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March 4, 1999
1. MISSION STATEMENT

Consistent with the Australian National University Act and with the Australian National University's aspiration to be one of the world's great research institutions, the Research School of Chemistry has established itself as a centre of excellence, both nationally and internationally. In order to maintain and enhance that position, the School proposes to:

• maintain its research and scholarship in the chemical sciences at the highest international standards;

• foster the advancement of fundamental knowledge in chemistry with special reference to research of national importance and activities which not only strengthen the discipline of chemistry in the Australian context, but also contribute to cognate research fields both within and outside the University;

• provide the best possible training and education of graduate students and postdoctoral fellows;

• nurture the career development of early career academic staff;

• encourage links with Australian Universities and other research organisations which enable the intellectual and material resources of the School to be broadly utilised by the Australian research community;

• develop links which enable the Australian community, industry and government to benefit from the scholarship and research undertaken in the School;

• maintain and enhance international networks that benefit both the University and the Australian community as a whole.
2. STRUCTURE AND PROFILE

The Research School of Chemistry (RSC), founded in 1967, has established itself as one of the world's leading centres for chemical research. It plans to continue the pursuit of fundamental research in the discipline of chemistry and to maintain its established major strengths in the fields of theory, reactivity, structure and synthesis. These strengths will also be brought to bear on various research themes, including, for example, the interface between chemistry and biology, and the science of materials. The School is organised into 22 research groups (19 headed by a continuing member of academic staff), ca. 35 non-continuing academic staff, 60 research students, and 75 general staff.

2.1 Fiscal Situation

The orderly development and planning of School activities has recently been upset by government funding cutbacks (~12% over 3 years) and inadequate supplementation of both cost of living increases and the depreciation of the Australian dollar. The effect of inadequate supplementation to counteract the effects of inflation is clearly shown in Figure 1. While the recurrent RSC expenditure has apparently risen year by year, when expressed in constant 1990 Australian dollars\(^1\), the RSC budget has shrunk from some $11.3M in 1980 to $9.7M in 1997 – a decline of 16%.

Because research is an internationally competitive activity the depreciation of the Australian dollar against key international currencies makes our ability to purchase equipment from overseas or hire and/or retain staff difficult. Reserve Bank data for 1998 indicates that the Australian dollar was worth 54% of its 1981 value in US dollar terms (Figure 2).

![Figure 1. RSC recurrent expenditure.](image-url)

\(^1\) Australian Bureau of Statistics data.
The picture, however, is even more bleak than these gloomy figures indicate. In a recent article Satis Arnold has pointed out that a UK study revealed the price of carrying out internationally competitive research has spiralled over recent decades. It was pointed out that for the replacement of an obsolete item of equipment, the replacement cost was 60% more expensive (after allowance for inflation). In order to be at the leading edge of international research, 170% more money would be needed. This means that "constant funding" in real terms leads to a gradual decrease in a researcher's ability to carry out cutting edge research. Figures 1 and 2 show that funding for the RSC has not even been constant.

The precarious state of government funding for scientific research in Australia seems to be out of step with that which is occurring overseas – particularly in the US, the UK and Japan. To illustrate this point, an excerpt from a recent speech by the US Vice President, Al Gore, describing the US’ new "21st Century Research Fund" is included in Appendix A.

In the 1980's, the RSC embarked on a program of diversification. Towards the end of the 1980’s the School decided to increase its presence in the areas of biological and bio-organic chemistry. This also partly anticipated retirements in the late 1990's both within the RSC and across the country. The change in research emphasis reflected the increasing importance of the chemistry/biology interface.

More recently, we have encouraged the career development of promising female chemists. There are now two small research groups that are led by women with non-continuing appointments. The aim of this initiative was to enhance the prospects of the women in securing continuing research positions in the future.

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2 Satis Arnold, recorded on 17/11/98 by Robyn Williams for Ockham's Razor, ABC Radio National.
The diversification program was made in response to the recommendations of the 1982 Review Committee and there was a staged process for increasing the number of research groups. However, it was not possible to foresee the reduction in funding that failed to keep pace with inflation and most recently the effective cut of approximately 12%. Taken together, these developments mean that the RSC is approaching a crucial watershed in its history.

Figure 3 shows how the recurrent attributable research expenditure (excluding equipment) has been distributed among the School's research groups over the years since 1981. The figures are expressed in constant 1990 Australian dollars. It shows that in spite of the decline of the School budget over the period (Figure 1), the total attributed expenditure has been kept almost constant. This has been achieved by strenuous cost reductions in the central (non-attributable) budget areas of the School (e.g. administration, central services, technical). We believe that further savings in these areas are no longer possible for two reasons. First, further cuts will be impossible without serious and damaging cuts in service. Second, the cuts to the central areas of the University have meant that more administration has, and is continuing to be, devolved to the Schools. Although there will be some increase in administrative efficiency resulting from the introduction over the next few years of the Enterprise Solution PeopleSoft administrative software package, these advantages are unlikely to accrue to the School because they will be offset by further devolution of administration to the School.
Under the pressure of reduced recurrent funding, the School has made vigorous efforts to increase the level of support from external sources. There are currently 12 externally funded staff and 10 externally funded students in addition to 20 holders of Australian Postgraduate Awards. Figure 4 shows external earnings from 1992 onwards. These figures do not include externally funded fellowships from overseas sources (e.g., von Humboldt, Deutsche Forschungsgemeinshaft (DFG), Royal Society, etc). Nor do the figures include funding by RIEF or the Major Equipment Committee. The School intends to optimize the level of external support (see Section 3.2).

2.2 Structure and Staffing Profile

The Dean is appointed for three years from among the professors in the School and has the final discretion for the distribution of funds, after receiving advice from the Faculty Board and various advisory committees.

On average, the School has attempted to provide sufficient recurrent funds for 2–3 support staff (in most cases, two postdoctoral fellows and a technical officer) with the view that this level optimises productivity by ensuring technical and academic continuity. Although this level of support is substantially below that available to groups in the USA and Europe, and may be below the levels available to some academics elsewhere in Australia, it can be leveraged with external funding. However, as a consequence of recent budget cuts the School is now unable to provide this level of support.
As postdoctoral fellow vacancies occur, the positions are pooled and then refilled, in a School-wide competition. This maintains appointment standards. In special cases where research groups have fallen below the minimum support level, a special advertisement may be placed. The maintenance of academic standards is crucial, however.

On a national scale, the RSC is a significant provider of postdoctoral training and support. Its program of postdoctoral training is consistent with the mission of the Institute of Advanced Studies (IAS) and assists the return to Australia and subsequent employment of a significant number of early career expatriate Australian chemists.

A notable feature of the School’s organisation has been its insistence that, with one exception, research groups, have no more than one continuing academic staff member. This structure is unusual within the IAS and allows the regular introduction of new research activities. This is especially evident in Figure 3. Since 1981, 8 research groups have been disestablished and have been replaced by 13 new groups. In the School's non-departmental structure, once a group leader retires or resigns, the resources of that research group are reallocated. Consequently, since 1981 the financial reallocation that has taken place amounts to ~50% of the School’s recurrent allocated budget.

Figure 5. Trend in equivalent full-time staff posts.

Figure 3 clearly shows that the recurrent budget of the RSC is now being spread more thinly than at any time since 1981. Given that there are 3 research groups headed by non-continuing staff

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3 Actually, at any time in its history.
involved in career development, it is clear that restructuring and consolidation is required. Average group sizes have fallen below those of leading Australian competitors. This situation must be remedied. Figure 5 shows that recurrently funded staff numbers have declined by ~22% since 1990.

3. OBJECTIVES

The primary aim of the School is to conduct chemical research of the highest international standard and in so doing provide the most intellectually stimulating environment in which to train and educate promising scientists. From its beginnings, the School has given little weight to the traditional divisions of the discipline into inorganic, organic, physical and theoretical chemistry and has established major strengths in realms that transcend those divisions, namely theory, reactivity, structure and synthesis. These strengths have also been brought to bear on the cognate disciplines of physics, biology, earth sciences, mathematics and materials science.

Over the next 4 years (1999–2002), the School aims to:

- maintain its commitment to fundamental and mainstream chemical research with due regard to areas of national importance and those leading to developments of practical significance, e.g., the synthesis, structure and properties of bioactive compounds and new materials, the structure and function of biomacromolecules, molecular recognition, catalysis, the molecular basis of disease, scientific instrumentation, and the discovery of bioactive molecules such as antibiotics, plant growth regulators and toxins;
- expand its structural studies on materials such as catalysts, polymers, ceramics, nonlinear optical materials and biologically important compounds; this will be achieved through the use of techniques using major new facilities in X-ray diffraction, mass spectrometry and laser spectroscopy;
- maintain the presently flourishing programs in theoretical and computational chemistry and use them to make predictions of thermophysical properties, molecular structure and chemical reactivity, and the structure and function of biologically significant molecules;
- enable the intellectual and material resources of the School to be broadly utilised by the Australian research community;
- expand the School's international links; and
- provide a research and educational environment for PhD scholars and postdoctoral fellows at the highest international standard.

3.1 Measures Proposed to Achieve Objectives

At the beginning of 1999 the Photophysics Group (Bramley) was disestablished (Figure 6). A further 5 research groups are expected to be disestablished by the end of 2002. By that date, the School plans to establish two new groups, one in inorganic chemistry and one in experimental physical chemistry. The timing of these replacements will, unfortunately, be dictated by external influences. The nett saving by the end of 2002 should be ~12 equivalent full-time posts.
Figure 6. Retirement profile for continuing academic staff in the RSC.
In order to achieve these objectives the School will undertake the following initiatives:

- rationalise and consolidate selected existing activities, and encourage collaborative research both within the School and with groups in other Research Schools and The Faculties;

- maintain the current level of external funding, keeping in mind the need to maintain control of the research agenda;

- maintain the School's non-departmental structure and its flexible system of resource allocation, whereby all posts vacated are reallocated competitively on a School-wide basis, and seek to diversify the School's funding sources;

- strengthen and extend links with other Australian Universities, CSIRO, ANSTO, government institutions, industry, and with international universities and agencies;

- provide these links through joint programs of research and secondment, and through the School’s Visitors Program;

- continue participation in the ANU Centre for the Science and Engineering of Materials, including participation in its educational program of seminars and undergraduate lectures;

- Participate in the ANU Centre for Theoretical Physics;

- be an active member of new CRCs;

- be a strong participant in the newly announced Australian Partnership for Advanced Computing;

- recruit outstanding and creative academic staff by advertisements that allow appointments in broadly defined areas of research;

- recruit outstanding students and general staff, and maintain a working environment that allows individuals to realise their full potential;

- as resources permit, establish new research directions through the creation of new research groups with the view to creating synergies between groups within the School and elsewhere in the University;

- as resources permit, make further appointments of outstanding female chemists to Rita Cornforth Fellowships;

- maintain a low continuing:non-continuing academic staff ratio and utilise the research group as the basic unit of research activity within the School;

- achieve an appropriate balance of non-continuing academic staff, research students and technical staff between and within each research group;

- as resources permit, increase research student numbers; and
• maintain an active Graduate Lecture Program in Chemistry and participate in the educational program, seminars and lectures of the ANU Centre for the Science and Engineering of Materials and the ANU Centre for Theoretical Physics.

3.2 Constraints on the Achievement of Objectives

The School's chief concerns are the inadequate supplementation for inflation and devaluation of the Australian dollar, and unfunded salary increases arising from the Enterprise Bargaining process. The latter is a seriously flawed process for public institutions with no control over the price of their "product". The process is made more difficult because, under law, negotiations cannot begin on the next Enterprise Bargaining agreement until an existing agreement has terminated. Since pay rises are very frequently back-dated to the beginning of the negotiating period, forward planning is seriously compromised.

The deterioration of pay and conditions for ANU staff, compared with national comparator institutions, is also a concern because it undermines efforts to attract and retain top researchers.

Inadequate supplementation for inflation and devaluation has had and continues to have, a particularly detrimental effect on library funding. Cancellations of 117 titles costing approximately $240,000 (as compared with a current budget of approximately $500,000) have been necessary since 1993. The library, which is sited within the School, is an essential part of the School’s infrastructure and it is hoped that the university will give priority to reversing it declining budget.

There is no simple answer to the question of the appropriate level of external funding. If external funds are available in a form that allows group leaders to control the research agenda in a comprehensive manner, then a comparatively high percentage of external funding is acceptable. However, even in this circumstance, the lack of continuity that is inherent in external funding means that the funds cannot be used to support continuing positions (and therefore should not dominate). If external funds are provided for "contract" research, only a much smaller percentage of external funding can be tolerated. External funds should not be accepted if it means that the resulting research is inconsistent with the School's mission or research agenda.

Another difficulty with external funding is the question of full cost recovery. With all Australian universities being short of funds, departments are often so anxious to attract additional funding that they do not pass on the full costs (e.g., IT, library, buildings maintenance, etc). When this occurs the externally "supported" research slowly bankrupts the department and the university. This problem is exacerbated when full cost recovery is not obtained and, worse, recurrent funds are used to leverage the external support.

The issue of combining government and corporate funds to support basic science research is hotly debated by national policy makers in the USA - see Appendix B. Moreover, compared to the situation in the USA, Australian industry has shown a reluctance to invest in scientific ventures. This has led the Australian government to develop policies that encourage corporate research to be carried out in universities with government financial incentives. However, many of the drawbacks seen by the Americans in employing taxpayer dollars for corporate purposes are universal and apply equally well to Australia.

Although corporate support of basic research can augment government funding, it should never be a substitute for government funding. As US Congressman Vernon J. Ehlers said in a congressional address on 22 April 1998, "While it is clear that [in the US] industry does fund a
substantial amount of basic research, and that the federal government should continue to fund research of a more applied nature, because the results of industrial basic research are almost always proprietary, the federal government has an **irreplaceable** role to play in generating new knowledge that is available for widespread dissemination". The generation of new public knowledge is one of the core missions of universities in western society.

Another substantial constraint on performance is the sheer cost in both time and money, of research accountability. When governments and organisations call for reviews, bibliometric surveys, publication surveys, etc, scant attention is paid to the costs of these investigations. This is because the organisation calling for the study rarely bears the cost of the review or survey. The full cost of the 1995 Review of the IAS and its Schools was not considered or estimated before or after that Review but it certainly ran into the millions of dollars. A cost benefit analysis should always be carried out before any survey or review is initiated.

### 4. EVALUATION OF PERFORMANCE AND SUCCESS

The success of the School in achieving its goals can be measured against the following excerpts from the Mission Statement:

*Maintain its research and scholarship in the chemical sciences at the highest international standards; and foster the advancement of fundamental knowledge in chemistry with special reference to activities which not only strengthen the discipline of chemistry in the Australian context, but also contribute to cognate research fields both within and outside the University.*

No section of the higher education sector in Australia has been submitted to a greater degree of scrutiny and review than the ANU’s IAS. In the recent 1995 Review, copious quantities of objective and subjective data were gathered, compiled and analysed (the RSC submission comprised 3 volumes). Perhaps the greatest shortcoming of that process was not the lack of data on the IAS and its constituent Schools, but rather the lack of comparable data for national and, more importantly, international comparator institutes, schools and departments.

Certain assessment criteria are well-established and obvious. This School expects that individual research activities should, in the fullness of time, become the best of their kind in the country and that some would be of the highest international standing as recognised by peer review, *e.g.*, by the researcher’s election to the Australian Academy of Science, or an academy of comparable standing. By a significant margin, there are presently more Fellows of the Australian Academy of Science within the RSC than in any other Australian chemistry department; there are 9 fellows of the Australian Academy of Science who are, or have very recently been, on the RSC staff. The School also expects that many of its senior faculty (again, in the fullness of time) will be elected to major overseas academies, such as the Royal Society, London. Since the foundation of the School, there are or have been more Fellows of the Royal Society in the RSC (7) than in all other Australian chemistry departments combined (3).

Bibliometric indicators may also afford useful information in the evaluation process, provided that the level of aggregation is appropriate and like is compared with like. In 1992, the US magazine *Science Watch* ranked ANU 45th in the world on the basis of citations per paper in chemistry.\(^4\) In

the same year, the ANU was ranked as 8th in the world for organic chemistry, and 24th in the world for physical chemistry. No other Australian university appeared in these rankings. Although the precise criteria used for ranking in these studies is arbitrary and the data sets used by Science Watch were not "cleaned" to tidy up inconsistent byline addresses for institutions, these studies do have the advantage that they were carried out uniformly and by an unbiased party. For 6 months during 1998 the most highly cited chemistry paper worldwide was written by two members of the RSC. Although one can argue interminably about the precise meaning of citation data such as these, it is clear that chemical research carried out at the ANU is having an international impact.

Because the major sources of funding for basic research in Australia (ARC and NH&MRC) are not available to staff in the IAS, the criterion of success in attracting outside research grants should not carry its normal weighting. Nevertheless, the School's success in the competition for ARC postdoctoral fellowships, obtaining external funds, and the attraction of non-continuing academic staff supported by overseas granting agencies such as the DFG, The Royal Society, etc, provides a useful measure. Moreover, peer review as measured in terms of election to learned academies (loc. cit.), invitations to speak at major conferences, prizes, and success in competition for research grants is generally regarded as the most suitable indicator.

Provide the best possible training and education of graduate students and postdoctoral fellows; and nurture the career development of early career academic staff.

The School has an outstanding research infrastructure and excellent technical services, and has a long established postgraduate course work that is enriched further by an exceptionally vigorous seminar program that includes a major involvement by international visitors. Accordingly, the School provides one of the very best environments for the education and research training of graduate students and postdoctoral fellows. The School boasts an outstanding completion rate for PhD students and expects to continue the placement of both students and postdoctoral fellows in other Australian Universities, and in positions of responsibility in Australian industry or government.

Encourage links with Australian Universities and other research organisations which enable the intellectual and material resources of the School to be broadly utilised by the Australian research community.

The proportion of the School's recurrent budget committed to collaborative activities with other Australian Universities as last measured, was estimated to be 14%. Interactions with CSIRO and ANSTO are also considerable.

Develop links which enable the Australian community, industry and government to benefit from the scholarship and research undertaken in the School; and maintain and enhance international networks which benefit both the University and the Australian community as a whole.

The School will measure success in these areas by the scale of joint collaborative activities and by the diversity of its funding sources. Measures of its international visibility will include the demand

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by prospective non-continuing staff for positions in the School and the quality of its visitor program.

5. RESEARCH AND ORGANISATIONAL STRENGTHS

The School has established major strengths in most mainstream areas of chemistry, including theoretical and computational chemistry, mechanistic chemistry, solid state chemistry, structure determination (based on spectroscopy and diffraction), and synthesis (organic, inorganic and organometallic). However, these strengths extend well beyond those of the individual activities. While seeking to establish an appropriate diversity of research activity, the School has been mindful of maintaining an intellectual cohesion between its activities, giving advantages of shared resources and equipment. This cohesion has been facilitated by the organisation of the School, which has avoided a departmental or divisional structure, in recognition of the seamlessness of the discipline of chemistry.

In the absence of imperatives imposed by the need to support a teaching curriculum, and with the flexibility afforded by block funding, the School has carefully chosen staff and subject areas that have led naturally to synergetic interactions between research groups. In addition to their major research focus, most groups bring experience and expertise in techniques that are utilised by other groups within the School, the ANU at large, and in other Universities, e.g., in the areas of NMR, ESR, FTIR, and laser spectroscopy, mass spectrometry, X-ray crystallography, neutron diffraction, electrochemistry, electron microscopy, supercomputing, synthesis and microanalysis.

In recognition of the importance of the chemistry/biology interface, the School was a prime mover in the creation of the Centre for Molecular Structure and Function, and has made key appointments to underpin the activities of the Centre. Equally, the discipline of chemistry is central to the study of materials, including the determination of structures and properties and the preparation of new materials through synthesis or the modification of natural substances. Accordingly, the School was a founding member of the new Centre for Materials Science and Engineering, and expects to play a major role in its activities.


6.1 Core Activities

The pursuit of fundamental research in the disciplinary core of chemistry and the maintenance of strengths in theory and mechanism, computational chemistry, spectroscopy, diffraction methods and synthesis will always be central to the School's mission. These strengths also ensure that the School is exceptionally well placed to support broader endeavours both within the School and the University as a whole. A brief summary of current research activities in the School is provided below, with further details provided in Section 6.3

Broadly defined, Inorganic Chemistry is concerned with a description and understanding of the structure, properties and reactivity of compounds of the elements of the Periodic Table with the exclusion of carbon compounds bonded to non-metallic elements (i.e., organic chemistry). School activities that fall into this area are concerned with organotransition metal chemistry, inorganic stereochemistry and asymmetric synthesis, mechanistic aspects of enzyme reactions mediated by Vitamin B_{12}, the application of electrochemical methods to provide fundamentally new insights into the structure and electronic properties of transition metal compounds, new materials whose
structures and properties can be easily altered via temperature, pressure or chemical doping and new framework silicate structures.

The goal of the Physical and Theoretical Chemistry research groups is to strengthen further a tradition of excellence in the study of gas phase and condensed matter through theoretical and experimental investigations of structure, dynamics and chemical reactions. In the experimental areas major developments have been made in Laser spectroscopy and structure determination using electron microscopy, as well as neutron and X-ray scattering methods. There is a strong overlap of interest and staff member participation with the School’s inorganic chemistry research groups in both structure and spectroscopic studies.

The Organic Chemistry research groups are broadly concerned with the structure determination, synthesis and biosynthesis of naturally occurring, biologically active compounds, with supramolecular chemistry, and with the study of interactions between molecules, i.e. molecular recognition and structure-activity relationships. Several groups are also concerned with synthetic methodology (including new strategies), with the construction of compounds that have unusual architectures, and with the study of reaction mechanisms, particularly those related to biochemical processes. The quest for better mechanistic and theoretical understandings of molecular behaviour, the search for more efficient and flexible synthetic procedures, and mankind’s need for new materials and bioactive agents are evergreen themes.

Research in Biological Chemistry is directed toward fundamental questions in biology. Frequently the outcome of this research leads to practical and commercial application. The central theme of research in the groups is macromolecular structure and design. In particular, research aims at development of knowledge of the structures of biological macromolecules, and the relationships between their structures and the chemistry that governs their actions and interactions with other molecules. It is recognised that the biological chemistry is growing rapidly in significance, and there is a critical need to establish a focussed centre for protein structure and design at ANU, which might occur as a development from the Centre for Molecular Structure and Function (CMSF). The School views collaboration between existing biological groups and other groups in the traditional areas, as being of increasing importance. Two groups use as their primary tools structure determination by X-ray crystallography and NMR, while a third uses molecular genetics and protein biochemistry to study macromolecular interactions in complex systems.

6.2 Future Appointments

Given the reductions in recurrent funding, the School has decided to reduce the number of independent research groups supported by that funding. Figure 6 shows the School’s retirement profile and indicates that retirements will occur at fairly evenly spaced intervals. It also gives an indication of the research group activities involved. Although 6 groups will be disestablished in the period 1999 - 2002, the School plans to create only two new groups during this time frame. For reasons outlined below, it is proposed that appointments will be in the areas of experimental inorganic chemistry and experimental physical chemistry/chemical physics. This downsizing will go some way to restoring the level of research support for groups to nationally competitive levels. Should resources allow, there would be considerable advantage in establishing a group in a selected area of experimental organic chemistry as well.

Consistent with the School’s policy of independent research groups operating in a non-departmental structure, the School endorses a policy of wide advertisement of all continuing positions to advertisements in broadly defined areas of the discipline. This policy is based on the philosophy that the selection of the most creative individuals is of paramount
importance to the strategic development of any basic research enterprise. If one seeks the individual with the preeminent research record, the research area that the individual works within must itself be vigorous and developing rapidly. It is improbable that a superior record can be established in a research area that is in decline.

Inorganic chemistry has expanded enormously in scope and ramifications and overlaps strongly with other parts of chemistry, physics, materials science and biology; links to research programs in organic and solid state chemistry are especially important. The RSC has demonstrated internationally recognised excellence in inorganic chemistry, especially though not exclusively resulting from the researches of Professor Alan Sargeson in Biological Inorganic and Coordination Chemistry and Professor Bennett in Organo-transition Metal Chemistry. The former retired at the end of 1995, but was not replaced at that time, while the latter is due to retire at the end of 2000, leaving only one tenured staff member at Senior Fellow level specifically concerned with synthetic, molecular inorganic chemistry. There is, therefore, a pressing need for an additional appointment in the area. Consistent with the School's policy of wide advertisement, an appointment could be made in any of the following areas:

(i) Organometallic chemistry, concerned with the chemistry of compounds containing element-carbon bonds. This field is continually spawning the development of new reagents in synthetic organic chemistry, for example, for the formation under mild conditions of carbon-carbon bonds and for specific oxidations. Investigations of the chemistry of organometallic compounds have led, and are continuing to lead, to the development of new industrial processes based on coal and oil feedstocks, most notably in the specific polymerisation and oligomerisation of olefins. These processes are catalysed homogeneously by well-defined organometallic precursors but inorganic and organometallic compounds are increasingly being attached to specific support materials, such as metal oxides or pillared clays, to form new heterogeneous catalysts.

(ii) Biological inorganic chemistry and coordination chemistry, concerned with the elucidation of the mechanism of action either of naturally occurring inorganic compounds that play vital roles in living systems, such as haemoglobin, Vitamin B12, or nitrogenase, or with the biological function of synthetic compounds, such as the anti-cancer agent cis-platin. An important role in these studies is played by the synthesis of new coordination compounds that attempt to model the structure, physical properties, chemical behaviour, and function of naturally occurring systems. The study of coordination chemistry is also important for the development of methods for the separation and purification of metal-containing systems.

(iii) Supramolecular chemistry, that is, the formation of new chemical structures by the assembly of molecular sub-units bound together by non-covalent interactions, is having a large impact on current chemical research and is likely to do so in the foreseeable future. Examples of supramolecular assemblies include 'host-guest' compounds in which a large 'host' molecule encapsulates a small 'guest' molecule within its structure. So defined, the field is not specifically inorganic but the incorporation of, for example, transition elements into such structures can confer interesting chemical, spectroscopic and magnetic properties.

With the recent termination of the Photophysics and Magnetic Resonance Group and the projected winding up of the Solid State Molecular Science Group in 2002, there is a serious concern that the School will go sub-critical in the area of experimental physical chemistry as well. Broad advertisement will determine the choice of appointment but major priorities identified relate to the fact that, for soft-matter chemical physics, the accessibility to Australia of major home based
and international facilities such as synchrotrons and intense neutron sources will open up opportunities for structural and spectroscopic work in the nanosecond, picosecond and possibly femtosecond time domains relevant to a fundamental understanding of the dynamics of chemical reactions in solutions and solids. The RSC is the logical place in Australia for these developments, given the School's high profile in computer simulation and theory. Experimental studies of the dynamics of fluids and weakly aggregated materials such as liquid crystals and gels on the above fast time-scales are also relevant to our work at the biology interface, including biological self assembly, biological mobility and photobiology. In these domains there are strengths in the School, the ANU in general, and the CSIRO. The existing infrastructure could provide a solid base for development.

With the establishment of two new groups in 1995, the pursuit of organic chemistry in its various facets constitutes one of the School's major strengths, but two groups, "Bio-organic Chemistry" and "Mass Spectrometry", are scheduled to be disestablished during the time frame of this strategic plan, while a third (Synthetic Organic Chemistry) is due to close down in 2004. A selection of these activities should be continued and/or replaced and be given suitable priority as funding permits, otherwise this section of the School could all too easily go sub-critical.

The areas of theoretical chemistry and biological chemistry have younger age profiles and are represented in as much strength as current or projected funding will realistically allow. Nevertheless, it will be important to continuously update the School's future hiring plans in response to unexpected staff movements. It is for this reason that the Strategic Plan only considers a 4 year horizon and foreshadows only two new appointments of research group leaders.

6.3 Research Groups

Synthesis and Mechanism: Dr Martin Banwell

The research activities of this group are focussed on developing new and efficient methodologies for the synthesis of target molecules ranging from biologically active natural products to compounds having unusual architectures that could be exploited for molecular recognition or materials science purposes. Natural products that have been targeted for synthesis include a range of anti-mitotic agents, herbicides and anti-influenza drugs. A second research focus involves microbial oxidation of aromatic substrates to provide enantiopure cis-1,2-dihydrocatechols for use as starting materials for the synthesis of a wide range of natural products. Another broad area of activity is concerned with exploiting ring-fused gem-dihalogenocyclopropanes in chemical synthesis. These compounds allow for the construction of molecular clefts which complex guest molecules and may serve as catalysts for various organic reactions.

The synthetic studies will continue into the foreseeable future, but in addition a program is being initiated that is aimed at the use of molecular biological techniques to generate new classes of micro-organisms that are capable of producing, in a predictable manner, novel metabolites of value as feed stocks for chemical synthesis.

Organotransition Metal Chemistry: Professor Martin Bennett

We have continued to develop the chemistry of benzylene-nickel(0) complexes, especially their regioselective double insertion of alkynes to generate substituted naphthalenes. Regiospecific insertions of acetylenic phosphines RC=CPPH₂ have allowed the synthesis of napthylene-2,3-diphenylphosphines, a new class of chelating ligand having a small bite angle. In future work, we intend to study alkyne insertions into benzdiyne complexes L₂Ni(C₆H₂)NiL₂, which should lead to 2,3,6,7-tetrasubstituted anthracenes, C₁₄H₁₆R₄. These are important building blocks for rigid conducting polymers and films in microelectronic devices but they are difficult to make by
conventional organic chemistry. This work will be continued by Dr Eric Wenger during the term of his ARC Fellowship (end of 2002).

Other work is focussing on the chemistry of unusual paramagnetic organometallic compounds of ruthenium, on the preparation and properties of novel compounds that contain unexpectedly close interactions between late transition metal atoms and mercury, and on the insertion of unsaturated hydrocarbons into platinum–oxygen bonds. These projects will close when Professor Bennett retires in December 2000. A project supported by Dr Wenger’s ARC Fellowship on the synthesis of early transition metal acetylides as models for the structures of metallocarbohedrenes that exist in the gas phase has been started and some promising leads are being pursued.

**Coordination Chemistry, Kinetics and Mechanism: Dr Nicola Brasch**

This new group is currently interested in mechanistic aspects of enzyme reactions mediated by Vitamin B$_{12}$. The main projects over the next few years will be (1) to examine the formation, stability and redox behaviour of the biologically important compound glutathionylcobalamin; (2) to investigate reactions that model the substitution of the $\alpha$-dimethylbenzimidazole of the B$_{12}$ coenzymes by a protein histidine side-chain; (3) to investigate the existence of five-coordinate “base-off” Vitamin B$_{12}$ complexes.

**Theoretical Chemical Physics: Dr Michael Collins**

This group has pioneered a new approach to constructing molecular potential energy surfaces (MPES) from *ab initio* calculations. Reaction mechanisms and rates for small polyatomic molecules have been revealed by the dynamical calculations that have been made possible with these MPES. Future methodology development is directed towards MPES for larger molecules and, if possible, fluids. At the same time, the group will expand their understanding of reaction mechanisms through the study of significant gas phase reactions.

**Protein Synthesis and Evolution: Dr Nick Dixon**

This group uses techniques in protein chemistry and molecular genetics to probe the chemistry of interactions between proteins and other molecules. Research is focussed in two areas. One aims to develop understanding of the structures and functions of bacterial DNA replication proteins, and involves strong collaboration with groups in RSC and elsewhere. Recent structural studies on the DnaB helicase, an intriguing molecular motor, will assist in discovery of new antibacterial drugs. The other area aims primarily to develop a new technique for directed molecular evolution of proteins. This technology promises to give access to entirely new proteins with selected new functions for use for a variety of purposes, and to provide important new tools for understanding the chemistry that determines protein function.

**Biochemical Reactions and Molecular Recognition: Dr Chris Easton**

The research of this group addresses a range of diverse areas which may nevertheless be characterised by one of two common themes: the study of reaction mechanisms, particularly those related to biochemical processes, and the area of supramolecular chemistry. In the first area, particular emphasis is given to free radical chemistry and reactions involving amino acids, peptides and proteins, while aspects of lipid synthesis, biosynthesis and metabolism are also under investigation. The second general theme of ongoing research is in the area of supramolecular chemistry and molecular recognition, involving the design and synthesis of cyclodextrins and other molecular hosts, tailored to form inclusion complexes with specific guests. Applications of this chemistry in the development of molecular reactors and switches are being pursued.
**Liquid State Chemical Physics: Professor Denis Evans**

This group has interests which include nonequilibrium statistical mechanics and thermodynamics. The group has been involved in the development of nearly all the computer simulation algorithms used in the calculation of transport properties of classical liquids. Applications have been made to studies of lubrication - particularly of hydrocarbons. The group derived the first exact, practical link between the mathematical theory of chaos, dynamical systems theory and thermophysical properties.

In the future new algorithms for simulating strong shear flow of molecular fluids will be developed. New theoretical methods will be applied to solving difficult problems involving molecular fluids undergoing strong flows. Work will continue on the elucidation of a theorem first enunciated by the group in 1993 - the so-called Fluctuation Theorem. This theorem gives an analytic expression for the probability that, for a finite system and for a finite time, the dissipative flux flows in the reverse direction to that required by the Second Law of Thermodynamics. The group plans to develop local, stochastic versions of the theorem applicable in a wide variety of thermodynamic ensembles.

**Coordination Chemistry and Inorganic Electrochemistry: Dr Graham Heath**

Recent achievements include identification of the first true di-osmium blues, the spectro-electrochemical characterization of diporphyrins linked by extended conjugated bridges containing up to eight carbon atoms, and the design of linear confacial homo- and hetero-tetrametallates including redox-active RuRuRuRu, RuOsOsRu, and OsRuRuOs arrays.

Our aim is to remain at the forefront internationally in applying electrochemical methods (UV-Vis, FTIR/EPR) to provide fundamentally new insights into the structure and electronic properties of transition metal compounds. Major goals for the next three years are the detailed investigation of mixed-valency in binuclear systems, and the urgent development of the unprecedented linear polymetallic arrays noted above.

**Nuclear Magnetic Resonance: Dr Max Keniry**

The Nuclear Magnetic Resonance group uses high-field and multidimensional NMR techniques to solve structures of biological macromolecules. Recent achievements include the structure determination of a DNA quadruplex, of a 4:2:1 mithramycin: Mg$^{2+}$:d(ACCCGGGT)$_2$ drug-DNA complex, of a potent analogue of insulin-like growth factor I, and of a subunit of a bacterial DNA polymerase. Future structural studies will probe the interactions between DNA polymerase subunits. To enable the group to target specific biological problems in larger proteins, it aims to set up in vitro protein synthesis technology aimed at specific labelling of proteins with stable isotopes. It will continue to develop pulse sequence technology as problems arise, particularly in relation to obstacles presented by dynamics within macromolecules.

**Laser and Optical Spectroscopy: Dr Elmars Krausz**

In recent years this group has pioneered and developed the application of spectroscopic techniques such as microcrystal spectroscopy and laser selective spectroscopy to the study of chemically and biologically important species in the condensed phase. This has enabled them to identify and study, critically, the microenvironment of fluxional species.

Continued introduction of innovative laser and other techniques will doubtless add to their armory. Strategically, the group intends to further pursue studies on important problems in biophysics and biochemistry, geophysics and geochemistry and nanostructured materials.

**Mass Spectrometry: Dr John MacLeod**

The group has introduced to the ANU new ionisation methods, including electrospray (ESI) and matrix assisted laser desorption (MALDI), for studying high molecular weight biopolymers. Using
picomole quantities of material, molecular weights of proteins can be accurately determined, sequences confirmed and post-translational modifications identified. The group has collaborated with biochemists in the ANU and elsewhere on a number of such projects using ESI to analyse the structures of highly sulfated sugars derived from chemical and enzymic cleavage of heparins, and in addition, it has developed GC/MS methodology to follow the incorporation of $^{13}\text{C}_2$ into sugar phosphates during photosynthesis in isolated chloroplasts. This research has produced results which could necessitate a modification of the long-established Calvin Pathway of photosynthetic carbon reduction.

A further interest of the group is the elucidation of the structures of a number of natural products derived from plant and bacterial sources, some of which exhibit interesting biological properties. Plans for the future include the further development of analytical techniques and their application to biological problems.

*Organic Synthesis: Professor Lew Mander*

The group is concerned with the development of methods and strategies for the stereo-controlled assembly and manipulation of complex organic molecules, and with structural, synthetic, biosynthetic and biological studies on plant hormones, pheromones and secondary metabolites, especially of the gibberellin bioregulators.

Future plans involve the continuation of several total syntheses that have been initiated in the last year or so, further development of strategies and methodology for the synthesis of complex organic molecules. A further focus of future research will be concerned with the role of the gibberellins in the regulation of plant growth and development and will include attempts to isolate and identify the molecular receptors. This work will underpin a large part of a global network involving approximately 40 groups. A licensing and research agreement is in place with the German company BASF and is likely to lead to a commercial product.

*Protein Crystallography and Engineering: Dr David Ollis*

The group uses X-ray crystallography to determine protein structures. The group’s work has increased understanding of mechanisms of signal transduction in the regulation of nitrogen uptake in bacteria, and has recently provided a structural explanation for light-controlled regulation of enzyme activity in plants. The group activities will continue with protein structure determination and protein engineering. New initiatives will be taken in the directed evolution of enzymes, focussing on esterases forming part of the $\omega/\beta$ hydrolase family. This work will led to a better understanding of how enzymes functions. It is of considerable interest to groups in the CSIRO division of Entomology and since it may have application in bioremediation. Other work may lead the group into the field of drug design. Structural studies of the IL-5 receptor suggest that this may be a useful target for anti-asthma drugs . This is a collaborative venture that involves other groups in the school as well as a group in the JCSMR.

*Theoretical Organic Chemistry: Professor Leo Radom*

As a culmination of several years of research in this group a neutral saturated hydrocarbon containing a planar tetracoordinate carbon atom has been designed and characterised through *ab initio* calculations. In addition the group has used *ab initio* calculations to help understand the mechanisms of enzyme-catalyzed reactions, particularly those involving coenzyme B12.

Future plans include building on initial work in the enzyme-catalysis area, and further development of the group’s partial-proton-transfer approach in this context. A key continuing interest will build on their fundamental studies of the theoretical treatment of free radicals to embark on detailed studies of free radical chemistry, including the involvement of radicals in biological and polymerization processes.
Bio-organic Chemistry: Professor Rod Rickards

The group studies the organic chemistry and biochemistry of compounds of medical, veterinary, agricultural and biological importance. Their research interests range widely and include antibiotics produced by microorganisms, regulatory factors which initiate antibiotic production and control cell differentiation and sexuality in microorganisms, juvenile hormones which mediate the development of insects, and the potent mammalian hormones of the prostaglandin group which control much human physiology. Their work involves an integration of organic synthesis, biomimetic synthesis, structural and stereochemical studies, and biosynthetic studies using isotopically labelled precursors in vivo.

Structural chemistry is also an important activity of this group, utilising advanced spectroscopy and assisted where appropriate by the biosynthetic or chemical incorporation of isotopic labels. A range of novel antibiotics from microorganisms has been isolated and characterised, and collaborative work in this area with other laboratories has been supported by major grants from the pharmaceutical and agrochemical industry and from government departments.

X-ray Crystallography of problem crystal structures: Professor David Rae

An ongoing interest in the reliable determination and refinement of problem crystal structures will be continued. A new CCD data collection system in late 1999 will greatly enhance the ability to handle such structures and is part of a general upgrade of X-ray data acquisition. Problems involving pseudo symmetry, twinning and disorder are often best understood using a modulated structure concept and this leads to a sensible hierarchical approach to such problems. There is usually an idealised parent structure (or substructures) from which the true structure can be derived. However important information is often associated with systematically weak reflections or small differences in reflection intensities, and often the various features make essentially uncorrelated contributions to the diffraction pattern. Consequently, modulated structures present challenging refinement problems requiring sophisticated refinement techniques.

Physical Chemistry of Polymers: Dr Edith Sevick

The research of this group focuses upon the physical properties of polymers, single chain molecules, polymers in solution and polymers at interfaces. Using theory and computer simulation, the group has studied polyelectrolyte electrophoresis in microlithographic arrays, compression of single-chains by finite obstacles, compression-induced phase transitions in polymer brushes, and polymer brushes as pressure-sensitive microvalves. Future plans include probing single chains using simulation, theory and a new experimental tool, optical tweezers, which allows imaging and micromanipulation of polymers. Another theme will be biologically important polymers, such as DNA and proteins, as well as self-assembly of non-linear polymers.

New Silicate Materials: Dr John Thompson

A major review paper has been published on cristobalite-related oxide structures, the culmination of 10 years’ research in this area with Dr Ray Withers of the Solid State Inorganic Chemistry group. A major research program has been carried out from 1997 to early 1999 on the synthesis, characterization and properties of talc derivative materials for application as detergent-builders in laundry detergent formulations. The research was partly funded by WMC Talc Asia Pacific, a subsidiary of WMC Resources.

Fundamental research will continue in pursuing new framework silicate structures in alkali aluminosilicate systems and in isoelectronic alkali magnesiophosphate systems. The group will be wound down towards the end of 2000 with the termination of Dr Thompson's current appointment at the beginning of 2001. This corresponds to the end of the five year New Silicate Materials strategic initiative funded by the ANU's Strategic Development program in the 1995 round.
Biomolecular Simulation and Calculation: Dr Andrew Torda

The aims of this group has been to build functions like molecular mechanics force fields, but optimised for special purposes such as recognising the 3D shape of a protein. En route, novel optimisation algorithms have been developed. In the future the group will continue to develop force fields but also to mix bioinformatics, molecular mechanics and algorithm design. The new methods will improve structure prediction and allow a move into areas such as protein design.

Disordered Materials: Dr Richard Welberry

Pioneering research has been performed by this group on the measurement, interpretation and analysis of diffuse X-ray scattering from disordered crystals. Not only has the group developed an experimental system for recording high-quality diffuse diffraction patterns from a wide range of materials but also the group has established a general framework of methods and strategies to model these systems using computer simulation. Convincing models have been established for the complex disordered structures of the commercially and geologically important materials, which had puzzled scientists for over 30 years. Recently, the group has developed a method for directly fitting a Monte Carlo (MC) simulation to observed X-ray diffraction data, using a least-squares technique - a very considerable advance on the group’s previous more qualitative approaches. This new technique puts the analysis of diffuse scattering on a par with that held by conventional crystal structure determination at the point when digital computers first began to be used in the 1950’s. With the expected increase in computational power available in the next few years, Dr Welberry’s methodology will really come into its own and begin to make widely available for the first time the unique structural information obtainable from diffuse scattering. The group’s present intention is to diversify the method to as wide a range of problems as possible and so show the way for future applications.

Solid State Molecular Science: Professor John White

The group has developed new X-ray and neutron scattering methods to study the structure and dynamics of adsorbed molecules, the process of self-assembly at interfaces, the dynamics of polymers, and the induction of structure by template molecules. The insights gained are used to guide new materials synthesis. A recent success has been to follow the template induced growth of a mesoporous silicate at the air-water interface. This could only be observed in detail by use of the group’s X-ray reflectometer, the first instrument of its kind in Australia. The world’s first millisecond reflectometer is being constructed at RSC in collaboration with University of Queensland, ANSTO and the Consortium for Advanced Radiation Sources at the University of Chicago. This will be capable of measuring monomolecular film structure on second to millisecond time scale, for example, in connection with lung surfactancy.

Inorganic Stereochemistry and Asymmetric Synthesis: Dr Bruce Wild

The first optically active dinuclear and trinuclear metal helicates containing tetra- and hexa-tertiary phosphines have been isolated and structurally characterized. The disilver compounds, in particular, show high activities in vitro against certain mouse tumour cell lines and are relatively non-toxic. In other work, the first simple phosphiranium and phosphirenium salts have been isolated. The three-membered heterocycles undergo facile olefin and alkyne exchange, which is unprecedented in heterocyclic chemistry. Future work will be directed towards the synthesis of the helicating diastereomer of a linear octatertiary phosphine. Molecular modelling suggests that the optically active octaphosphine will stereoselectively self-assemble double-stranded tetranuclear metal helicates with univalent Group II ions. The small phosphorus heterocycle chemistry will be extended to include intramolecular cycloadditions. The use of chiral phosphine-stabilised phosphonium and arslenium salts for the asymmetric syntheses of tertiary phosphines and arsines will be explored. The biological syntheses
of optically active arsines will also be investigated in detail, following the discovery of this phenomenon in our group some years ago.

**Solid State Inorganic Chemistry: Dr Ray Withers**

Our research interests centre upon flexible materials whose structures and properties can be easily altered via temperature, pressure or chemical doping. Recent achievements include the detailed structural characterization of a range of incommensurately modulated, “infinitely adaptive” solid solutions and the discovery of displacive flexibility and its consequences in tetrahedral framework structures.

Future research will be aimed at understanding oxygen ion conductivity in various solid electrolyte systems, the compositional– and temperature–dependent ranges of existence of various non-stoichiometric solid solutions, and the systematic application of group theoretical techniques to the structural characterization and inter-relation of families of related phases.

**6.4 Infrastructure Support**

There will be a continuing requirement to replace and augment ageing and technologically obsolescent equipment. While the cost for individual items may not be large, the numbers are considerable. Microcomputers and computer workstations, in particular, are a major cost burden (~$130K p.a.). The equipment budget for the RSC will accordingly need to be maintained at a minimum of $600K p.a.

In addition, further funding for major items will be required. A CCD area detector X-ray diffractometer based on new high speed, two-dimensional imaging technology ($0.56M) will be installed late in 1999. Upgrades to HPLC equipment ($100K) will occur in 2000. Access to regional, national and international facilities, *e.g.* synchrotrons will also need to be financed, such as by the "purchase" of beamlines. Because of Health and Safety issues, the School has special needs required by the upgrade and augmentation of fumehoods ($0.75M over the next 10 years). A millisecond reflectometer to study molecular film structure and dynamics, and a bioreactor for large scale batch production of novel metabolites have recently been supported by RIEF grants of $100,000 and $172,000 respectively.

A major problem is the replacement of large numbers of relatively inexpensive equipment items (less than $20K). For example, the School has approximately 100 Rotavaps with an average age of 25 years. These have been repeatedly repaired and refurbished, but they must soon be replaced. Although the replacement cost for each is modest, the total replacement cost is $400,000.

A large part of the School’s equipment budget is expended on these small equipment items. The University’s major equipment fund has a threshold which is typically set at $70K so most equipment must be supported from School resources. This ratio of internally supported to University supported equipment is very discipline dependent. In experimental physics for example, a much greater proportion of equipment falls into the major equipment category. Upgrading of electronic test equipment and lathes etc also fall outside the conditions for the Major Equipment Fund. In an era of declining budgets our support of many items of small equipment is severely compromised by the somewhat arbitrary cost threshold of the University’s Major Equipment Fund and its requirement for matching funds.
Appendix A

Extract from a speech by Vice President Gore on Science and Technology on 24 January 1998 to the annual meeting of the American Association for the Advancement of Science:

"Ever since our nation's founding, our boundless search for new frontiers - our ceaseless quest for knowledge and discovery – has defined the American experience. Today, more than at any time in our history, the strength of our economy, the health of our families, and the quality of our lives depend on the advances that each of you will make. As our research into science and information technology goes, so will go our jobs, our incomes, and the prosperity of our nation. Put simply, the success and health of our families in the next century will depend upon the decisions - and the investments - we make today.

That's why President Clinton and I have so aggressively pushed for new and targeted investments in research and information technology. Six years ago, we took office with a fundamental belief: that government must support fundamental investments in science and technology -- even when we don't know precisely where those investments will lead.

Last year, we launched the 21st Century Research Fund -- including the largest investment in civilian research and development in American history. I am here today to reaffirm our commitment to research and discovery and to announce some of the next steps we are taking to lead America into the 21st Century."
Appendix B

The issue of combining government and corporate funds to support basic science research is hotly debated by national policy makers in the United States. A nationwide debate of this depth has not taken place in Australia – but it should if we hope to remain competitive. Here in Australia, institutions are responding to the decline in basic research dollars from the government by increasing external funding targets. But the value of one external funding dollar is very different from a taxpayer dollar and that balance depends upon the mission of the institution.

Bipartisan Committee on the S.1305 the National Research Investment Act of 1998: Phil Gramm, Joseph Lieberman, Pete Domenini & Jeff Bingaman:

"The Federal Government should patiently invest in science, medicine and engineering that lies within the public domain. Once an industry or company begins to pursue proprietary research, then support for that particular venture is best left to the private sector. This is what we mean by the term precompetitive research."

Richard Nelson, an economist from Columbia University:

"My second proposition … is that civilian technology policy in general should stay away from supporting research and development in individual firms. I believe that this stricture applies even when the project proposed by researchers in an individual firm is quite basic in nature, and some distance away from any clearly defined commercial objective. While one can think of exceptions, it is highly unlikely that a firm would put forth a proposal for public support unless it believed that it could gain commercial advantage by undertaking the project."

Or in other words, the taxpayer might not want to partake in projects whose complete return on investment is handed to the firm rather than retained fully in the public domain. And it is unlikely that a firm would contribute to the research without some type of market control; either placing restrictions on the dissemination of the information, or limiting others from using it."

US National Academy of Sciences (NAS), panel chaired by NAS President Frank Press, as reported by Claude E. Barfield, Director, Science & Technology Policy Studies, American Enterprise Institute:

"In the face of the reality of declining R&D budgets, the (Frank) Press panel argues that . . . lower priorities (be) assigned to federal support for commercial technology development. ..The panel noted its belief that 'government policies, such as those related to taxation, regulation, intellectual property rights, social mandates, and others are usually more important to commercial outcomes than is direct government to industry.' Regarding specific technology development programs such as the Commerce Department's Advanced Technology Program (ATP) and the DOD Technology Reinvestment Program, the panel was 'skeptical' that they represented the most efficient use of scarce federal funds."