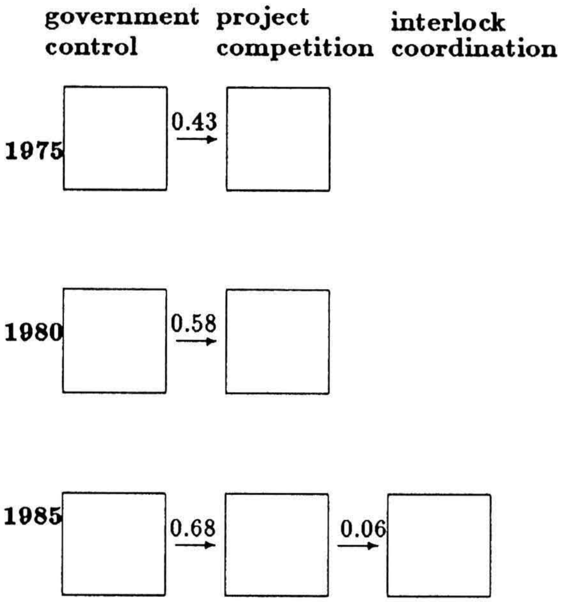
Table 5. Centrality in Cooperation 1985

order. Interestingly, both participate in all of the projects; implying that they are very similar to each other but to no one else.
The GKSS is noteworthy in that it occupies a relatively unique position in the interest structure; in contradistinction to that presented in the competition rank order. If this interest structure is illustrative of the future structure of competition, then the GKSS seems to be on the right track to maneuver itself into less troubled waters.

Formal Dependencies Between Structures in Time

While a look at the rank order of organization-specific statistics is informative about global trends, it is ineffective in tracing more subtle change. Changes in relation to other specific organizations may remain undetected because they cancel out when the structural information is aggregated. Any control or competition affecting only certain types of interorganizational relations may not show up in the rank order. This is dependent upon the degree to which an affected organization can compensate with other types of relational changes relations. Any comparision between the structures of the whole subsector, the goal of which is to characterize the more abstract system level, requires more detailed information. In the following, a shift to the system level is made in the analysis of the cross-sectional influences at certain points in time (see Figure 3). A stability analysis and tracing of crosslagged influences in time may give information about causes and effects (see Figure 5).

There is an increased correlation between government organization at the Ministry of



Cross-sectional isomorphism between government control, project competition and interlocks in executive and advisory boards.

Fig. 3. Cross-sectional dependencies

Stability of governmental control potential, project competition and interlocks in executive and advisory boards.

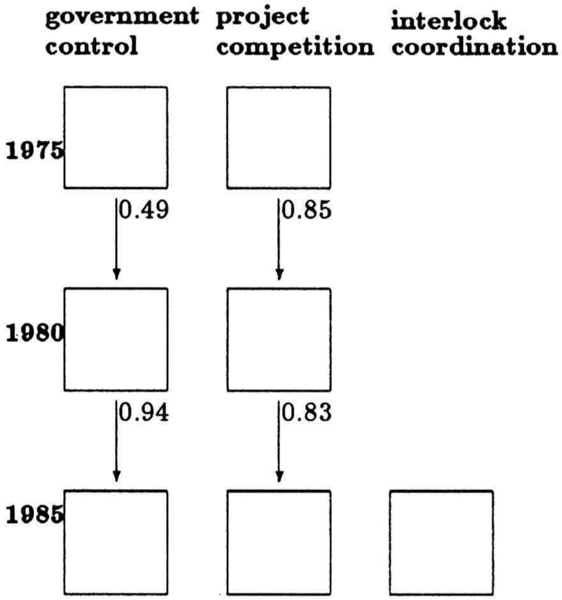


Fig. 4. Stability of Control and Competition

Cross-lagged contingencies between structures of government organization, project funding and interlocks in executive and advisory boards.

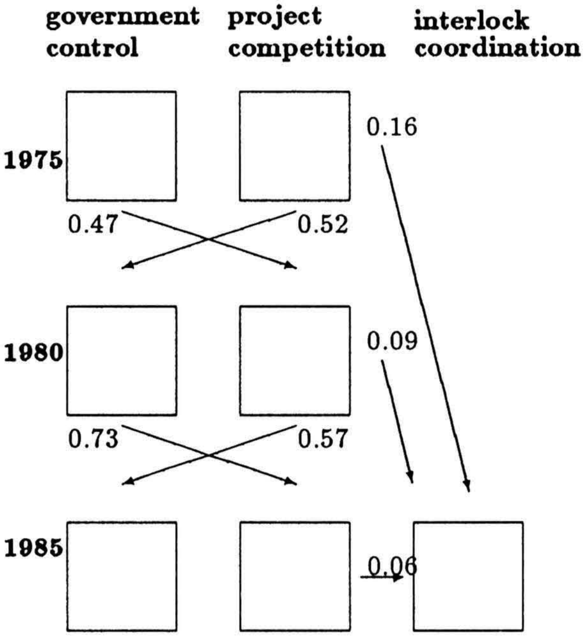


Fig. 5. Cross-Lagged Influences

Research and Technology and the overlap in project funds (competition) received by big science establishments over the long term (1975: 0.43; 1980: 0.58; 1985: 0.68). The similarity between the competition structure and interlocks in the boards of Big Science establishments in 1985 is minimal (see Figures 4 and 5). Interlocks seem to be unrelated to competition among organizations.

The stability coefficients indicate that the governmental control structure changed between 1975 and 1980 (0.49); it has been almost stable since then (0.94). The competition structure for funds is also stable (0.85, 0.83).

While governmental administration of big science has undergone some changes, partly due to political changes in government, this has not created a substantially new situation for the big science establishments.

The cross-lagged correlations show some directed influences over time (see Figure 5). They suggest that there is a small circular influence from the competition structure in 1975 on governmental organization in 1980, which induced change in the competition structure of 1985.

More interesting are the lagged correlations for the interlock and the competition structure. They reveal that interlocks in 1985 are becoming consistently more similar to the older competition structures, especially to competition in 1975 (1985: 0.06; 1980: 0.09; 1975: 0.16)!

A Closer Look

A puzzling result of the preceeding is the lagged similarity of coordination through interlocks with the competition-for-funds matrix: coordination through interlocks is more similar to the pattern of competition in 1975 than to the actual pattern in 1985. Cooptation of board members, when it is based on individual reputation, implies a considerable time lag in the selection and nomination of candidates for the boards of the institutions. This may create serious problems, since the understanding and information basis of such representatives is structurally similar to the old pattern of organizational competition and not necessarily necessarily helpful for today's problems. Though still moderate in size, the result characterizes a gap between political control and institutional coordination through interlocks (see Figure 6). Whether or not this is increasing must be answered on the basis of earlier interlock structures. These have not been completely available until now.

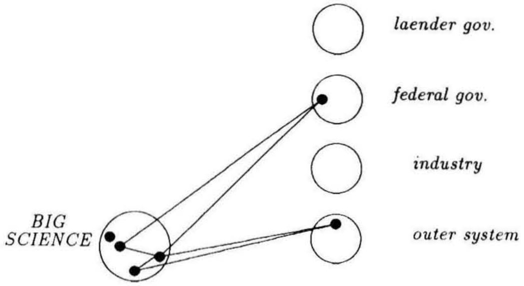


Fig. 6. Decomposition of Interlocks

Since competition for funds in 1975 was exclusively particular to institutes of the nuclear power and particle physics section (compare ranks 1 to 6 in Table 4), the time lag indicates that the response to such competition was a stronger coordination of this group through organizational interlocks.

A look at the competition rank order of 1985 shows that the institutes for cancer research (DKFZ) and biotechnology (GBF) have taken ranks 5 and 6. While this tells us that both were working in increasingly attractive domains, there are obviously no corresponding interlocks on the board level with their competitors.

One of the problems with this interpretation is that the interlock structure is to some extent arbitrary: it contains links created with group of actors (government, outer system, industry and big science), and any individual who links any two establishments in the subsector.

The problem can be solved if we decompose the global interlock structure into a set of matrices which are more informative about who creates interlocks between the big science establishments. In Table 6 only the densities of the resulting matrices are shown, whereby a high density indicates an important degree of coordination from a specific influence group. The results reveal that the largest amount of interlocks is created by government officials holding more

	% of total interlock density
state	*0.530*
laender	*0.045*
industry	*0.030*
science	*0.205*

Table 6. Density of Decomposition Matrices

Institutional funding of the Big Science Establishments. Rank orders in absolute terms (million DM) and of growth rates (1976 = 100 %)

	absolute terms			*growth rates*	
	1976	*1980*	*1985*	$\Delta_{76,80}$	$\Delta_{76,85}$
Rank	**order abs**	**order abs**	**order abs**	**order growth**	**order growth**
1	KFK 245	KFA 315	KFA 381	GBF 2.71	GBF 4.43
2	KFA 224	KFK 288	DFVLR 365	GMD 1.81	GMD 3.23
3	DFVLR 189	DFVLR 264	KfK 347	GSI 1.68	DESY 2.56
4	DESY 94	DESY 143	DESY 241	HMI 1.67	HMI 2.10
5	IPP 68	IPP 86	IPP 121	DESY 1.52	GSI 1.95
6	GSF 62	GSF 78	GSF 113	GKSS 1.49	DFVLR 1.93
7	DKFZ 50	HMI 70	HMI 88	KFA 1.41	GKSS 1.93
8	GKSS 43	GSI 69	GMD 84	DFVLR 1.40	GSF 1.82
9	HMI 42	DKFZ 64	GKSS 83	DKFZ 1.28	IPP 1.78
10	GSI 41	GKSS 64	GSI 80	IPP 1.26	KFA 1.70
11	GMD 26	GMD 47	DKFZ 74	GSF 1.26	DKFZ 1.48
12	GMBF 7	GBF 19	GBF 31	KfK 1.18	KfK 1.42

based on: Programmbudget 1976,1980,1985

Table 7. Rank order: institutional funding GFE

than one seat in research establishments. The science sector is second in importance. Here, interlocks reflect coordination from the 'outer system' of the science system: from universities, the MPG and the FHG. Interlocks created by Länder or industrial representatives are almost exclusively bilateral.

Organizational Growth Over Ten Years

A last step is to analyse the specific explanatory power of the different structures characterizing the organizational environment in the sector of big science establishments. The structural positions of the establishments should be useful for explaining differential organizational growth. The growth rates in funding over the ten-year period between 1975 and 1985 are used as a dependent variable (see Table 7).

The growth rates of big science establishments reveal substantial differences over a ten-year period. As mentioned above, almost all of them have grown in real terms. The highest growth rate is held by the GBF, an organization specialized in biotechnical research. This is followed by GMD, specialized in computer science, and DESY, HMI and GSI, which operate various types of accelerators. At the end of the rank order is DKFZ, the institute for cancer research, and the KFK.

If we look at the absolute amount of funds received, the KFK seems to be the big looser among big science establishments; the biggest in 1976, it dropped to second place in 1980 and third in 1985.

After the GBF became a big science establishment in 1976 (the beginning of the period under study), most of its growth reflected the build up of a new organization.[2]

Modelling Organizational Growth

In the foregoing, we have derived several structures which help to provide a detailed understanding of the big science system. Thus far, the results are fairly consistent with what can be read in and between the lines of official reports. They also draw our attention to the specific meaning of the interlock structure and the potential coordination of that system which may result from it. Proceeding in this direction, we have decomposed the interlock structure to locate the origins of coordination. The final step is to analyze the competing explanations of this system. This analysis will validate our structural information, providing we can show that it explains organizational growth. Our structural explanations are governmental control, competition for funds, cooperation and interlocks among boards of directors.

The explanatory power of the model is quite satisfactory: almost 53% of the differences in the growth rates are 'explained' by this model. There is a strong correspondence between control by the ministry and overall *competition* between the organizations of big science. As we already know, it has consistently increased over time. Organizational control by the ministry reflects a high degree of interorganizational competition for funds, which occurs mainly between those organizations having similar research programmes. The two kinds of organizational interlocks which have been separated are very different. *Coordination by government officials* on the boards of the organizations is almost a complement to governmental control. Coordination is high for those organizations minimally controlled by the Ministry for Research and Technology and low for those which are easily controlled by the ministry. Coordination by members of the science system is neglibibly related to governmental control; indeed, it is slightly negative.

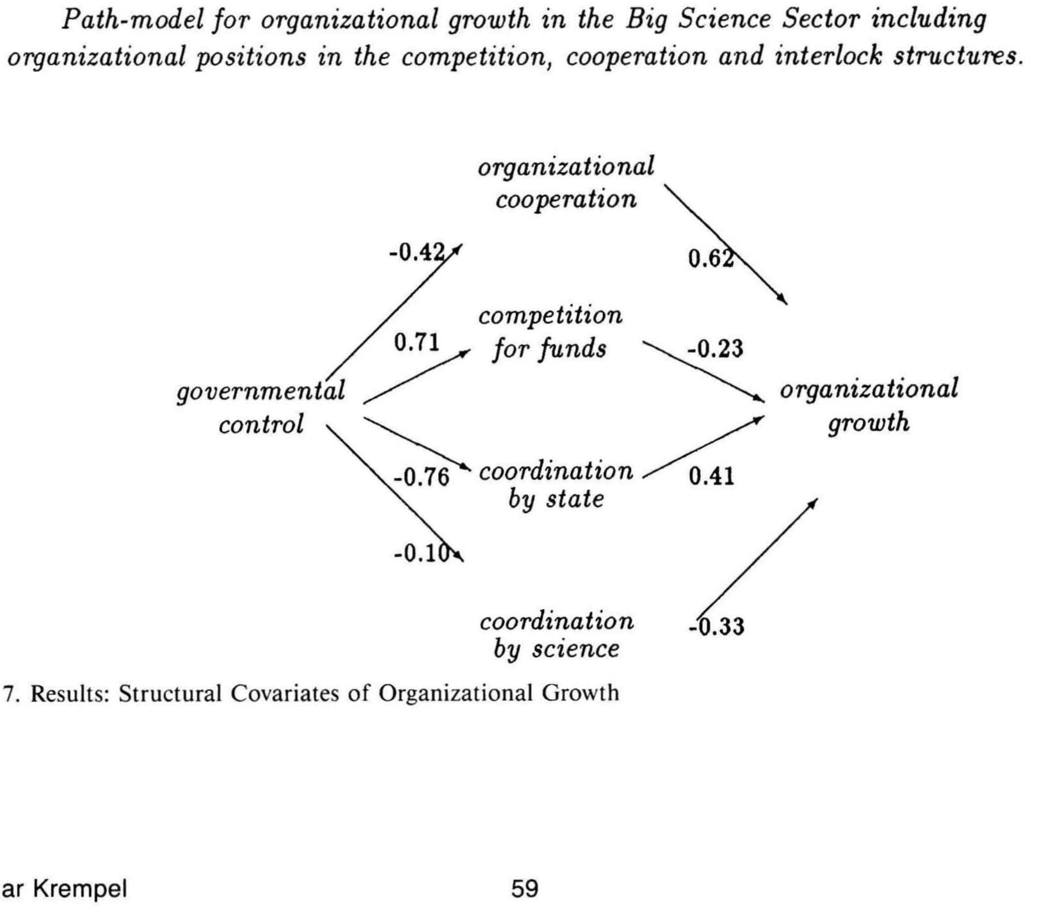
While governmental control and competition for funds are almost synonymous in this system, interlocks and cooperation between organizations capture different environmental aspects. These therefore qualify as potential explanations of growth. Organizational growth is strongly affected by the organizational positions in the various interorganizational structures (see Figure 7).

As expected, interorganizational *competition* reduces growth. The nature of the two interlock structures has different effects on organizational growth. Especially those organizations coordinated by governmental interlocks (on their boards) evidence extensive long term growth; while interlocks from the inner and outer science sector are situated between those organizations with smaller growth rates.

Coordination by governmental representatives in the boards is positive in contrast to control by the ministry. While there is strong statistical evidence for positive coordination, it is still an open question how it occurs. One possibility could be that especially governmental representatives highly experienced in various other organizations - and having an intimate knowledge of the Ministry, are efficient advisors on open slots in the system and good navigators for steering clear of administrative obstacles. Such an explanation is particularly plausible if one takes into account that government representatives who hold seats have high positions in the formal ministerial hierarchy.

Coordination by members of the inner and outer science system is especially found in those areas where organizations show less growth.

The centrality in joint cooperation strongly re-



Path-model for organizational growth in the Big Science Sector including organizational positions in the competition, cooperation and interlock structures.

Fig. 7. Results: Structural Covariates of Organizational Growth

sembles the extent to which organizations have grown over the past decade. Considering that cooperation is a future oriented activity, it is striking how organizational success during the prior decade affected this interest structure. If we speak of negative organizational coordination by the ministry, it can be noted that the future activities which might emerge from the cooperation patterns are positively coordinated. Interests are strongly affected by the amount of funding allocated in the past; the stronger an organization has grown, the more it (and its research domains) is of interest for everyone.

Some of this is statistically explained by the age of the organizations. The notion that age indicates research programmes in an advanced stage, where large investments do not usually occur, is problematic for this study since age, in terms of membership in the big science system, is different from a given organization's real age.[3] While age, to some extent, suggests that thematic growth in the primary organizational programmes has reached equilibrium - and leads us to expect smaller growth rates for older organizations, it also increases the probability that, after a time, the latter will become involved in new programmes. It does not, therefore, add to our understanding of the specific circumstances of growth in this case.

Conclusions

The objective of this paper was to study the interplay between governmental control, competition for funds and interlocks between boards in a system of state sponsored research organizations. Competition for funds and interlocks are two environmental dimensions believed to drive organizational developments. A quantitative study of an organizational system, characterized by both, may help, in part, to fill the theoretical gap between the two diverging developmental trends reported for these influences:

- that of increased similarity (isomorphism) due to environmental pressures by adaptation to societal norms for strongly dependent organizations, and
- that of growth and decline resulting from an organization's ability to use its interorganizational relations to cope with change in its environmental resources.

The results of our empirical data show that growth of Big Science establishments can be explained on the basis of this information, and that organizational interlocks are an important medium for change in this system. The detailed analysis of organizational interlocks reveals that they mediate a different type of governmental influence than is exercised by governmental control; rather, as it is implemented in the formal layout of the Ministry for Research and Technology. Organizations highly coordinated in the government grow more slowly than others; whereas organizations with a high degree of governmental interlocks to other big science establishments grow quickly. While direct control occurs for those organizations which face heavy competition for funds, governmental interlocks between organizational boards occurs mainly between organizations having a relative high degree of autonomy in the competition structure. The results illustrate a sophisticated, two-level system of political control, in which institutional control plays the restrictive part, whereas the less formalized interlocks are related to organizational growth. The more functions governmental representatives have on the boards of other Big Science establishments, and the larger their number (or the larger the number of different departments involved), the greater the growth of an organization.

Interlocks having their origin in the science sector occur less often, and their effect on organizational growth is very different. In the structure of science coordination, organizations which are members of the early starting configuration of the system are linked. Coordination between them relies mainly on individuals of the 'outer system', which may be read as a strategy to import growth by cooperation across system boundaries. There is, however, no specific benefit for organizational growth which can be read from our results, no payoff which could be expected for such a strategy; organizations linked through members of the inner and outer science system show less growth than others.[4]

An evaluation has been made of a specific organizational arrangement of the state-sponsored German research system, into which mechanisms of organizational competition for funds and formal organizational independence have been introduced. It has been questioned whether this introduces flexibility and change into the system. A special feature of this system is the fact that governmental organization and competition for funds are highly isomorphic. Viewing this finding from the perspective of the administration, we see that the government is efficiently designed to control its clients[5] with minimal effort. Looking at the same finding from a theoretical perspective we must ask ourselves if such a duplication of control is necessary, as competition usually works well all by itself.

Most of what could be explained using the competition matrix has been successfully integrated into the organizational design of the Ministry for Research and Technology; with an increase of fit over time. The increasing degree of similarity, through time, between these two patterns indicates strong isomorphism of organizational political control and interorganizational competition for funds. As a result, there is no separate 'motor of change', working as an independent element and designed to ensure permanent adaptation to a changing set of priorities, having a *specific* influence on interorganizational competition. Up to now, most of the interdepencies in research topics have been covered by the organizational structure of the departmental organization of the Ministry.

NOTES

1. Another GFE, the "Alfred Wegener-Institut für Polarforschung" Bremerhaven was founded in 1980. It is excluded from this analysis for reasons of comparability.
2. Including the GMB into the regression analysis enlarges the variation of the dependent variable and thus reduces the explanatory power of the model. By doing so an unfavorable (conservative) strategy was chosen to test the model.
3. The predecessors of the DFVLR reach back to 1909. The DFVLR was founded as an Big Science organization in 1962. The GMD was founded in 1962 and is the successor of the DRZ.
4. It is important to remember that we are studying differential growth between organizations. As has been shown above, almost all Big Science establishments have grown in real terms - even the old ones. This could be interpreted as a payoff of the interorganizational activities of the older part of the system.
5. Thompson, Vertinsky, Kiras and Scharpf (1982) conducted simulation experiments with different forms of governmental organization to determine which are optimal (reduce informal interactions and waiting times), given a fixed organizational capacity and certain patterns of customer interdepencies characterized by their joint payoff. Governmental performance is highest when the design takes competition among customers into account and assigns them to the same organizational units according to this dependency structure.

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