THE MANAGEMENT OF SCIENTIFIC RESEARCH

Joe Landsberg

This paper examines the way publicly funded research organisations are managed in terms of the ethos of the scientific staff. Three models for the management of such organisations are considered and the recent management history of CSIRO is examined in relation to these models. The Organisation has changed its management style as result of recent reviews; the consequences of this are considered.

Keywords: management, research, scientific ethic, models

INTRODUCTION

Scientific research today is an activity involving thousands of people and, in many countries, heavy expenditure, much of it through large governmental organisations. Most discussions about scientific research and the way it is managed tend to focus on the type of research (basic, strategic, applied) and on management structures. Analysis by sociologists has necessarily been more concerned with the underlying philosophy and ethos of the scientific community, but there does not appear to have been any analysis in these terms of the way groups of scientists are managed. This paper is an attempt to supply such an analysis. It outlines the scientific ethos and reward system in science, and develops the argument that the 'classical' view of the scientific ethic applies only to a small proportion of scientists and is an inappropriate basis for the management of large groups. Three models of management systems are presented and the recent history of management in an Australian organisation (CSIRO, the Commonwealth Scientific and Industrial Research Organisation) examined. The CSIRO provides an excellent illustration of the problems of research management and has recently undergone major changes in its management system and methods.

The concepts of basic, strategic and applied research are familiar, but to ensure clarity in this discussion the sense in which the terms are used here is as follows:

- basic research is research intended to produce knowledge without attempting to determine the likely value of that knowledge;
- strategic research is 'basic' research intended to produce the knowledge base, at a fundamental level, needed for the pursuit of practical activities or the achievement of practical results;

- applied research is research aimed at producing knowledge for a definite, clearly-defined practical purpose. Applied research is not concerned with underlying mechanisms or understanding, except insofar as these are essential to solve the problem or produce the required result, when the research needed becomes strategic.

There is increasing surety about the output of research (less risk) as we go from basic to applied. The corollary is that the knowledge emerging from basic research — since it relates to 'laws of nature', or at least general phenomena — is likely to be of more general value than the information coming from more applied research. However, it is important to recognize that there is not necessarily a progression in knowledge from basic to applied research. They overlap and interact; there is a continuum in the activities which, although separated for convenience in discussion, are in reality neither separate nor independent.

The management style of any organisation depends on its objectives, on its ethos and on its history. In the case of research organisations the source of funds and the expectations of those who provide the funds also exert major influence. If the objectives of the organisation are to do basic research, then the funding body would be expected to accept that much of the work would be long-term, that it may not lead to any practical result and that scientists must be left free to develop their own research plans without constraints and attempts at direction from 'above'.

If an organisation is 'mission-oriented', having as a major general objective the solution of practical problems, then there may well be a considerable component of strategic research, but the freedom of the scientists to pursue objectives recognized by the scientific community as important, achievable and of 'scientific merit' will be curtailed, or completely eliminated. Funds will be provided with the aim of reaching clearly defined objectives, the attainment of which is considered likely to result in clearly identifiable, and preferably quantifiable, benefits. It will be expected that these benefits will be transferred relatively quickly to user groups (the current jargon is 'stakeholders'), with whom links might be very direct. Indeed such groups may contribute to the funding and will almost certainly exert pressure to ensure that their objectives are considered in the formulation of research programs.

The 'limit' situation — in the spectrum of activity ranging from basic to applied research — for an organisation is reached when its research becomes completely applied, and blends into product or process development. Such research is aimed quite specifically at clearly identified users. It is doubtful if it can be called science.

THE SCIENTIFIC ETHOS AND REWARD SYSTEM

There is a dichotomy between the modern tendency to consider science as the instrument of technological advance, and the 'classical' view of

scientific research, which regards it primarily as an intellectual enterprise aimed at the acquisition and formal organisation of knowledge about nature. Ideally, the activity is considered to be politically and economically neutral, universal and objective, concerned with natural, independent laws that can be established by appropriate methodology. The assumptions underlying the classical view were formalised by Merton.[1] They are that science is characterized by its *universalism,* which requires that information presented to and by the scientific community be available to all and be assessed by all; its *communality,* which requires that scientific knowledge is the property of all; by *organised scepticism,* which never takes results on trust, and by *disinterestedness,* which implies a commitment to objective knowledge. Mulkay[2] points out that these 'norms', insofar as they apply at all, apply only to pure (basic) research, yet they are still widely accepted and many scientists regard conformity to them as an essential pre-requisite to successful research.[3] As a corollary, they consider that they must have the right to select their own problems for study, without intervention from centralised — and presumably non-neutral — authority. Consequently tensions may be generated by institutional attempts to direct scientists towards specified objectives, to be pursued in clearly defined ways, and to impose external constraints and demands for accountability upon them.

The audience, or 'consumer group' for the products of basic research is the community of scientists, and the stamp of approval of this community is the mechanism by which knowledge is certified and validated.[4] Recognition by colleagues within that community is one of the major rewards for the scientist, although Mulkay points out that "most of the studies (on this point) are American and there (has been) a tendency among investigators to concentrate on physics. . . .". There also appears to have been a tendency to concentrate on very 'high profile' scientists, like Nobel prize winners.[5] However, the personal experience of any scientist who has achieved even modest recognition will support the view that recognition by their particular sub-group of the community of scientists is of paramount importance to them. This is certainly not unique to Americans, to physicists or to high-flyers.

The early stages of recognition bring to the (usually young) scientist the feeling of belonging, the confidence that attendance at meetings will be a pleasurable experience where, as time goes on, increasing numbers of people will recognize him and be interested to talk to him/her. Increasing recognition brings invitations to present papers, involving travel, visits to interesting places and other people's laboratories — and so on. It is an important social phenomenon, related to man's need for a sense of identity, to his very strong urge to identify with some group where he is recognized and accepted as unique. We do not need to invoke animal studies or anthropology to see the evidence for this; the most cursory examination of society provides endless examples — it is the basic cement of the family, the tribe, the club, and the street gang. Even

modest recognition is, therefore, a powerful incentive to remain within the scientific community and seek the rewards of recognition for work on problems regarded as scientifically important.

The standard method of submitting the results of scientific research to the critical evaluation of peer groups is through publication, presentation at conferences and the informal networks of communication between the practitioners of a particular field around the world. These networks rely, to a considerable degree, on the free exchange of information, and access to them may be restricted for scientists whose primary 'user groups', and hence the targets for their communications, are development engineers, policy makers or entrepreneurs, rather than other scientists. Therefore as research moves into the more applied areas the rewards of recognition by the international scientific community (or at least that section of it relevant to the field in question) become more difficult to obtain.

Scientists are no less concerned about a decent standard of living than any other sector of the community but, while those who get much of their reward and job satisfaction from recognition by the scientific community may be prepared to forego some material rewards, those who are closely tied to applied work will be more inclined to seek more tangible evidence of their value to the (general) community in the shape of high salaries and other employment-related benefits. Therefore the propensities and expectations of the scientists in an organisation must be considered when the management system is to be changed.

As a basis for more focused discussion of some of the points raised so far, I present in the next section of this paper three models for the direction and management of scientific research organisations. Like all models these are idealized and oversimplified, and are intended more as a framework for discussion and analysis than an attempt to describe reality. The models are called

- the linear/applied management model (referred to as the linear model)
- the classical/*laissez-faire* model (referred to as the classical model)
- the mixed mode model.

MANAGEMENT MODELS

The management models will be discussed in relation to the organisational structure shown in Figure 1. This is intended to be completely general; it does not purport to indicate the 'optimum' structure for a research organisation and the numbers of personnel involved at any level may vary widely.

In large governmental organisations such as CSIRO, the top level should be concerned with policy rather than management, and will have direct links with government. Level 2 (group) managers will be concerned

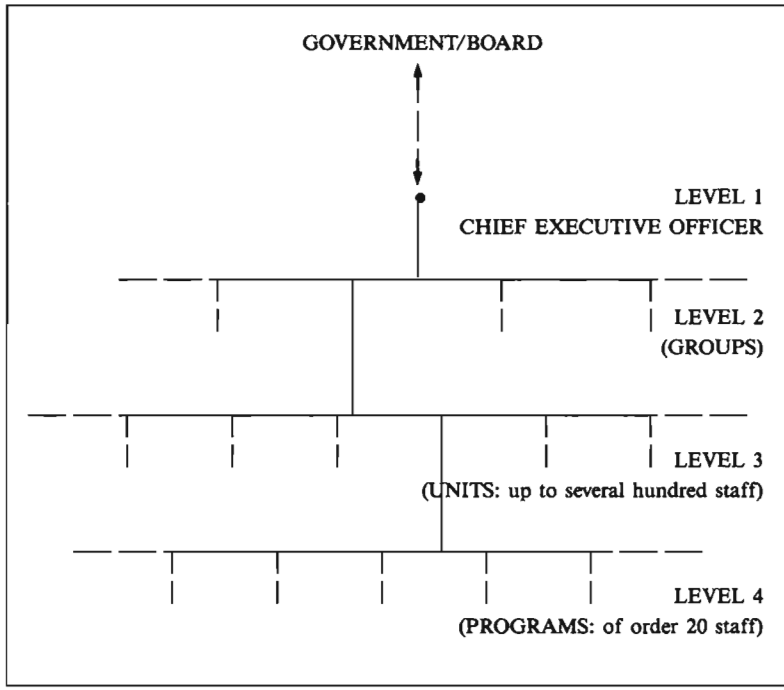

Figure 1: Diagram of the organisational structure typical of a publicly funded research organisation.

with the implementation of policy in their particular areas, with the allocation of resources and evaluation of trends in the sector of the economy with which they are concerned. Level 3 (unit) managers will be concerned with scientific performance and the utilization of the available resources, while Level 4 managers — who may be better termed leaders — are those who are finally responsible for getting the work done.

The linear/applied model

The structure shown in Figure 1, and the above brief outline, implies a linear management model. In its most uncompromising form this model is essentially 'top down', with policy decisions taken at the top (Level 1) determining those problems, areas of science or sectors of the economy to which research resources should be allocated. More detailed decisions about the allocation of the resources available for each sector

will be made at Level 2 and to some extent Level 3, although Level 3 management will be more a matter of decisions about the portfolio of projects to be done, about project and personnel management, detailed budgeting and reporting back.

The linear model involves relatively tight control at every level, particularly at the operational management levels that really affect scientists — Levels 3 and 4. Here the model would require detailed proposals of the work that is to be done, with assessment of the probabilities of success and the likely returns stemming from success, so that judgements can be made about the relative (expected) value of the returns from mutually exclusive projects competing for resources. Proposals for research projects would include operational goals — identifiable objectives that should be reached at specified stages of a project — and criteria for continuing the work. Under this model Level 3 and 4 managers become responsible for 'quality control', because the stamp of approval, the 'validation of certified knowledge' bestowed by the community of scientists working in a particular research field, is not an important basis for assessing the success of a project, even if it could be quantified.

Decisions about resource allocation using the linear management model in a non-industrial context may cause some difficulty. They will almost certainly be influenced by commercial — and probably political — pressures, which may well result in sub-optimal decisions about personnel deployment and resource use. Furthermore, managers are not necessarily the best judges of what is scientifically useful or feasible in any particular area. Industry of any sort (certainly Australian industry) tends to have a poor perception of what science is about, and to demand that research resources be allocated to areas, or perceived problems, where an economic return can be anticipated within the short time scales on which industry operates. In theory, if resource use decisions are based upon rational analyses of the problems most likely to yield returns from research, in the sense of being scientifically 'do-able' as well as having a high probablity of economic return, then the allocation of resources could be optimised.[6] In practice there are so many imponderables that results would probably be no better than those achieved under a *laissez-faire* system of project selection (see next section). Furthermore, as scientists never fail to point out, attempts to 'select for success' take no account of the serendipity factor; the discovery that cannot be forseen and therefore cannot be planned for.

To implement a linear model successfully it would be necessary to be able to move staff between groups and projects at short notice, otherwise the optimum deployment of the skills and resources necessary to undertake selected projects will not be possible. Staff reward and promotion systems would also have to be geared to performance criteria relating to goals achieved rather than to knowledge gained and accepted by the scientific community. Staff management under the linear model is likely to be — at least in principle — relatively straightforward, since

performance criteria are clearly defined and the capacity of individuals to meet them easily assessed.

*The classical/*laissez-faire *model*

The classical model of science management is based on the assumption that scientists conform to the Mertonian 'norms', and that the best management system is minimal management. Project selection by scientists operating under the classical model is generally a matter of working in that area of their own field which seems to them most interesting and most likely to yield scientifically profitable results. Clearly defined projects are the execption rather than the rule and most activity is essentially open-ended. Objectives stated in terms such as "the aim of this research is to study . . ." are accepted as adequate justification for the use of resources, and specific intermediate targets are not set. Judgement about when to terminate a project is a matter for the individual concerned, and the statement: "more research is required . . ." is automatically included in any report on work done. Economic evaluation of the returns on scientific research is always difficult,[7] but the open-ended nature of much of the work done under the classical model makes estimation of the returns on an investment in research in a particular area almost impossible.

Scientists operating under the classical model communicate mainly with other scientists, and their work is judged by peer group evaluation. This may mean that many of the scientists working in a particular field will have a clear idea of the standing and abilities of an individual in that field, although evaluation of his work may be difficult for a manager who is not part of the appropriate 'sub-culture'. This situation has led to the system of evaluation in terms of publications, whereby those who have to assess the merit and standing of scientists do so by evaluating their publications, taking them to provide a measure of contributions to the field and of standing in it. This system can work well, but suffers from the problem that there is no objective basis for judgements and comparisons of the relative value of scientific contributions in widely differing fields.

Staff management under the classical model is fraught with problems, since scientists convinced that their stage is the world and their audience the community of scientists (or their sub-group within it) do not respond well to suggestions that they should stop lines of work for which they are recognized, and change direction or even re-train to work in a new area. The best management options open are those stemming from the capacity of managers to control resources, which can be used to persuade (or pressure) reluctant scientists to change direction.

The classical management model allows maximum opportunity for serendipity and will almost certainly, periodically, yield scientific results of great practical value. Because the selection of areas for research is governed more by scientific than by economic considerations such

advances may well be in areas which would not have been strongly supported by managers — even managers who were scientists. However, because the scientists are not oriented to communicate and explain their results to development engineers, industrial managers, decision makers and entrepreneurs, and because they are likely to see their first line of communication as being to other scientists, there is no guarantee that the funding body, or their own country, will be the major beneficiaries of their discoveries. There is also no guarantee that the scientist(s) concerned will be disposed to become involved in the business of developing their discovery to the point of practical application. They may well take the view that that is someone else's business.

The classical management model is based upon the assumption that scientists conform to the Mertonian 'norms', but there is evidence that many do not.[8] Furthermore, many of the scientists in government laboratories — and in universities — are no more than competent. They need direction and do not resent it. The myth that for scientists to be productive they should simply be provided with resources and left alone, not constrained or pressured to produce, not asked to meet deadlines or commit themselves to clearly defined projects involving the use of clearly specified methods, is a *myth.* It is becoming recognized as such by many and the scientific community does not enhance its credibility by attempting to perpetuate it.

The mixed mode model

As the name implies the mixed mode model for the management of scientific research is a mixture of the linear and classical models. The objective is to combine the best features of both, and a key requirement is that management should recognize explicitly the need for this and designate clearly those staff operating in linear/applied mode and those operating under the classical system.

Under a mixed mode model the research organisation would support a range of research from basic/strategic research — aimed at providing the knowledge base needed to solve a particular problem or to develop the strategies to manage a particular system — to applied research and some development. Policy from the top would indicate the areas to which resources should be directed; Level 2 and 3 managers would decide, in relation to each program area, what the proportion of strategic basic to applied research should be. This decision will be influenced, in many cases, by the availability of staff with the ability to work at the more basic end of the spectrum. There is little point in commiting resources to such research if the staff available are not suited to it.

The mixed mode system requires that units, or programs, collaborate in research in a particular area. It would be difficult to ensure a continuum from strategic basic to applied research/development, because of the different time scales that might be involved. For example, consider the lead time normally needed for the production of basic

knowledge in materials science, in relation to the time needed for the solution of engineering problems associated with manufacturing a product. Similarly, research to produce a vaccine against a disease may take years, while evaluation of empirical methods of controlling the disease using available medication would probably be short term. The problem for research managers lies in deciding, in consultation with scientists, whether the commitment of resources to the strategic/basic end of the spectrum is likely to be worthwhile. If it is considered worthwhile, a general program of research would be planned, to be carried out by people who would essentially operate in the classical mode; i.e. with minimum interference, relatively loose project control, with the publication of research papers and participation in the general community of science as major parts of their brief. They would, however, be required to keep in close touch with the more applied aspects of the area in which they were working and their work would be reviewed in relation to developments in the field as a whole.

The mixed mode model would, in many respects, be more difficult to manage than either of the others. It demands considerable flexibility in management, without sacrificing control. The first problem would relate to the allocation of staff to the different types of research. This would be determined, in the first place, by qualifications and expressed preference at time of employment, but allocation to a classical/basic research mode would not include freedom from performance assessment and ability evaluation. Performance criteria for basic-type research will not be the same as those for applied research, but they should serve to show whether a scientist really is the type who should be doing basic research, or whether he/she should move to the more applied area. The reverse can also hold: a scientist working on an applied problem may identify areas where more fundamental knowledge is needed, and be able to suggest the program that may provide that knowledge. In that case it may be necessary to shift that scientist into basic research, at least for a period. The performance criteria for the two areas must therefore be compatible, and overlap.

One of the problems with the classical management model arises from the scientist who has reached his career asymptote. This is a relatively common phenomenon. A common scenario is the scientist who, in his/her doctoral/post-doctoral period, worked on a problem in a research area that was developing, and in which there was considerable opportunity to make a significant contribution. In many areas the opportunities decline rapidly after the first expansion of the field or recognition of the problem,[9] the area becomes less fashionable and less rewarding and those who do not have the ability, inclination or flexibility to move get left in a backwater. Alternatively (or in addition), many who start their career in pure research find themselves increasingly less inclined to sustain the effort needed to compete at the international level, to retain the recognition of their scientific sub-culture. The rewards do not seem worth the effort and they settle for a quiet, and in research

terms, unproductive life. In governmental research organisations — and universities — such people are well protected and can continue to draw their salaries until they retire. The problem can be alleviated by the formal adoption of a mixed mode management system. It provides the opportunity to offer to those no longer motivated by the challenge of basic research the more structured work of applied research, utilizing the skills and knowledge that they have about the subject area. The transition can be made without the stigma of identifying a person as having 'run out of steam', by offering at any time the opportunity to move from the basic to the applied field, and perhaps to follow an innovation, or some technical area related to the research the scientist had been doing, through to the development stage.

The implications of the mixed model could — and should — be explored in considerably more detail, but the principle should be clear. The essential elements are a definite, formal policy that such a system will be followed, clearly stated procedures, which must include review procedures for those in the basic research areas, clearly formulated staff assessment and reward systems, and management flexibility. An essential element of the model would be consultation with staff; it is not a top-down model. The priority areas may be determined by management policy, but the proportions of strategic/basic and applied research needed in the selected areas, and the approach to that research, must be planned in close consultation with the staff who will do the work. This means that management at the program level (Level 4) has to be excellent. It does not mean *laissez-faire* indulgence to pursue hobbies without let or hindrance on the grounds that this is the way to scientific creativity and progress.

CSIRO: RECENT MANAGEMENT HISTORY

In this section of the paper I outline briefly the recent history of CSIRO, in terms of its approach to the management of the resources for which the Organisation has been, and is, responsible. The Organisation's management is considered in relation to the management models discussed above.

CSIRO is an organisation with about 7000 staff, of whom about 2500 are professional scientists in various grades and categories. For a long period it enjoyed a world wide reputation for scientific excellence and productivity, but in recent years has fallen into disfavour with government and has lost some of its standing in the community.[10] Whatever the reasons for this the result has been two major reviews in the space of ten years.

The Birch and ASTEC reviews

The report of the Birch committee[11] was submitted to the Prime Minister in August 1977, and the ASTEC review[12] was submitted to the

Prime Minister in November 1985. The political and historical background to these reviews is given by Johnson and Buckley. From the point of view of management, the relevant facts are that, for most of its history after the Second World War, CSIRO operated very much according to the classical model. Sir David Rivett,[13] Chief Executive of the then CSIR (Council for Scientific and Industrial Research), set the scene in the late 1920s with the stipulation that, in each field to be covered by the fledgling organisation, there should not be control by committee, but the best available man should be appointed and given responsibility for the success of the work in that field. CSIRO grew throughout the 1950s and 1960s, with a series of major successes and a high degree of autonomy, jealously and largely successfully defended against bureaucratic control until the late 1970s. The Organisation was run by an Executive, responsible to the government, which set policy and decided on the broad allocation of resources — a relatively simple task when new resources were generally available to meet the research needs of newly defined priority areas. The Divisions, which were and are the main working units of the Organisation were (and still are) run by chiefs (Level 3 managers; Figure 1) who, under the Rivett doctrine and the prevailing ethos, developed almost complete autonomy in the way they ran these units.

The Birch report produced 122 recommendations (R1-122), dealing with all aspects of CSIRO's operations, few of which are in any way seminal. The most important (in my view) were recommendations 8 and 27:

- the principal type of research should be strategic mission-oriented, but fundamental and tactical problem-oriented research should be undertaken when related to the role of CSIRO (The role is defined in R3: scientific and technological research in support of Australian industry, community interests and other perceived national objectives and obligations.);
- CSIRO should as a matter of priority modify its internal structure by grouping Divisions into Institutes, the number of which should not exceed six.

It was recommended that the institute directors should be part of the Executive. The Birch report also recommended the setting up of an advisory system (R34-38) to try to solve the problem of priority setting and resource allocation.

The ASTEC review was apparently commissioned by the government as a result of increasing dissatisfaction with the returns on the public investment in science in terms of the conversion of scientific findings into technological advances. The committee made 25 recommendations, of which the most important was "that CSIRO's main role be the conduct of applications oriented research combined with a commitment to ensuring the effective transfer of its research results to end users. To fulfil this role a significant shift is required in the overall ethos of the Organisation . . . " The report proposed a clear separation of policy and

management functions, with a board of part time Directors drawn from outside CSIRO, with the Organisation's Chief Executive as a member. There was to be a management committee, chaired by the Chief Executive, consisting of institute directors and the senior administrative manager.

Implementation of review recommendations

Most of the recommendations of the Birch committee were accepted by Cabinet, but the most visible change that resulted was the formation of institutes and the appointment of institute directors. The recommendation of the Birch committee that these directors should be part of the Executive was not implemented. This, in the view of the ASTEC committee, ". . . has led to blurred lines of responsibility and has made it difficult for the directors to establish a substantial role for themselves in the overall management structure . . . The reduction in the status of the institute directors in comparison with the intention of the Birch report has limited the authority of the directors and enhanced that of the chiefs. While it is clearly essential that the chiefs have a high degree of autonomy in the manner in which the research objectives of the divisions are achieved, it is very much in the Organisation's interest that divisions are seen to be components of institutes rather than as completely independent research units . . . "

As a result of the ASTEC report the Act of Parliament under which CSIRO operates was amended and the recommendations with regard to the Board and management committee implemented. In early 1987 the Board decided to re-examine the structure of the institutes, and consultants were called in to recommend on management systems. The consultants, after a relatively brief assessment of the Organisation, recommended that the institutes be restructured along 'business system' lines; in other words each institute should be oriented to a sector of the economy with which it should deal in a coherent manner. As an example of a business system, and the changes this entailed, consider sheep and wool. Previously CSIRO's considerable research effort on wool had been in an industrial technology institute, its research on various aspects of sheep production and management in an institute of animal husbandry and its research on pasture production scattered through institutes concerned with both animal and crop husbandry. Under the new recommendations all these research areas were to be in one institute, with a director charged to ensure collaboration and interaction between the various aspects. Working with the (then) institute directors and acting directors, the consultants re-arranged the whole of CSIRO. Some divisions were broken up and the parts patched onto others. Some were amalgamated almost *in toto*. The end result was that the 41 divisions were reduced to 30, placed in six new institutes. The directorships of those institutes were advertised.

The consultants also recommended much stronger line management for the Organisation. The only written result of their work is The Model

Institute Study,[14] in which the roles of managers at various levels (Chief Executive, Institute Director, Chief, i.e. Levels 1, 2 and 3) are specified. This document includes such statements for directors as: "hold chiefs accountable for divisional performance; report to Chief Executive on Institute performance"; and for chiefs: "instill awareness of economic and community issues in divisional staff; engage in inter-institute and inter-divisional collaboration . . . ". Research managers (program leaders) are expected to "provide research leadership and direction to project teams; develop and promote corporate ethos . . .". These statements are taken almost at random, but they make the point: CSIRO is now irrevocably committed to the linear model.

As a consequence of this commitment, and the ASTEC recommendations, the Organisation now has formalized project management, a project data base, a strong commitment to applied research and, both to try to reduce the cost to the taxpayer and to ensure greater involvement with industry, there is a strong push to obtain funds from industry in support of its work. This has the result, as many scientists are finding, that industry claims the right to specify much more closely what is done, and often expects relatively precise specification of what the product will be. There is also a considerable emphasis on communicating the results of research to users, which implies that they should be communicated in usable form — not buried in scientific papers.

The management situation in CSIRO

The formation of institutes and the appointment of institute directors in CSIRO, as a result of the recommendations of the Birch committee, had very little effect on the way the Organisation was managed — at least at the level of the scientists and the way they operated. The classical scientific ethos, with its concepts of scientific autonomy, was so dominant and unquestioned throughout CSIRO that the idea that real changes in attitude and procedure were intended does not seem to have been taken seriously. Management was assumed to consist of providing the researchers with resources and leaving them alone. The divisions were essentially autonomous units. It is therefore not surprising that the directors, in the period between the Birch and ASTEC reports, were largely powerless. The chiefs generally held strongly to the view that they were the people who should make the decisions about what research would be done in their divisions. They either ignored, or paid lip service to directorial attempts to direct them, and many went round the directors to discuss matters with their contacts on the Executive whenever they felt it necessary. This would not have been allowed to happen if the Executive had been trained or had experience in management, especially the concepts of line management and accountability. However, since the members of the Executive invariably came from academia or from within CSIRO this was outside their experience. There was, in any case, no mechanism for control, since there was no formal system of project

proposals and review, and no way of accounting strictly for the time and resources used by a researcher. Promotion was on scientific merit — measured largely by the output of papers and assessed standing in the scientific community — a widely acclaimed system but one which caused problems for the technologically-minded scientist who became closely involved with industry.

The Executive's ideas about management are probably encapsulated in the matter of the priority research areas. In the early 1980s, with the increasingly stringent scrutiny by government of the resources allocated to science, it became apparent that there must be some focus of CSIRO's remarkably diffused activities, and redeployment of resources into priority areas. The Executive discussed the need to identify low priority areas that could be closed down, but never tackled the problem of how this might be done. Since most research was in general areas of activity or scientific fields without clear accounting for the time and resources devoted to particular projects, and since the Executive had neither the means nor the will to enforce detailed accountability, nothing was done.

In an attempt to focus CSIRO's efforts, the Executive designated so-called growth areas, such as information technology, generic (broadly applicable) manufacturing, water and soils, space science and technology and biotechnology. The basis on which these were selected was never clear. Resources were extracted from divisional budgets at the beginning of the financial year to be allocated to these areas, and the chiefs bid for the resources. They put up cases for positions and equipment, with generalised project descriptions, usually firmly based on what was already being done in their divisions. The system did lead to some shifts in the balance of the research done, but the extent to which these were real was almost impossible to decide, since so much depended on the way the work being done by a particular scientist was described, and the stated objective. Consideration of the priority areas will show that they were so broadly defined that a little ingenuity would ensure that almost any research in the general area could be made to fit. Furthermore, there was never any clear indication of what should be shut down to favour the priority areas. The method of taking resources 'off the top' simply sidestepped the decisions.

CSIRO's commitment to the linear model, following the adoption of the recommendations of the ASTEC report and the exercise with the management consultants, is undoubtedly genuine at the top levels, but it has caused confusion and a drop in the morale of many scientists. The Introduction to the Organisation's Operational Plan for 1988-89 says: "a substantial management restructuring has taken place in CSIRO since 1986. This has resulted in a new style of management that emphasises the responsibility and accountability of line managers throughout the Organisation. Particular reference is now given to the need to define goals and objectives against which resources can be allocated . . . The new ethos follows a major management review of the Organisation, the formation of a new Board and a restructuring of the

Institutes . . . '' The point that immmediately emerges from this derives from the (mis)use of the word 'ethos'. What has taken place is structural change; whether a change in ethos follows remains to be seen. To bring it about requires that the existing ethos, with its assumptions about reward systems and methods of working, about accountability and job satisfaction, be recognized, and that the problems of changing the ethos — as opposed to the structure — be addressed in a realistic way.

Some of the confusion among scientists is the result of conflicting signals from the Chief Executive and the Board. They have given repeated assurances that the Organisation is still committed to 'high quality science', and that there is still a need to do strategic basic research. Indeed, although ASTEC made no recommendation about this, the committee commented (p.19): ''In the overall CSIRO program, however, it is essential that a substantial continuing effort is devoted to strategic basic research in order to keep abreast of international developments and to develop research skills and expertise which will be needed by industry and other end users in the future . . .'' Such signals are interpreted by scientists as indicating that they can continue to operate in the classical mode, and yet the imposition of the linear/applied management model does not support this assumption.

There is, therefore, a case for CSIRO to consider the mixed mode management model. There will be many in the Organisation who claim that this is already, *de facto,* the management system, but since it is not formalised it is unlikely to be as effective as it should be. It is not an objective of this paper to try to provide a recipe for the implementation of the system; that is a matter for the management.

CONCLUDING REMARKS

I have put forward, as a preliminary framework for the analysis of research management, three models, called the linear, classical and mixed models. The management style involved in using these models — or some variant of them — would differ not only because of the structure of the group or organisation concerned, but also, and most importantly, because of the underlying ethos governing the behaviour and responses of those being managed. If there is a requirement that the product of the research organisation be changed this may involve not just a change in procedures, but a change in ethic. For example, considering a research group or organisation as a knowledge producing entity, if the policy of the funding body dictates that its output change from 'pure' knowledge/basic information to information in a form that can, and must, be readily put to practical use, this will entail a change in ethic. The scientists may have to abandon some of the 'classical' ideas about universalism, communality and disinterestedness and accept that they may not be able to speak about or publish information of value, that they will be directed into certain areas of activity by centralised authority

and that the pursuit of understanding in the cause of advancing knowledge may not be a high priority. These implications must be recognized by both management and the managed, otherwise the consequence will be poorly functioning and inefficient systems and dissatisfied staff with low morale.

Turning to CSIRO and its changes in management style over recent years provides some insight into these matters. The *laissez-faire* style of management (my 'classical' model) that pertained through the post-war years derived from the unquestioned assumption that this was the best model for science. It seems highly probable that great inefficiencies and considerable resource waste were hidden by the steady increase in resources available, and by the high performance of a proportion of the scientists. But CSIRO's reputation was a source of pride and simply belonging to the Organisation provided scientists with a degree of recognition. The decline in the regard in which CSIRO is held, and the (implicit) demands for a change in ethic as a result of a move to conform to the requirements of government and become more applied, more oriented to the perceived requirements of industry, have combined to create uncertainty and lower morale. The problem is no doubt soluble, but requires recognition by management that new structures do not, of themselves, result in a new style of management.

In attempting to solve the problems associated with the changes to which it has been subjected, CSIRO is, rightly, turning its attention increasingly to management training. If the analysis that I have presented here is accepted, it follows that this training should include analysis of the scientific ethic and the things that motivate scientists. No group of people can be successfully and effectively managed from a base of misconception and ignorance.

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