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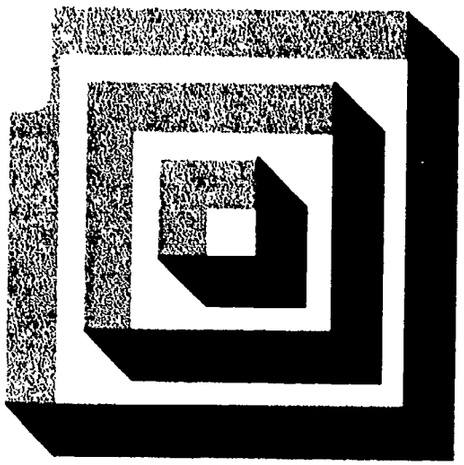
ABSTRACT

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning has conducted a planning assessment for graduate studies in physics and astronomy. Contents of the report encompass future enrollment projections in physics graduate studies, the distribution of physics graduate students among the universities, and graduate work in astronomy in Ontario. Recommendations of the committee suggest: (1) That the universities plan on a level of enrollment suggested by the consultants; (2) That the Discipline Group report annually on the location of the undergraduate training of the new graduate students in each department; (3) That urgent attention be given to the question of research funding for professors whose departments do not offer graduate programs in their fields; (4) That the Physics and Astronomy Discipline Groups, in their normal role, annually review admission standards by examining records of newly enrolled graduates, and periodically review the plan for physics and astronomy as to enrollment levels and adequacy of coverage of the specialities, including neglected fields; and (5) That the universities formulate policies governing applied research. (MJM)

Council of Ontario Universities

Perspectives and Plans for Graduate Studies



14 Physics and Astronomy 1974

Advisory Committee on Academic Planning

Ontario Council on Graduate Studies

Council of Ontario Universities
Conseil des Universités de l'Ontario

PERSPECTIVES AND PLANS FOR GRADUATE STUDIES

14. PHYSICS AND ASTRONOMY 1974*

Advisory Committee on Academic Planning
Ontario Council on Graduate Studies

* The status of this report is given in Item 2 of the statement of principles, on page 1.

PERSPECTIVES AND PLANS FOR GRADUATE STUDIES

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FOREWORD

The Advisory Committee on Academic Planning (ACAP), as presently constituted, was established by the Ontario Council on Graduate Studies at the request of the Council of Ontario Universities in January, 1971. The Advisory Committee's terms of reference were directed broadly toward the effective planning and rationalization of long-term graduate development in Ontario's universities both at the level of individual disciplines and at a more general level. The Advisory Committee's activities are based on the premise that graduate work is the one area of university activity in which specialization among universities, cooperative arrangements and comprehensive planning are most necessary.

In March, 1971, concern over the rising costs for support of graduate work prompted the Ontario government to institute a general embargo on funding for any new graduate programme, that is, one which had no students enrolled on May 1, 1971. This embargo was subsequently modified to include only those disciplines in which over-expansion was felt to be potentially most serious. ACAP was to begin immediately planning studies in those disciplines which remained embargoed.

The disciplinary planning process begins with the formation of a discipline group composed of one representative from each university with an interest in graduate work in the planning area. The discipline group assists in defining the precise academic boundaries of each study, scrutinizes the data collection forms, prepares a list of potential consultants, maintains contact with the consultants during the study, and prepares a commentary on the consultants' report.

The final decision on consultants for the planning study is made by ACAP. The consultants are requested to make recommendations on programmes to be offered in Ontario, desirable and/or likely enrolments, the division of responsibility for programmes among universities, and the desirable extent of collaboration with related disciplines.

While the consultants' report is the single largest element in the final report on the planning study, ACAP considers the statement of each university's forward plans to be most significant. These forward plans are usually outlined prior to the planning study, and are used as a basis for comments from the universities concerned on the consultants' report.

On receipt of the consultants' report, and comments on it from the discipline group and the universities, ACAP begins work on its own recommendations for submission directly to the Council of Ontario Universities. COU considers the input from all sources, and prepares the position of the Ontario university community.

The following report is one of a series of disciplinary planning studies carried out by the Advisory Committee on Academic Planning and to be published by the Council of Ontario Universities. The emphasi of the report is on forward planning, and it is hoped that the implementation of COU's recommendations will help to ensure the more ordered growth and development of graduate studies in Ontario's universities.

Council of Ontario Universities
Conseil des Universités de l'Ontario

Report and Recommendations concerning Graduate Studies in Physics and Astronomy

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning has conducted a planning assessment for physics and astronomy. The resultant report from ACAP is attached together with the consultants' report, the comments by the discipline groups, and the comments of the individual universities. The procedure followed and the planning techniques used are described in the ACAP report and are not repeated here. It is important for the reader to read the ACAP report and attachments in order to understand the recommendations in this Report from COU.

The Council received the ACAP report and supporting documentation on September 6, 1974. The report was discussed on that occasion and on October 3 and December 5, 1974.

As a result of these discussions this Report and Recommendations were prepared, and approval by the Council was completed on December 5, 1974. The Report is addressed to the Ontario Council on University Affairs and the universities of Ontario.

The following principles have been adopted and will apply to this and all other COU Reports arising out of assessments.

1. Discipline assessments by ACAP should form the basis for planning by the universities of their development of graduate studies, particularly PhD programmes. On the basis of these assessments, COU should make its own recommendations on currently embargoed programmes. Each university must retain the freedom and responsibility to plan and implement its own academic development. However, the universities in embarking on a cooperative planning process have signalled their intentions of cooperating with the COU recommendations.

2. Universities generally plan their emphases in graduate study on the bases of related departments, not of single departments. Initially the sequential nature of the discipline planning assessments made this difficult. However, by the summer of 1974 assessments of most of the social sciences, all of the physical sciences, engineering doctoral work, and a number of professional areas were completed. On the information and recommendations available, each university should be able to make decisions concerning its support of graduate programmes in these areas. Amendments to university responses to the individual discipline planning assessments may then be made in the wider context of a group of related disciplines and amendments to COU's original Reports on an individual discipline may be required.

3. The first concern in planning is to review the quality of graduate opportunities and of students in Ontario universities and to make judgements about how to proceed or not proceed based on quality considerations. The procedures have made use of highly qualified independent consultants who have no direct interest in the universities in Ontario. Accordingly, COU feels bound to accept their judgements about quality where they are stated clearly unless unconvinced that their conclusions about quality are consistent with their evidence. COU's recommendations in the case of programmes which are of unsatisfactory or questionable quality will call for discontinuation or the carrying out of an appraisal, if the continuation of the programme is not crucial to the province's offerings. In some cases, however, there may be a particular need for the programme and the appropriate recommendation will be to strengthen it, with an appraisal following that action. It is also possible that if there were found to be too large a number of broadly based programmes there could be a recommendation to discontinue the weakest; in this case an appraisal for a more limited programme might be relevant.

4. A second consideration is the scope of opportunities for graduate work in the discipline. Do the Ontario programmes together offer a satisfactory coverage of the main divisions of the discipline?

5. Numbers of students to be planned for will depend on the likely number of applicants of high quality and in some cases may relate to an estimate of society's needs. Such estimates may be reasonably reliable in some cases and not in others. If the plans of the universities appear to be consistent with the likely number of well-qualified applicants and there is either no satisfactory basis for estimating needs or there is no inconsistency between a reasonable estimate of need and the universities' plans, then COU will take note of the facts without making recommendations on the subject of numbers.

   If the numbers being planned for by the universities are grossly out of line with the anticipated total of well-qualified students, or a reliable estimate of needs, COU will make appropriate corrective recommendations. Depending on the circumstances, these may call for a change in the total numbers to be planned for and indications of which institutions should increase, decrease, or discontinue. The recommendations in serious cases may need to specify departmental figures for each university for a time. If the numbers being planned for are insufficient, the recommendations may call for expansion, or new programmes, and may have implications for both operating and capital costs.

   Unless there are exceptional circumstances, the recommendations concerning enrolment will not call for a university to refuse admission to any well-qualified student who wishes to work in a field in which that university offers a programme and in which it has the capacity to accommodate the student.

6. The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design.

7. Universities will be expected to notify COU if they intend to depart from the COU Report in any way which they believe might have a significant bearing on the provincial plans.

8. Appraisals arising as the result of assessments are to be based on the standards but not necessarily the scope of the acceptable programmes in the province.

General observations

1. The quality and breadth of coverage of Ontario graduate physics programmes is variable. Two are very good and in a decade or so could be amongst the world's recognized centres of excellence. The others all have a valuable specialized role to play in Ontario graduate physics education.

2. The fields of physics and astronomy are adequately covered but more attention should be given to optics and acoustics in physics departments and the astronomers should continue to concentrate their efforts on a few selected fields.

3. The enrolment is unlikely to reach the levels forecast by the universities and they are advised to plan accordingly.

4. Astronomy is well covered in the province by the renowned programme at Toronto and the smaller specialized programme at Western Ontario. In addition, several universities cover astronomical topics in their physics departments. Vigorous cooperative programmes with other countries hold the key to Canada's future in astronomy.

5. There is concern that too many students are remaining for graduate work at the university where they studied as undergraduates.

Action by COU

1. COU requests ACAP to arrange that the physics and astronomy discipline groups, in their normal role, in consultation with ACAP, annually review admission standards by examining records of newly admitted students, annually report the universities at which newly enrolled graduate students received their undergraduate education, and periodically review the plan for physics and astronomy as to enrolment levels and adequacy of coverage of the specialties, including neglected fields.

Recommendations

It is recommended that:

1. The universities plan for the level of enrolment expected by the consultants.

2. Urgent attention be given to the question of research funding for members of faculty whose departments do not offer graduate programmes in their fields.

3. McMaster University and the University of Toronto continue their master's and general doctoral programmes in physics in accordance with their plans.

4. The universities with specialized doctoral programmes not commit additional resources in order to pass appraisal in current fields of specialization other than those specified in the appropriate recommendation below. Enrolment of new students in fields other than those specified below should cease after April 1, 1975. If a university wishes to continue doctoral work in one of the fields not specified below it is recommended that the university submit the programme in that field for consequent appraisal by February, 1975, ceasing to enrol new students in that field after January 1, 1976, if a favourable appraisal has not been obtained.

5. Carleton University continue its master's programme according to its plans and continue its doctoral programme in high energy physics, both experimental and theoretical.

6. The University of Guelph continue its master's programme according to its plans and begin doctoral work in:

   a) condensed matter physics and nuclear physics,
   b) molecular physics but only after referral to the Appraisals Committee for clarification of its current status, and
   c) theoretical physics (which is a new programme) after a favourable finding by the Appraisals Committee.

7. The University of Ottawa continue its master's work according to its plans and continue its doctoral programme in solid state physics, both experimental and theoretical.

8. Queen's University continue its master's programme according to its plans and continue its doctoral work in nuclear physics, solid state physics, theoretical physics, and astronomy and astrophysics.

9. The University of Waterloo continue its master's programme according to its plans and continue its doctoral work in theoretical physics, and solid state physics, both experimental and theoretical.

10. The University of Western Ontario continue its master's programme according to its plans and continue doctoral work in chemical physics, atomic physics, and atmospheric science. It is recommended that the University consider what organization will be most advantageous to concentrate and improve its resources for offering doctoral work in theoretical physics and submit a proposal for appraisal, ceasing to enrol new students in theoretical physics in either its Department of Physics or its Department of Applied Mathematics after the fall term, 1976, if a favourable appraisal has not been obtained.

11. The University of Windsor continue its master's programme according to its plans and continue doctoral work in atomic and molecular physics, relativistic physics, and solid state physics.

12. York University continue its master's programme according to its plans and continue doctoral work in atomic and molecular collisions and structures, chemical physics, atmospheric physics, and astronomy and astrophysics.

13. Brock University continue its master's programme in physics, subject to review by the Appraisals Committee.

14. Lakehead University continue its master's programme in physics subject to obtaining a favourable appraisal. Enrolment of new students should cease after the winter term, 1976, if a favourable appraisal has not been obtained.

15. Laurentian University, in accordance with its plans, cease to enrol new students in a master's programme in physics after the fall term, 1975, unless:

    a) the physics programme has been favourably appraised, and
    b) the University has obtained approval for an amended five-year plan that includes physics.

16. Trent University continue its master's programme in physics, subject to review by the Appraisals Committee.

17. The University of Toronto continue its master's and doctoral work in astronomy according to its plans.

18. The University of Western Ontario continue its master's and doctoral work in astronomy according to its plans.

19. In view of the acceptance of these recommendations by COU and the completion of this planning assessment, the Ontario Council on University Affairs request the Minister to remove the embargo on physics and astronomy in accordance with the original announcement of the Minister that new graduate programmes would be embargoed until for each discipline, a planning study has been conducted.

Notes concerning the Recommendations

Re: Recommendations 3 and 4

Universities are specified for general programmes in this report, as in previous reports, because of their breadth of coverage of the fields of the discipline as well as their overall excellent quality. A university with a general programme must, like all universities in Ontario, submit a proposal to add a new field for review by the Appraisals Committee. The breadth of coverage in specialized programmes, although not as great, varies considerably and these programmes submit new fields not only for appraisal, but also for planning action by COU.

ADVISORY COMMITTEE ON ACADEMIC PLANNING

ONTARIO COUNCIL ON GRADUATE STUDIES

REPORT TO THE COUNCIL OF ONTARIO UNIVERSITIES

ON

PHYSICS AND ASTRONOMY PLANNING ASSESSMENT

November 8, 1974.

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PROCEDURE

On the advice of the Ontario Council on Graduate Studies, the Council of Ontario Universities on April 7, 1972, instructed the Advisory Committee on Academic Planning to conduct a formal planning assessment in physics and astronomy.

A Physics Discipline Group and an Astronomy Discipline Group were formed consisting of members named by each interested university. A list of members is attached as Appendix E. Professor B. N. Smallman, followed by Professor H. C. Clark held the ACAP physics and astronomy portfolio and attended meetings when ACAP representation was necessary.

The procedure and terms of reference for the planning assessment were approved by OCGS and COU, the latter's approval being received on April 6, 1973. This document is attached as Appendix D.

The Discipline Groups began their meetings in September, 1972. In accordance with the procedure, the Discipline Groups provided ACAP with a list of possible consultants. ACAP obtained the services of Professor L. H. Aller, University of California, Dr. A. E. Douglas, NRC, Professor R. R. Haering, University of British Columbia, and Professor P. N. Nikiforuk, University of Saskatchewan. Brief curricula vitarum appear as Appendix G. Dr. Nikiforuk played the role of the senior Canadian academic from outside the discipline in this planning assessment. The consultants held their first meeting in Toronto in June, 1973 and discussed, with the Discipline Groups, their schedule of visits to the universities. These began in July and continued through October.

The draft report of recommendations was presented to the Discipline Groups for informal comments on March 18, 1974, and the final report was subsequently received and distributed March 29, 1974. The Discipline Groups and the universities were requested to submit comments to ACAP by June 7.

After receipt of these comments, a subcommittee of five ACAP members met to draft the ACAP recommendations to COU. A number of universities in their responses to the consultants' report, raised points that the subcommittee thought needed clarification. In particular, it was felt that the consultants had not fully discharged their responsibility to describe strengths and weaknesses of departments and it also seemed desirable to explore alternatives to their enrolment "quotas". The subcommittee met with three of the consultants to discuss these points and subsequently letters were exchanged with the consultants. These letters are appended to the consultants' report, which is Appendix A to this report. The Discipline Groups' comments plus those of the universities appear in Appendices B and C respectively. The latter includes only those comments specified by each university for publication.

This report then is based on these data, reports and comments, and sets out recommendations for COU on the plan for graduate work in physics and astronomy in the province for the next several years.

As is required, ACAP presents this report directly to COU. It has been transmitted, as well, to the Ontario Council on Graduate Studies and the Council of Deans of Arts and Science for information.

PLANNING TECHNIQUES

For some years now, the universities of Ontario have been committed to the belief that the quality and effectiveness of graduate study in the province can be ensured only by collective and cooperative action. This implies a mechanism for continuing consultation and agreement so that the plans of each university for each of its disciplines are concerted with those of the other universities. At any given time there will exist a plan for the development of each discipline, with agreed and understood roles for each department; since graduate education is the most advanced formal intellectual activity and is, therefore, undergoing change, it is necessary that such plans be kept under regular review and be subject to ready amendment.

The Council of Ontario Universities has assigned to the Ontario Council on Graduate Studies the task of advising it on the development of such plans and of the steps to be taken to carry them into effect. The standing committee which carries out these tasks for OCGS is the Advisory Committee on Academic Planning. A significant role is also played by the discipline groups, one of which is established for each subject, with a representative from each interested university. Each discipline group has the function of assisting and advising ACAP in connection with its own subject.

The above may give the impression that the planning activity is fragmented on a disciplinary basis. This would, of course, not be acceptable. Since the development of one department in a university should not be considered independently of its contribution to the rest of its university and of the influence of the university as a whole on the department, it is most important that universities as institutions play a central role in the planning process. One of the most effective ways of doing this is by indicating to ACAP the nature of institutional commitments to a department and institutional aspirations for the department.

The most significant single input to a planning assessment is the set of statements from each university of its plans for its department. When these are subjected to collective scrutiny it may be found that their totality constitutes a reasonable plan for the discipline in Ontario, but in any case this set of plans is the first approximation to the provincial plan, which the planning assessment may have to refine if there are duplicated features, lacunae in offerings, too large a total enrolment, or other reasons to recommend altering some of the university plans. The universities are also involved in that the bodies that act on ACAP reports, i.e. both COU and OCGS, are composed of universities.

The formal documents stating the responsibilities of ACAP and the Discipline Groups are Appendix F. Briefly summarized, it is ACAP's function to advise on steps to be taken to implement effective provincial planning at the graduate level, to promote the arranging of the graduate programmes of the province in order to enhance and sustain quality and to avoid undesirable duplication, and, when necessary, to carry out formal planning reviews for disciplines. A discipline group has the responsibility of keeping under review the plans for graduate work in the discipline and making regular progress reports to ACAP in connection with graduate work in that subject. To make all this possible, it has been agreed that ACAP

may communicate directly with universities and discipline groups, to request necessary information, to discuss reports, to convene meetings, and to make and receive proposals for the future.

The above information has been given in some detail because it constitutes the mechanism currently approved by COU for cooperative graduate work. It is fair to say that in 1971 there was no mutually agreed plan for graduate study in any discipline. Our task is not only to generate the first such plan for each subject but also to ensure that it is kept under continual review.

There are four fundamental components in the plan. The first is analysis of the fields of study, the formats of study which should be available to prospective students in the province. The second is an estimate of overall provincial enrolment at master's and doctoral levels based principally on the likely numbers of highly qualified applicants. In regard to considerations of manpower needs for the province of Ontario, ACAP is conscious of the unreliability of forecasts and, except in special cases, subscribes to the approach proposed in the Macdonald Report (1969):

> "The country as a whole and the provinces must be concerned about manpower requirements. This concern can be expressed in the first instance through careful survey and forecasting of manpower needs on a continuing basis. Such forecasts should be given wide circulation. It is reasonable to expect that universities will respond by creating additional opportunities for study in the areas of shortage. In addition, the universities through their counselling services have a duty to advise students about the opportunities in various fields from the standpoint not only of intellectual challenge but also of vocational prospects and social utility. The reaction of prospective students to such forecasts is likely to provide an effective control. We believe the market-place, if its trends are made explicit, offers an adequate governor to prevent serious surfeit and to encourage movement of students toward fields of opportunity."

The third component of the plan is an indication of the role to be played by each department in terms of the programme it will offer and its academic emphasis. Cooperative arrangements between departments are stressed. The fourth component consists of an examination of the enrolment plans of the universities and consideration as to whether the universities' plans and the predicted enrolment for this discipline are consistent. If not, some appropriate action should be recommended to COU. It will be seen that although there may also be other aspects, these are four necessary components in such a plan.

In the physics and astronomy assessment, an imbalance appeared, with the universities planning for more doctoral students than the expected number of highly qualified students, and while this report does not propose any numerical restrictions on enrolment at any university, the recommendations of the report are consistent with an atmosphere of static or falling enrolment, and it is recommended that the universities in general plan accordingly.

One must hasten to add that the future is uncertain and that to forecast intellectual trends, student interests, and employment markets five years hence is to undertake to examine many variables. Of course, this is not a new exercise since all universities have had to make decisions about building, staff hiring, library expansion, equipment investment and so forth and have done so on a basis of similar forecasts. Perhaps sometimes the forecasts have been more intuitive than consciously recognized, but they have certainly been there. All that is new is to make such plans systematically for the province.

It will be realized that, at a minimum, the ongoing planning procedures we have indicated require annual reporting of enrolments and annual examination of admission standards. When there are indications from these or other sources that some aspects of the plan for the discipline are not being realized, it will be necessary for ACAP to initiate a review. Such a review would usually not involve outside consultants. Whether the impetus came from a discipline group, a university or ACAP itself, comments would be sought from all concerned and the review would culminate in a report to COU recommending an amendment to the plan.

If a university notifies ACAP of its intention to depart from its accepted role (for example to enrol students in a field not included in its understood plan), ACAP will review the situation in the light of any other such notifications it may have received and any other pertinent factors. The extent of any further study would depend on the situation, but if ACAP felt that the university's new plan could be a cause for concern, its first step would be to seek full discussion with the university. Normally there would already have been discussion in the discipline group and between universities and the university would have reached its intention after a careful examination of the general situation of graduate study in the discipline. Thus the ACAP decision would be straightforward and a change in plan would be recommended to COU through OCGS. If, however, ACAP still felt that there was a probability that the university's action might be found, on further study, to be potentially harmful to the system, it would probably next seek comment from other universities concerned and from the discipline group. In any case, ACAP would eventually make some recommendation to COU (through OCGS) concerning the variation.

It is difficult without a concrete case to speculate on likely recommendations, but perhaps two hypothetical situations will illustrate the extremes. If a university indicated that, without any marked change in the academic emphasis of its department, it proposed to arrange to enrol somewhere around 70 graduate students instead of about 50, and if there were no changes at other universities and no potential developments which could be substantially affected, ACAP would presumably simply notify COU of the university's intention and recommend that it be recognized as an alteration in plan for the discipline. At the other extreme if a university proposed to begin a new programme designed to enrol fairly soon some 30 PhD students in a field of the discipline already well covered in other universities, it would clearly be necessary to obtain reaction from the discipline group and from other universities and perhaps even some expert advice, in order for ACAP to generate an advisory position concerning the impact of the

proposal on the system and suggestions to the university concerned and to COU. As has been noted, if there had been advance inter-university discussions and agreement, this would be a positive factor in ACAP's assessment, but there is of course the possibility that the recommendation would call for modification of the university's intention; we take that to be the obvious consequence of system planning. Of course, the university could decide to act in a manner contrary to a COU recommendation, accepting whatever consequences would result; we take that to be the basic right of university autonomy. It is understood that a university will not act in this way without the notification and review described in the preceding paragraph.

GENERAL RECOMMENDATIONS

This section will contain recommendations of a general nature applicable both to physics and astronomy.

References following a recommendation refer to the consultants' report. It is important to remember that the consultants' report and addendum plus the universities' and discipline groups' comments should be read at the same time as this ACAP report, of which they are an integral part. They provide substantiation for the recommendations made here. As has been our custom with other disciplines we prefix our recommendations to COU with the symbol 'C' to avoid confusion with numbering in the COU report.

Enrolment Forecasts

The universities, in their submissions to ACAP have projected a growth in physics enrolment to about 590 full-time graduate students for 1978, a 40% increase from the 1973-4 enrolment of 420. This contrasts sharply with the consultants' best estimate of about 350. The consultants' figure is based on their discussion of demand for physicists found on pages A-16 to A-20 and on the probable number of undergraduates now enrolled who will continue on to graduate work. The number of students in honours and major BSc courses in physics has not increased for some years. This disparity in the numbers forecast can be somewhat lessened by the knowledge that the universities projected a "desired rather than an expected" number of students.

At the moment, it is not apparent that the number of jobs for physicists is once again increasing (as appears to be the case in engineering) but the time may well come when the job market will be more healthy. In ACAP's view, it is wrong to discourage bright young Canadians from entering graduate physics study. One of the main problems to be faced is the small number of well-qualified Canadians who want to undertake graduate work. This, coupled with changes in the immigration regulations which will reduce the number of non-Canadians, will make qualified candidates in short supply.

On pages A-46 to A-48 the consultants paint a similar picture for astronomy. They predict that the PhD enrolment will fall to 15 by 1978 from its present level of 24 and that the master's enrolment will level off. Both Toronto and Western in their statements have agreed with this downward enrolment trend and are prepared for it.

Recommendation C1

> It is recommended that the universities plan on the level of enrolment suggested by the consultants. (See pages A-16 to A-20.)

Mobility

Recommendation C2

> It is recommended that the Discipline Group report annually on the location of the undergraduate training of the new graduate students in each department. (See Recommendation 6 and page A-51.)

The consultants were concerned with the lack of mobility of the undergraduates who often stay on to do all graduate work at the institution from which they obtained bachelor's degrees. ACAP feels that withholding BIU support is impractical as a means of increasing mobility, particularly since there would be no similar factor influencing actions in departments outside Ontario. It was suggested as an alternative that NRC might be asked to alter its regulations so that scholarships would not normally be tenable for three degrees from the same university. However, at the present time, we make the same recommendation which has been made for other disciplines. It is clear that this is a general problem - albeit one about which the physics community feels strongly - and for the moment we propose only a watching brief. If the situation remains unsatisfactory, further action may be proposed to OCGS.

Research Funding

Recommendation C3

> It is recommended that urgent attention be given to the question of research funding for professors whose departments do not offer graduate programmes in their fields, including the possibility of assignment of a BIU weight for post-doctoral fellows. (See Recommendation 11 and page A-55.)

The consultants felt that the emergent universities need special grants to support research but ACAP feels this is a problem faced by all the universities and should be studied by the province. It has been referred to in almost all our other reports.

Role of the Discipline Groups

Recommendation C4

> It is recommended that the Physics and Astronomy Discipline Groups, in their normal role, in consultation with ACAP, annually review admission standards, by examining records of newly admitted students, annually report the undergraduate universities of all newly enrolled graduates, and periodically review the plan for physics and astronomy as to enrolment levels and adequacy of coverage of the specialties, including neglected fields. (See Recommendations 3,6,9, and 10.)

The consultants feel there is a continuing role for the Discipline Groups to play in the planning of physics and astronomy in the province. As

well as monitoring the mobility of graduate students by checking the university of their earlier degree(s), the Discipline Groups can also assure equal standards of admission by post facto examination of new admissions. They also have the job of advising on the coordination of research areas covered by the province's various departments and in particular considering the desirability of covering neglected fields such as acoustics and optics in physics, and solar physics and meteor astronomy in astronomy.

Applied Research

Recommendation C5

> It is recommended that the universities formulate policies governing applied research. (See Recommendation 7, page A-52 and the addendum page A-84.)

The consultants make a number of disquieting remarks about the extent of applied physics in some departments. They propose it constitute no more than 25% of research activity. Applied research should, in its proper sense, be a practical application for some of a professor's fundamental work and not a project undertaken simply because there is funding available. The student should be free to publish his research findings, not restricted because his professor's work is proprietary. The consultants recommend and ACAP concurs, that guidelines should be drawn up by the universities governing applied research, paying particular attention to the questions of academic freedom and of the coherence of the departments. ACAP urges all universities which have not already developed such guidelines to do so.

DOCTORAL PROGRAMMES IN PHYSICS

Some confusion has arisen because of the consultants' use of the word "competent" to characterize some doctoral supervisors. Although the term is "defined" on pages A-37 and A-38 of their report, there was an incorrect impression that anyone who was not counted as "competent" was incompetent. The consultants have clarified this further in their addendum, point number 1, page A-83. A better phrase would have been "highly qualified." The faculty the consultants are referring to are "those outstanding individuals who...are the backbone of the PhD programme. The number and fraction of the faculty who are 'competent PhD supervisors' determine the quality of the PhD students' experience in the department." There are many young faculty members whom the consultants feel have not yet reached full potential, who are quite capable of supervising doctoral students and who are doing so. These were not included in the count.

Simply adding up the number of highly qualified supervisors does not give a true picture of a department, as some faculty members just meet the standards and others have international reputations. The consultants assigned double weight to this latter category; there are 23 of these professors in the province. Consequently the numbers in the second column of the consultants' Table 5, page A-39, should be regarded as an index of quality for a department, but not as a count of competent individuals.

The consultants believe that graduate students should work with the best professors. They have tried to apportion enrolment in the province according to how many highly qualified supervisors a programme has. Although ACAP agrees that this principle is sound, we fear that this method of distribution is unworkable - it would require a quota system and perhaps a highly centralized process for identifying supervisors. Instead, the universities should enrol students in their various high-quality programmes as discussed in the next section of this report, keeping in mind the supply of and demand for physics graduate students as discussed in Recommendation C1.

A last point the consultants would raise in connection with doctoral supervisors is the question of tenure and promotion. They find enough disquieting evidence in the departments of physics and astronomy to suggest that the requirements for a faculty member to be eligible to supervise doctoral students, should be reviewed and enforced. ACAP takes no position on whether or not there should be a separate Graduate Faculty, but there must be a mechanism to ensure that only those faculty members with a proven research ability and productivity supervise doctoral students. Since this concern has been mentioned in other assessments, ACAP feels that OCGS should conduct a review of this area, as already recommended in our engineering report. (See Recommendation 8 and page A-53.)

The consultants have given a second kind of indication of the quality of the graduate work in physics in Ontario, by providing an assessment of each thesis research area in each department. The definition of areas of research varies from university to university, since each department has its own preferred way of stating its fields of study, and it is important, of

course, that the judgments be made about the programmes each university actually offers or proposes to offer. The consultants have put the work in each research specialization in one of three categories: centre of strength; good or adequate; doubtful or inadequate or ill-defined. The concept of "centre of strength" is an important one: the Physics Discipline Group defines it as "a group having a world class status in one area of physics. In a university department such a group may be expected to attract high quality students and generate a stimulating intellectual atmosphere in its field."

It is gratifying to note that, of the 33 subfields offered for doctoral work in the province's physics departments, 12 are considered centres of strength. We have already noted that there are 23 professors of sufficient international reputation that the consultants felt they should be weighted double in assigning an "index of professional quality" to each department. It seems therefore correct to assert that there is some very good doctoral physics training in Ontario.

On the other hand, while 12 subfields are considered centres of strength there are also 8 which are either of doubtful quality or ill-defined or inadequate.

The distribution of the strength and weakness amongst the departments is of course crucial for planning purposes. Seven of the 12 centres of strength are found in two departments. One other department has two centres of strength, and three others one each. Not unexpectedly, a similar pattern is found for the distribution of "highly qualified supervisors" (consultants' Table 5, page A-39). Another significant quality index (as the University of Windsor suggests) is the ratio of the "weighted number of highly qualified PhD supervisors" to the total physics professional staff; this should help indicate the prevailing atmosphere which a student experiences in the department. This index also shows a similar situation, in that its values are much higher (about 70%) for two of the universities than for the remainder. (The next highest value is for Windsor at 47%, three are between 30% and 40%, and the rest are 25% or less.)

It is clear, therefore, that two universities, McMaster and Toronto, have doctoral programmes in physics of a recognizably different character from the others. Each of these two departments offers four or five areas of specialization with at least three described as "centres of strength"; each has a very substantial number of "weighted highly qualified supervisors" (24 and 32 respectively), and each has a very large fraction of its staff in this category. Each has well-equipped laboratories and a substantial record of successful recent PhD graduates.

It is therefore recommended that McMaster and Toronto be considered to have "general" physics PhD programmes, while the role of the other universities at the doctoral level be more specialized.

Lest it be thought that ACAP is presenting a more favourable picture than the consultants do of the general state of physics in Ontario, we note that the consultants, having described the characteristics of the world's pace-setting departments, say "the two we have rated most highly approach the desired standard and, given the required conditions, could achieve the proposed quality in a decade or two. All others fall below and some far below these standards." The Discipline Group in its discussion of a "centre of excellence," page B-6, appears to share the consultants' view.

ACAP notes that both McMaster University and the University of Toronto indicate support of their physics departments' plans. It therefore seems reasonable to urge these universities to provide "the required condition" for increased strength.

We also note the desirability of rivalry among universities, and we believe our proposals for doctoral work will not inhibit any worthwhile aspects of such emulation.

In selecting two universities to offer "general" programmes, we note that each of the other current PhD programmes has at least one "good or adequate" field. We propose each continue for the present to give PhD work in these identified fields, but that the development of work in other areas be a matter for planning approval.

Since there appears to be some lack of knowledge of the appraisal procedure in connection with the introduction of new fields into existing doctoral programmes, we now recapitulate the long-standing agreement amongst the universities.

If a university wishes to offer a new research area for thesis work, it so informs the Appraisals Committee. The Appraisals Committee may decide that the new field is a natural and limited extension of work underway and that earlier investigations by the Appraisals Committee (or by a planning assessment) give sufficient assurance of quality. In this case, no appraisal would be required. Alternatively, the Appraisals Committee may decide that the new field is sufficiently unrelated to the established ones (in personnel, facilities or scientific interconnections) that an appraisal to establish quality is required. Lastly there is a situation wherein a professor will occasionally pursue a research topic (and employ a student) in a field bordering on the one in which he concentrates. This last type of "occasional thesis" would not normally be discussed with the Appraisals Committee, since it would not be listed amongst the fields the department "advertised" as research areas.

The above refers to appraisal. Insofar as system planning is concerned, all new fields anywhere are matters of report to ACAP and hence the other universities, but in the case of "general" PhD programmes COU approval of a new field is not required, whereas specialized programmes are expected to expand only into areas which seem appropriate to COU at the time a proposal is made.

PHYSICS

Universities with General PhD Programmes

As already indicated, ACAP believes that McMaster University and the University of Toronto should continue to offer general doctoral programmes in accordance with the plans submitted by them for this planning assessment (except for the impact of Recommendation C1) and also to further develop their physics departments. Proposals to offer new thesis fields are, of course, to be referred to the Appraisals Committee before initiation.

Recommendation C6

> It is recommended that McMaster University and the University of Toronto continue their master's and general doctoral programmes in physics in accordance with their plans.

Universities with Specialized PhD Programmes

ACAP considers all but two of the doctoral programmes in Ontario to be specialized. The consultants say "a small institution must specialize if it is to achieve excellence." ACAP agrees with the consultants' recommendation that there be no assignment of responsibilities for specific fields of physics, that the initiative for new fields should come from each university. The universities, in beginning their departments, decided what fields to offer. The consultants have reviewed their quality and competence to offer doctoral work and ACAP has recommended which specialties should be continued. A programme in a new area may be proposed by a university and the Discipline Group and ACAP would discuss this proposal with the university in light of the provincial plan for physics. Unless the proposal appears unwise, ACAP would then recommend a change to the plan and the university would offer its new programme after obtaining a favourable appraisal. (See page 5 of this Report.)

We indicate for each specialized programme which areas of study are recommended. The result is to eliminate a number of currently offered areas for which the consultants' assessment is that the quality is at best doubtful. ACAP believes there is no strong case to continue any of these areas - indeed we are recommending their discontinuance - but ACAP also recognizes that some university might wish for some reasons to continue doctoral work in one of these areas and might feel that the consultants' assessment was incorrect. In that case, a consequent appraisal, simply to settle the quality question, is indicated.

In all the areas in which there are already several good programmes in the province, ACAP does not encourage the universities to start new programmes nor to commit additional resources in order to obtain favourable appraisals rather than discontinue current offerings. For this reason any appraisal to establish the quality of one of the challenged areas should be undertaken immediately.

Recommendation C7

> It is recommended that the universities with specialized doctoral programmes not commit additional resources in order to pass appraisal in current fields of specialization other than those specified in the appropriate recommendation below. Enrolment of new students in

fields other than those specified below should cease after April 1, 1975. If a university wishes to continue doctoral work in one of the fields not specified below it is recommended that the university submit the programme in that field for consequent appraisal by February, 1975, ceasing to enrol new students in that field after January 1, 1976, if a favourable appraisal has not been obtained.

It should be noted that the universities with small graduate enrolments in physics may encounter difficulties in maintaining viable programmes if the consultants' predictions for falling enrolments are correct. In their addendum, they state that the total number of students, both MSc and PhD should be larger than the 5 or 6 which they call the "interaction sphere". Since this applies to each specialization offered, there has to be a certain number of graduates in each area to make the programme viable and stimulating. At the present time, each of the programmes recommended below appears to be of satisfactory size in each of its areas, but future decreases in enrolment and supply of well-qualified students may cause problems of maintaining an academically viable size of student body at some universities in some areas.

Recommendation C8

It is recommended that Carleton University continue its master's programme according to its plans and continue its doctoral programme in high energy physics, both experimental and theoretical.

A programme in nuclear physics would need a favourable appraisal. (See Recommendation C7.) ACAP discourages the university from providing additional resources to pass appraisal in this field since there is already adequate coverage of this specialty in the province. ACAP would like to draw Carleton's attention to enrolment and notes that if the consultants' forecasts of dropping enrolments materialize, this doctoral programme might be of marginal size.

Recommendation C9

It is recommended that the University of Guelph continue its master's programme according to its plans and begin doctoral work in
a) condensed matter physics and nuclear physics
b) molecular physics but only after referral to the Appraisals Committee for clarification of its current status and
c) theoretical physics (which is a new programme) after a favourable finding by the Appraisals Committee.

Guelph's original appraisal was approved for two areas, low energy nuclear physics, and molecular and solid state physics. In accordance with normal practice, theoretical physics must be referred to the Appraisals Committee before it begins, as it is a new field. The University has now split the original molecular and solid state physics specialization of the appraisals document into two areas, condensed matter and molecular physics, and ACAP feels the University should submit the latter programme to the Appraisals Committee to determine whether or not it is still covered under the original approval for the programme.

ACAP would like to draw Guelph's attention to the possibility of decreasing enrolments and the problems of maintaining 3 or 4 specialties of viable size in times of short supply of qualified students.

Recommendation C10

> It is recommended that the University of Ottawa continue its master's work according to its plans and continue its doctoral programme in solid state physics, both experimental and theoretical.

A programme in atomic and nuclear physics or high energy physics would require a favourable appraisal. (See Recommendation C7.) ACAP discourages the University from providing additional resources to pass appraisal since there is already adequate coverage of these specialties in the province. We would like to draw Ottawa's attention to enrolment and note that if the consultants' forecasts of dropping enrolments materialize, this programme might become of marginal size.

Recommendation C11

> It is recommended that Queen's University continue its master's programme according to its plans and continue its doctoral work in nuclear physics, solid state physics, theoretical physics, and astronomy and astrophysics.

A programme in molecular physics would require a favourable appraisal. (See Recommendation C7.) ACAP discourages the University from providing additional resources to pass appraisal since there is already adequate coverage of this specialty in the province.

Recommendation C12

> It is recommended that the University of Waterloo continue its master's programme according to its plans and continue its doctoral work in theoretical physics, and solid state physics, both experimental and theoretical.

This includes the limited amount of molecular physics now being done.

Recommendation C13

> It is recommended that the University of Western Ontario continue its master's programme according to its plans and continue doctoral work in chemical physics, atomic physics and atmospheric science. It is recommended that the University consider what organization will be most advantageous to concentrate and improve its resources for offering doctoral work in theoretical physics and submit a proposal for appraisal, ceasing to enrol new students in theoretical physics in either its Department of Physics or its Department of Applied Mathematics after the fall term, 1976, if a favourable appraisal is not obtained.

Western Ontario currently offers doctoral work in theoretical physics in both the Physics and the Applied Mathematics Departments. ACAP encourages Western to reorganize this activity adding new resources and, if necessary, submit a proposal for appraisal. This field has potential at Western, the University has taken steps to strengthen it, and it is therefore recommended that the University develop it.

Recommendation C14

> It is recommended that the University of Windsor continue its master's programme according to its plans and continue doctoral work in atomic and molecular physics, relativistic physics, and solid state physics.

A programme in nuclear physics would need a favourable appraisal. (See Recommendation C7.) ACAP discourages the University from providing additional resources to pass appraisal since there is already adequate coverage of this specialty in the province.

Recommendation C15

> It is recommended that York University continue its master's programme according to its plans and continue doctoral work in atomic and molecular collisions and structures, chemical physics, atmospheric physics, and astronomy and astrophysics.

Universities with Master's Programmes Only

The four emergent universities, Brock, Lakehead, Laurentian and Trent all offer a master's programme in certain areas of physics. These are all part of their approved five-year plans and have been appraised at all but Lakehead. In view of the comments made by the consultants and the low enrolment in the programmes, ACAP would make the following suggestions.

Brock and Trent have not attained the enrolment levels specified in their appraisals document. Five years has elapsed since a favourable appraisal was obtained and ACAP feels these programmes should be reviewed in much the same way an appraised doctoral programme would be after five years.

Lakehead's programme has never been appraised but ACAP feels it should be at this time. The consultants made some disquieting comments about the programme. ACAP notes there are no planning reasons why there should not be a master's programme at Lakehead - indeed it is in the approved five-year plan - but the appraisal would clear doubts of the quality of the programme.

The consultants recommend the programme at Laurentian be appraised. Laurentian is at present reorganizing its graduate programmes in accordance with its five-year plan. The questionable quality of the present physics master's programme makes an appraisal necessary if it is to continue.

Recommendation C16

It is recommended that Brock University continue its master's programme in physics, subject to review by the Appraisals Committee.

Brock's programme in solid state physics has had very few students each year. This past year there were no master's students enrolled. Although the faculty is "more than adequate" to supervise the master's candidates in this field, ACAP feels a review of the original appraisal decision is desirable at this time.

Recommendation C17

It is recommended that Lakehead University continue its master's programme in condensed matter physics subject to obtaining a favourable appraisal. Enrolment of new students should cease after the winter term of 1976 if a favourable appraisal has not been obtained.

The consultants state that the department members are "adequate" to give a master's in condensed matter physics but that the department is "not a strong one." There is also some concern about the range of courses at the master's level. ACAP feels an appraisal would be beneficial and also notes that the approved five-year plan contains a master's programme in physics.

Recommendation C18

It is recommended that Laurentian University, in accordance with its plans, cease to enrol new students in a master's programme in physics after the fall term of 1975 unless
a) the physics programme has been favourably appraised and
b) the University has obtained approval for an amended five-year plan that includes physics.

The five-year plan, proposed by Laurentian, approved by COU, and forwarded to the Minister for approval, contains the following: "an interdisciplinary programme in science to be favourably appraised by June 1976", and "the current programmes in chemistry and physics will cease enrolling new students when the interdisciplinary science programme is favourably appraised." "The University may decide not to proceed with the interdisciplinary science programme, in which case it would then review the decision to terminate the programmes in chemistry and physics." An altered plan would have to be reconsidered by ACAP and approved by COU and OCUA before going to the Ministry.

The consultants comment that the faculty members are "adequate" to offer a master's programme but that the programme is "weak in core subjects." They also feel there is too much emphasis on applied research. They recommend an appraisal of this programme and ACAP concurs.

Recommendation C19

It is recommended that Trent University continue its master's programme in physics, subject to review by the Appraisals Committee.

The Trent programme, like Brock's, has an adequate staff to offer graduate work but suffers from small enrolments. Trent had its programme appraised about five years ago and ACAP feels that it should be reviewed at this time.

ASTRONOMY

Many of the points discussed in the section on General Recommendations apply to astronomy as well as physics. The consultants believe the enrolment is dropping but, as noted earlier, the universities are prepared for it. The problem of mobility is important to astronomy although the choice of programmes is somewhat smaller. The Discipline Group in Astronomy also has a role to play, conducting periodic reviews of enrolments and admissions. The consultants note, on page A-44, that solar physics and meteor astronomy are "neglected" fields in Canada and perhaps this could be discussed by the Discipline Group.

Graduate work in astronomy in the province is carried out at Toronto and Western Ontario in their Departments of Astronomy and at Queen's and York and to some extent, Waterloo and Guelph, in their physics programmes. For many years, Toronto was the only university in Canada offering advanced degrees in astronomy and still maintains a preeminent position. A vigorous cooperative programme of building and operating observatories outside Canada would appear, to the consultants, to be particularly promising.

With this relatively healthy view of astronomy in the province, the consultants recommend no new PhD programmes be started during the next few years. This does not interdict any master's programmes in astronomy or astrophysical topics that may be proposed in physics departments.

University Recommendations

This section includes the recommendations made on the Departments of Astronomy at Toronto and Western Ontario. Recommendations on astrophysical topics given for physics departments are found in the Queen's and York recommendations in the physics section.

Recommendation C20

> It is recommended that the University of Toronto continue its master's and doctoral work in astronomy according to its plans.

ACAP notes that the future plans of the department include accepting a reduction from the present enrolment of 20 doctoral students.

Recommendation C21

> It is recommended that the University of Western Ontario continue its master's and doctoral work in astronomy according to its plans.

ACAP notes that Western's plans include a steady enrolment of 4 ± 2 students in its doctoral programme each year and ACAP considers this reasonable.

COU ACTION

Recommendation C22

It is recommended that COU adopt the recommendations of this report, and, in the expectation that its members will act in accordance with them, COU inform OCUA that it has adopted these recommendations and request that the embargo on physics and astronomy be now removed, in accordance with the original announcement of the Minister that new graduate programmes would be embargoed until, for each discipline, a planning study had been conducted.

RECOMMENDATIONS

C1

It is recommended that the universities plan on the level of enrolment suggested by the consultants. (See pages A-16 to A-20.)

C2

It is recommended that the Discipline Group report annually on the location of the undergraduate training of the new graduate students in each department. (See Recommendation 6 and page A-51.)

C3

It is recommended that urgent attention be given to the question of research funding for professors whose departments do not offer graduate programmes in their fields, including the possibility of assignment of a BIU weight for post-doctoral fellows. (See Recommendation 11 and page A-55.)

C4

It is recommended that the Physics and Astronomy Discipline Groups, in their normal role, in consultation with ACAP, annually review admission standards, by examining records of newly admitted students, annually report the undergraduate universities of all newly enrolled graduates, and periodically review the plan for physics and astronomy as to enrolment levels and adequacy of coverage of the specialties, including neglected fields. (See Recommendations 3,6,9, and 10.)

C5

It is recommended that the universities formulate policies governing applied research. (See Recommendation 7, page A-52 and the addendum page A-84.)

C6

It is recommended that McMaster University and the University of Toronto continue their master's and general doctoral programmes in physics in accordance with their plans.

C7

It is recommended that the universities with specialized doctoral programmes not commit additional resources in order to pass appraisal in current fields of specialization other than those specified in the appropriate recommendation below. Enrolment of new students in fields other than those specified below should cease after April 1, 1975. If a university wishes to continue doctoral work in one of the fields not specified below it is recommended that the university submit the programme in that field for consequent appraisal by February, 1975, ceasing to enrol new students in that field after January 1, 1976, if a favourable appraisal has not been obtained.

C8

It is recommended that Carleton University continue its master's programme according to its plans and continue its doctoral programme in high energy physics, both experimental and theoretical.

C9

It is recommended that the University of Guelph continue its master's programme according to its plans and begin doctoral work in
a) condensed matter physics and nuclear physics
b) molecular physics but only after referral to the Appraisals Committee for clarification of its current status and
c) theoretical physics (which is a new programme) after a favourable finding by the Appraisals Committee.

C10

It is recommended that the University of Ottawa continue its master's work according to its plans and continue its doctoral programme in solid state physics, both experimental and theoretical.

C11

It is recommended that Queen's University continue its master's programme according to its plans and continue its doctoral work in nuclear physics, solid state physics, theoretical physics, and astronomy and astrophysics.

C12

It is recommended that the University of Waterloo continue its master's programme according to its plans and continue its doctoral work in theoretical physics, and solid state physics, both experimental and theoretical.

C13

It is recommended that the University of Western Ontario continue its master's programme according to its plans and continue doctoral work in chemical physics, atomic physics and atmospheric science. It is recommended that the University consider what organization will be most advantageous to concentrate and improve its resources for offering doctoral work in theoretical physics and submit a proposal for appraisal, ceasing to enrol new students in theoretical physics in either its Department of Physics or its Department of Applied Mathematics after the fall term, 1976, if a favourable appraisal is not obtained.

C14

It is recommended that the University of Windsor continue its master's programme according to its plans and continue doctoral work in atomic and molecular physics, relativistic physics, and solid state physics.

C15

It is recommended that York University continue its master's programme according to its plans and continue doctoral work in atomic and molecular collisions and structures, chemical physics, atmospheric physics, and astronomy and astrophysics.

C16

It is recommended that Brock University continue its master's programme in physics, subject to review by the Appraisals Committee.

C17

It is recommended that Lakehead University continue its master's programme in condensed matter physics subject to obtaining a favourable appraisal. Enrolment of new students should cease after the winter term of 1976 if a favourable appraisal has not been obtained.

C18

It is recommended that Laurentian University, in accordance with its plans, cease to enrol new students in a master's programme in physics after the fall term of 1975 unless
(a) the physics programme has been favourably appraised and
(b) the University has obtained approval for an amended five-year plan that includes physics.

C19

It is recommended that Trent University continue its master's programme in physics, subject to review by the Appraisals Committee.

C20

It is recommended that the University of Toronto continue its master's and doctoral work in astronomy according to its plans.

C21

It is recommended that the University of Western Ontario continue its master's and doctoral work in astronomy according to its plans.

C22

It is recommended that COU adopt the recommendations of this report, and, in the expectation that its members will act in accordance with them, COU inform OCUA that it has adopted these recommendations and request that the embargo on physics and astronomy be now removed, in accordance with the original announcement of the Minister that new graduate programmes would be embargoed until, for each discipline, a planning study had been conducted.

A P P E N D I X A

REPORT ON

GRADUATE STUDIES IN PHYSICS AND ASTRONOMY

submitted to the

ADVISORY COMMITTEE ON ACADEMIC PLANNING

ONTARIO COUNCIL ON GRADUATE STUDIES

COUNCIL OF ONTARIO UNIVERSITIES

by

THE CONSULTANTS ON PHYSICS AND ASTRONOMY

L. H. Aller
A. E. Douglas
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March, 1974

26 March 1974

Dr. M.A. Preston
Advisory Committee on Academic Planning
Council of Ontario Universities
130 St. George Street, Suite 8039
TORONTO, Ontario
M5S 2T4

Dear Dr. Preston:

We are pleased to submit this Report on Graduate Studies in Physics and Astronomy. We trust that it conforms with our terms of reference and that it will prove helpful to the Advisory Committee on Academic Planning.

Yours sincerely,

L.H. Aller
Professor of Astronomy
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Los Angeles

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Contents

Figures and Tables

I Introduction and Summary

This report on astronomy and physics planning has been prepared by a panel of consultants consisting of:

L.H. Aller
A.E. Douglas
R.R. Haering
P.N. Nikiforuk

The astronomy and physics departments supplied the consultants with statistical data together with future plans of the departments and the curricula vitae of faculty members. This information was supplemented by visits to each of the fourteen physics and two astronomy departments which offer graduate training. At each university we endeavoured to meet officers of the university, the heads of the physics and astronomy departments, faculty members, postdoctorate fellows and graduate students. We found the visits very useful and wish to thank all those concerned with our visits for the warm receptions and cooperation accorded us.

The terms of reference of the consultants are given in Appendix I. On numerous occasions during our visits to the universities, these terms of reference and the validity of any report based on them were questioned. Although it is clear that many problems of graduate schools and their possible solutions lie outside the terms of reference and that many of the problems we have considered are linked to those we have not, we have limited our investigations to the areas assigned to us by the Advisory Committee on Academic Planning. Others must deal with the broader picture.

Reports involving matters of judgement must in the final analysis involve the prejudices of the authors. This report is no exception and it is strongly influenced by the following opinions:

(i) In times of difficulty, consultants, advisory committees and administrators tend to introduce new restrictions, new guidelines and stronger central authority. Too often the remedies are worse than the disease. We believe that universities must have a very high measure of independence and freedom in all areas except the freedom to be second rate and as far as possible we have avoided the temptation to recommend new regulations.

(ii) The building of a high quality astronomy or physics department is a difficult matter requiring great skill and many years of effort. In spite of the fact that we believe Ontario has too many physics departments and in spite of the weaknesses which we shall mention in the report, most astronomy and physics departments of Ontario have been built rather well. Sudden changes in policy could undo years of work and it seemed to us unwise to recommend drastic changes in the present

system. We have therefore attempted to devise remedies to difficulties in the forms of gentle but continuing pressures which will, over a period of time, achieve the desired result.

The largest part of the report is devoted to the Ph.D. programs in physics. We have not neglected the masters programs in physics and the graduate programs in astronomy. There are however only two astronomy departments compared with fourteen physics departments and the masters programs in both astronomy and physics appeared to us to present few problems. The material in the report tends to reflect the problems we have found rather than the relative importance we attach to the various programs.

Although the subject matter of physics and astronomy overlap to a considerable extent, the administrative problems of the two areas are quite different. The differences in numbers of students, in the number of graduate programs, and in employment opportunities and the need for observatories by the astronomers have made it necessary to deal with the two disciplines separately in much of this report. The major part of the report on astronomy is in section VI while sections III, IV and V deal exclusively with physics.

Summary of Recommendations

Physics

We recommend that:

1. no regulations be adopted which would place limits on the total number of graduate students. (page A-22)

2. the Ph.D. students of the province be distributed among the universities according to the numbers of faculty members who are found to be competent Ph.D. supervisors in the various physics departments. A recommended initial distribution is shown in Table 5. (page A-39)

3. the projected enrolments and distribution of Ph.D. students be revised every two or three years. (page A-40)

4. there be no assignment of responsibilities for specific fields of physics to particular departments but that the coordination of research activities of the departments be continued by the discipline group. (page A-54)

5. no limitations be placed on the movement of departments into new areas of research but that, in the periodic reviews (see reccomendation 3) of graduate programs, special attention be directed to new areas of research which have been started to ascertain that the students are under the guidance of well qualified supervisors. (page A-55)

6. a university receive no provincial financial support for any Ph.D. student who has received a bachelor degree from the same university

unless that student holds a masters degree from another institution or the university receives special permission from the Ontario Council of Universities. (page A-52)

7. all universities formulate policies governing applied research in physics graduate programs with particular attention being paid to the questions of the academic freedom, balance and coherence of the departments. (page A-52)

8. all universities review their tenure and promotion practices to assure a standard up to that adopted by universities which have achieved a well-deserved reputation for high quality graduate work and research. (page A-53)

9. serious consideration be given to developing graduate programs in optics and acoustics. (page A-54)

10. the discipline group annually review and grade the applications of graduate students who have been accepted by the universities and that the results of this review be made available to the appropriate committees for evaluation and planning purposes. (page A-55)

11. at the four emergent universities the income from the province for graduate students should not be proportional to student numbers but a special fund be set up at these universities to support their research programs. (page A-55)

12. in order that the University of Ottawa be given an opportunity to develop a high quality bilingual graduate school in physics, the University be allowed to plan for a number of Ph.D. students higher than that assigned, but if future assessments find no substantial improvement in the quality of the faculty, consideration be given to having the Ph.D. program discontinued. (page A-40)

13. an appraisal of the M.Sc. program at Laurentian University be carried out in the near future. (page A-35)

Astronomy

We recommend that:

1. no new graduate programs in astronomy be established in Ontario, but this is not to be construed that a thesis on an astronomical topic in an existing department of physics be interdicted. (page A-48)

2. for planning purposes the projected enrolment of Ph.D. graduate students in astronomy be reduced to 15 by the year 1978-79 and that these students be distributed between the University of Toronto and the University of Western Ontario in the ratio not less than 5:1 in favour of the University of Toronto. (pages A-47 and A-49)

3. recommendations 3, 4, 5, 6, 8 and 10 under "physics" also apply to astronomy departments.

II Bases of the Consultants' Report

The consultants have found that the Advisory Committee on Academic Planning has provided detailed information on the procedure for planning and the numerical results expected from the planning process. Lacking however is a general philosophy regarding the basic objectives of this process. It is possible that this lack of philosophy will result in a series of reports in the various disciplines which will be difficult to integrate into a coherent system. It appeared evident to the consultants that the nature of their report would depend to a large extent on their assumptions regarding the purposes of graduate schools and the best means of achieving these purposes. In this respect the consultants have been left to their own devices and have presented their own conclusions. Others with different philosophies may reach different conclusions and disagree with the recommendations of this report.

What is the purpose of a graduate school in physics or astronomy? Certainly a graduate school influences many different aspects of the intellectual, the industrial and the political life of the province. It provides a framework wherein research can be successfully carried out. It provides an institution wherein university professors are constantly in touch with the frontiers of knowledge. It is an institution wherein students of many disciplines interact and learn from each other. It is largely through the activities of graduate schools that universities exchange scholars and students and achieve much of their national and international character. More often than not it is the professors who are actively engaged in the research and teaching of graduate schools who are called upon to find solutions to the technical problems of industry and of governments. In spite of the importance of these many aspects of graduate studies, in the opinion of the consultants, a graduate school is above all else an institution wherein a student may acquire the critical judgement, the technical skills, the self-discipline and the self-confidence necessary to solve physical problems.

Even having agreed on the major role of a graduate school in general terms, we find that there is a great deal of latitude in establishing criteria for judging the quality of a school. The problems which graduates from the schools will be called upon to solve are highly varied and the skills necessary to solve them are correspondingly varied. It appears likely that the graduates of the future will be engaged in an even wider range of activities than those of the past. It therefore appeared unwise to us to place any great emphasis on identifying particularly desirable courses, exams, teaching methods, physical facilities or approaches to education. It is perhaps more important that graduate schools differ than that they meet some arbitrary set of standards. We are convinced however that it is essential that a graduate school have a stimulating atmosphere in which the students are brought in contact with the frontiers of physics, in

which their work is supervised by creative and talented professors who have demonstrated their ability to carry out significant research and in which the physical and intellectual surroundings assure the student that he is associated with a group which is playing a substantial role in advancing some area of astronomy or physics.

The chemistry consultants have dealt at some length with the commitment of the community and the university to meaningful graduate studies and research. In this matter we agree with their point of view. Instead of repeating these most essential matters here, we have attached the relevant portion of the chemistry consultants' report as Appendix II.

Once having accepted the principle that graduate schools should be judged on the basis of the quality of the staff and the intellectual atmosphere of the school, our procedure in assessing schools follows quite directly. First, and most important, we have attempted the difficult task of judging the competence of individual faculty members as supervisors of doctoral students. We believe that competence in this respect requires the faculty member to be a leader in some field of research. We have also attempted the even more difficult task of judging the intellectual atmosphere in the departments. Our procedures for reaching conclusions in these matters are outlined in latter sections.

In judging the quality of graduate schools we believe that we should adopt a high standard. At a time of decreasing enrolment, the best should be preserved. Throughout the history of modern physics and astronomy, a small number of schools have made contributions quite out of proportion to their size and cost. Members of these faculties are known throughout the world; they have made many of the major contributions to the advancement of knowledge and their reputation for excellence is such that it is generally assumed that they will continue to do so. Excellence attracts excellence; students eagerly vie for a place in their limited enrolment; able scientists seek the opportunity of spending their sabbatical years in these schools and the most able and ambitious Ph.D. graduates compete for postdoctoral fellowships in their laboratories. These schools provide a highly stimulating atmosphere within their own walls but their influence spreads far beyond these walls. They set the standards for all schools; their faculties set the standard for all other faculties; their courses, their research and their theses set the standard for all others. We believe that Ontario should have graduate schools in physics and astronomy equal in quality to the best schools of the world. We also wish to make it clear that we recommend the support of such schools, not as a matter of pride or intellectual snobbery, but as institutions which we believe will yield handsome dividends in the industrial, governmental and educational life of the province and the nation.

It is most unlikely that the required quality in Ontario graduate schools can be achieved by any direct administrative process. Competitions between schools, driven by a pride in excellence which

exists in a substantial portion of the academic community is likely to achieve the required result while designating particular universities as the homes of high quality graduate schools may lead to complacency and a decline in quality. The concept of competition between institutions, all largely financed by government funds, may run counter to the usual concepts of administrative efficiency. Achieving and maintaining exceptional quality is, however, a subtle matter and is not likely to be achieved through the usual blunt instruments of government administration.

In suggesting and, in fact, advocating competition between schools as a means of achieving a few graduate schools of exceptional quality, we realize that the conditions governing this competition become a crucial matter. Although we have not been asked to comment on suitable means of financing universities, it is clear that the financial regulations are of the utmost importance. If universities find that graduate schools and research are an unbearable strain on their finances then high quality schools will not be maintained. Although ample financial resources are in themselves insufficient to assure excellence in graduate studies, certainly excellence is unlikely to be achieved in a university unless it brings some financial reward. In our recommendations we have aimed to encourage graduate schools of the highest quality, but the regulations governing university financing, research grants and scholarships will in large measure determine the success of these efforts.

It is useful at this stage to consider very briefly the present state of graduate studies in physics in Ontario. By the standards outlined above, the graduate schools must be considered wanting. The two we have rated most highly approach the desired standard and, given the required condition, could achieve the proposed quality in a decade or two. All others fall below and some far below these standards. It is of course clear that the province can not have three or four, much less nine or ten really outstanding graduate schools in physics and an equal division of the facilities, the funds and the talented physicists among all existing schools will assure the existence of none of outstanding quality.

It appears to us that competition between universities for a position of eminence in physics graduate studies will not bring about an even distribution of the funds and the talented physicists. In order to achieve the highest quality in a university, all levels of the staff, but particularly the highest administrative officers, must be dedicated to this cause. University administrative officers are faced with many conflicting demands and attempts to achieve excellence brings them into conflict with other demands. Few appear to have given quality the highest priority. Also within each university, decisions must be made as to which particular faculty and even which particular department will receive strong support, since few universities can achieve the highest quality in all areas. Although the consultants have not studied the organization within Ontario universities in any

detail, it appears that there are a number in which there is little hope of achieving exceptional quality. In these the quality is low and there appears to be no authority in the university charged with maintaining quality. Faculty organizations and their committees are charged with the responsibility of selecting department heads, deans and other officers many of whom serve for only a short term. We expect that only rarely will men be selected who demand a standard higher than that which exists in the committee selecting them. It may be even more rare for an administrative officer, appointed for a short term, to take necessary but unpopular actions in a department of faculty where later he must serve in a junior capacity. We, therefore, believe that only a few universities will make the painful decisions necessary to achieve the highest quality in their physics departments and if departments are supported according to their quality, these will emerge as the major graduate schools in physics in Ontario.

Any planning procedure which is based largely on the quality of the faculty will require a frequent evaluation of that quality. This frequent evaluation will be particularly important during the next ten years since there are now many young assistant professors in the physics departments who can not be assessed reliably at this time. In section V of this report we present some recommendations regarding this evaluation procedure.

In astronomy the need for high quality is certainly no less than in physics but the concept of competition between Ontario schools is no longer valid. There are only two astronomy departments in Ontario and these are very different in size. The astronomy departments can be judged only with respect to departments outside Canada. This matter is considered in section VI.

The procedure we have adopted in evaluating graduate schools and recommending their future support almost entirely on the basis of their quality, raises a number of problems. The most important of these are:

(a) The need for graduate studies to maintain the quality of undergraduate instruction.

(b) The minimum acceptable size for a graduate school.

(c) Coverage of all fields of physics.

Each of these points will now be considered.

(a) The Relationship between Research, Graduate Instruction and Undergraduate Instruction.

In the course of our discussions at the universities, the opinion was often expressed that research, graduate instruction and undergraduate instruction can be performed effectively only if they are performed together. This point of view is presented most forcefully in

the submission from the University of Toronto where it is stated;

> "The University is the place where new knowledge is discovered, and where both old and new knowledge is passed on. As a result, University Faculty Members acquire new knowledge through research, and in their contacts with people outside the University. They re-interpret existing knowledge. They also pass on this knowledge in several ways - by publishing in journals and other literature, by teaching courses to both undergraduate and graduate students, and through "service to the community", for example, by being available for work on committees of the Government where their specialized knowledge is needed. Each of these activities can be performed well only because it is performed in conjunction with the others. Undergraduate teaching is much more effective when the teachers are actively engaged in research. Without research, the training of graduate students as we now know it is impossible. Without undergraduate teaching, a Professor tends to become over-specialized and research suffers. Real service to the community cannot be given unless a professor's knowledge is really up-to-date, and this is not possible without close contact with the latest ideas through research and through contacts with students. Again, contacts with the outside world obtained through community services make it possible to give better services within the University to students. The point of all these examples is that for each of these activities to be performed well, in the manner in which we are accustomed to seeing them performed, they must be performed together in a certain proportion, or balance, which has been found by experience to be appropriate."

This point of view is one which we have considered very seriously since it could lead to a totally different basis for evaluating graduate programs in physics. The physics departments in the universities of Ontario exist primarily for the purpose of teaching undergraduates. None of their other activities could justify their size and cost. If it is true that undergraduate instruction can be effective only if research and graduate instruction are carried out at a level which now occurs in a few of the universities with large graduate schools then probably the best compromise to support the major activity of the departments would be the distribution of research funds and graduate students according to the undergraduate enrolment at the university. We do not, however, accept the point of view that research, graduate instruction and undergraduate instruction are inseparable in a university.

It is generally accepted that research, graduate studies and undergraduate studies represent a desirable mix for a university We also are of this opinion. It is, however, quite a different matter to hold the point of view that none can be effective without the other. There is ample evidence that research can thrive without students of any kind and there is evidence that graduate studies combined with research can continue effectively without undergraduates. Neither of these possibilities are likely to be of importance to the Ontario universities. There is also evidence that in the past, and perhaps at present, some of the most effective undergraduate programs are at colleges and universities without Ph.D. programs. Research is without doubt essential for a graduate training program and we are of the opinion that research is also necessary if a stimulating atmosphere is to be maintained in the undergraduate program of a physics department. In brief, we are of the opinion that in any institution worthy of being called a university there should be an active research program, but we see no strong evidence that there need be a graduate school. The very strong pressures to maintain graduate schools in physics at every university appear to arise in a large measure from the close relationship between research funds and graduate students and if funds to pay for technicians and technical services were available from other sources the pressure would be much reduced.

(b) Minimum Acceptable Size of a Physics Graduate School

If the plans for graduate school enrolment are based on the quality of the department and if this is done during a time of decreasing total enrolment, it is likely that some schools will be left with very few students. The question then arises as to the minimum number of students necessary to maintain a viable graduate school. An interesting report on this matter has appeared recently(1). We have discussed this matter at some length during our visits to the universities and find that there are many aspects to this problem. Faculty-student, faculty-faculty and student-student interactions have to be considered along with the relationship between the various departments within the university and the role played by postdoctorate fellows and technicians. At some universities the cooperation between universities and between the university and non-academic laboratories is an important factor in the argument. There are also special problems in organizing the course work which must be considered in a small graduate school.

In our discussions with students we found that at all graduate schools, both large and small, a student had profitable interactions with only five or six other students. Students also usually had close contacts with their supervisor and one or two other

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(1) Science Policy Study 6; Research Environment and Performance in British University Chemistry. 1973, H.M.S.O.

professors. In the larger physics departments, the students, and to a lesser extent the faculty, found the numbers too great to have useful interactions embracing the whole department and there was a strong tendency for the department to separate into a number of smaller groups with very little contact between the groups. It appears that large numbers contribute little to direct student-student, student-faculty and faculty-faculty interaction.

There are aspects of graduate studies where size is of importance. It is inefficient to develop a graduate course program in which a professor deals with only two or three students in each course. It is inefficient to purchase expensive research equipment which is used by few students or professors. It is difficult to bring visiting scientists and colloquium speakers to small departments and, without these visitors, it is difficult to develop the stimulating atmosphere necessary in a graduate school. Each of these problems may find at least partial solutions in cooperative programs involving other departments within the university and cooperation between universities and in this respect each physics department must deal with its problems in manner determined by local conditions. In spite of the best efforts of the physics departments, if the total enrolment drops to the number we have projected (see sections III and VI) the distribution of students may be such that future reviews may recommend that the Ph.D. programs of some of the smaller departments be discontinued. If the total number of students drops appreciably below the number we have forecast, some programs will certainly have to be discontinued.

(c) Coverage of the Various Fields of Physics

The terms of reference of the consultants place considerable emphasis on the question of desirable programs and desirable provincial enrolments in major subject divisions and specialties. The distribution of students according to the quality of the departments could conflict seriously with any predetermined desirable distribution among the major subject divisions and specialties. We have, therefore, considered this question at some length.

Although there are many divisions and sub-divisions of the subject matter of physics, physicists have always changed readily from one division to another. Physicists who have changed from one branch of the subject to another have often proved to be leaders in their new fields. During the period of rapid growth of the universities when there was an active demand for physicists, a large fraction of the recent Ph.D. graduates were able to find openings and continue work in areas of physics directly related to their Ph.D. studies. Even during this period, most physicists in industry and a considerable number at universities did change their field and it seems clear that many others could do so without difficulty. Although we recognize that it is useful to have a broad range of subject matter studied in the physics departments of the province, we do not believe that it is necessary to

adjust the sizes of the various physics departments to train predetermined numbers of students in each of the divisions of the subject matter.

In later sections of this report the coverage of the various areas of physics will be discussed further. In our opinion the coverage in the Ontario universities is broad, and if the Ontario universities are considered to be a part of a Canadian system of universities, then the coverage is sufficiently broad that it will not suffer from a distribution of students in the manner we suggest.

III Future Enrolments in Physics Graduate Studies

To a large extent it is the question of numbers of graduate students, particularly Ph.D. students, and their distribution among the universities which dominates this report. The consultants are required to determine "desirable provincial enrolments year by year in the various levels of graduate study and major subject divisions and specialties where appropriate". We have found no basis upon which to determine a desirable enrolment. It does appear possible, however, to make a meaningful forecast of the numbers of physicists who may find employment in positions which require the advanced training associated with graduate studies and also forecast the numbers of students who will enroll for graduate studies in physics. We are aware that our predictions may suffer the unfortunate fate of many past predictions of student population. Nevertheless planning requires numbers and since these numbers influence much which follows, in this chapter we shall attempt to make an estimate of the numbers of physics graduate students to be expected in Ontario in the next ten years.

It is useful to look briefly at the numbers of graduate students in physics in Ontario in the recent past. These numbers are given in Table 1, and in Fig. 1 the numbers of fulltime doctorate and masters students are shown in graphical form. In this discussion we will deal only with the numbers of full time students. We do not belittle the effort devoted to part-time students but it is difficult to take them into account in any consistent manner and they contribute only a very small fraction to the total student body.

The number of graduate students reached a peak in 1969-70 when 593 students were enrolled. By 1969 Ontario had ceased to be the major supplier of physicists for the other provinces of Canada since the graduate schools outside of Ontario were for the most part able to supply the needs of the remainder of the country. In 196970 the United States of America with its numerous industrial laboratories and its very large government-financed science program had 71 physics graduate students per million population(2). The recent rapid decline in the size of physics graduate schools in the U.S.A. indicates that this number was higher than that required by the scientific activities of that nation. The corresponding figure for Ontario, where clearly there is a smaller demand for physicists in industry and government, was 79 physics graduate students per million population. There is also no evidence that the large size of the physics graduate schools arose as the result of Ontario or of Canadian students demanding entry into the schools. Less than sixty per cent of the students were Canadian citizens and it appears that many of the students from outside Canada were attracted to Ontario by the favorable terms offered by the

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(2) Physics in Perspective; Vol. 1. National Academy of Sciences. Washington, D.C.

TABLE 1

ENROLMENT OF FULL TIME PHYSICS STUDENTS 1969-74

University	1969-70		1970-71		1971-72		1972-73		1973-74	
	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.
Brock	-	-	1	-	2	-	5	-	-	-
Carleton	16	5	12	5	6	6	9	9	9	8
Guelph *)	9	(1)	13	(1)	11	(2)	7	(5)	9	(4)
Lakehead	2	-	4	-	5	-	2	-	3	-
Laurentian	2	-	7	-	8	-	6	-	1	-
McMaster	26	90	25	81	24	80	19	61	18	49
Ottawa	18	18	14	20	11	17	4	15	6	10
Queens	22	22	25	24	16	23	18	19	13	13
Toronto - Phys.	54	104	47	105	33	86	42	87	60	82
- Astr.	[12]	[12]	[16]	[12]	[11]	[21]	[8]	[23]	[8]	[20]
Trent	1	-	3	-	4	-	3	-	2	-
Waterloo - Phys.	43	38	42	39	23	39	27	33	16	31
- Appl.Math.	2	17	2	15	5	10	5	5	13	1
Western - Phys.	21	26	25	23	16	24	11	26	9	13
- Astr.	[8]	[3]	[11]	[2]	[5]	[4]	[4]	[5]	[6]	[4]
Windsor	9	13	8	13	7	16	9	16	10	14
York	8	27	6	33	9	29	11	31	11	30
SYSTEM TOTAL - Phys.	233	360	234	358	180	330	178	302	180	251
- Astr.	[20]	[15]	[27]	[14]	[16]	[25]	[12]	[28]	[14]	[24]
SYSTEM TOTAL (M.Sc. + Ph.D.) - Phys.	593		592		510		480		431	
- Astr.	[35]		[41]		[41]		[40]		[37]	

*) Bracketed numbers for Guelph not included in system total.

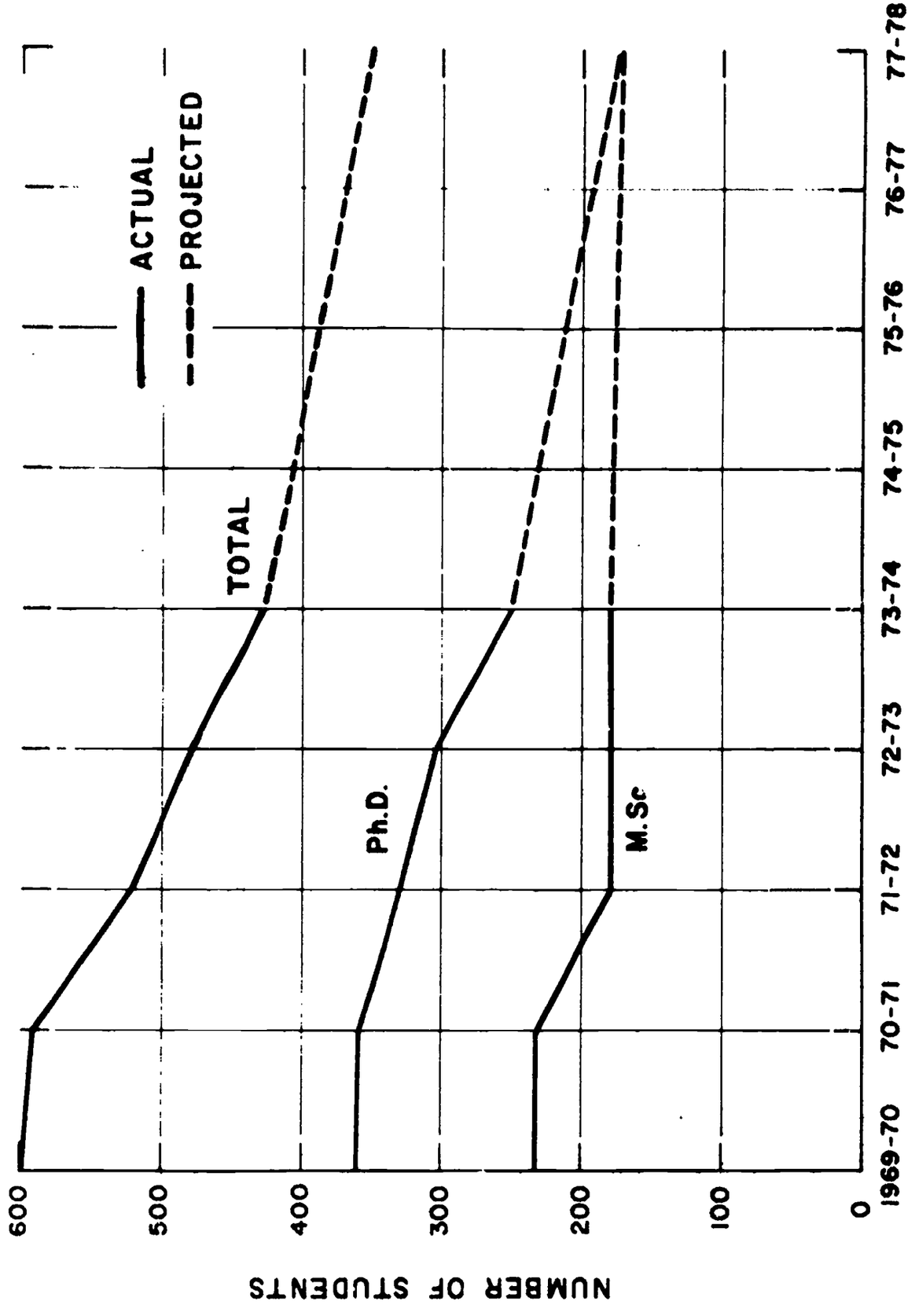

Figure 1 PHYSICS ENROLMENT PROJECTIONS, ONTARIO

graduate schools. Only a small number of the foreign students were supported by funds from foreign aid programs. We are, therefore, forced to conclude that by 1969-70 the graduate enrolment in physics in Ontario had reached an anomalously high value as the result of a number of factors which had little to do with the projected demand for highly trained physicists(3) or the demand for post-graduate training by Canadian students.

In attempting to forecast the future enrolment of graduate schools in physics, we believe that the anomalously high enrolment of the recent past is not a valid guide. Without the aid of a reliable base from which to extrapolate, we are left with the task of attempting to estimate the enrolment either by estimating the demand for physicists and assuming that over a period of time the choices made by students will adjust the supply to the demand or by directly estimating the number of students who will elect to enroll for graduate work in physics. Either method (and they are not independent) involves many unknown and unpredictable factors.

The consultants have very little input data upon which to base their estimates of the future demand for "physicists" and it appears that there is little reliable information to be obtained by further study. The scientific activities of industry and government are subject to the same types of pressures of economic conditions and public opinion as those in the universities. Furthermore, the demands of industry and government are often for trained scientists, not specifically for physicists, and the number of physicists employed depends strongly upon the number of other trained scientists such as chemists, metallurgists, engineers, mathematicians and astronomers who may be available to fill the posts. Since universities employ physicists primarily to teach students who are not specializing in physics, the demand for physicists at universities is closely tied to the total enrolment. The rapid and unpredicted fluctuations in this enrolment during the past few years indicates the difficulties in predicting the future need for physicists in the universities.

In attempting to estimate the enrolment in physics in graduate schools directly from the number of students of the appropriate age, we find an equal number of difficulties. The attitude of students to the long and difficult studies of a physics Ph.D. program varies with the times. Questioning of graduate students gave qualitative but little quantitative data on which to base predictions of future enrolment.

In spite of all the difficulties in making reliable predictions we believe that predictions of some value can be made. The fact that our predicted enrolments turn out to be very different from the sum of the forecasted enrolments given by the physics departments, give our numbers somewhat greater importance than they otherwise might merit.

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(3) Projections of Manpower Resources and Research Funds 1968-72: A Report of the Forecasting Committee, National Research Council of Canada.

Demand for Physicists

Physicists are employed in many activities. Particularly in recent years Ph.D. physicists have become involved in computing, business and government administration, economic studies and many other fields not directly related to physics. It may, therefore, be claimed that the demand for physicists is almost unlimited. With few exceptions, however, the recent Ph.D. graduates in physics have entered these fields only because there were no openings in areas more closely related to their training and some have felt that the time they had spent in studying physics could better have been spent in areas more closely related to their careers. From the point of view of the physics Ph.D. graduate moving to these areas, he is not filling a demand for a physicist. We believe that we must take this more restricted point of view in considering the demand for physicists and take into account only those areas in which physics training is a requirement for employment. Other consultants are estimating the demands in their disciplines and the totals would be unrealistically large if each discipline counted all possible openings for its Ph.D. graduates.

In the past the demand by Canadian industry for Ph.D. physicists has been small. For many years, the physics community has urged Canadian industry to undertake more research and development. There has been little increase in these activities in the past few years and there appears to be no active force which will bring about a rapid increase in the near future. Although the maturing Canadian industries are likely to increase their research and development work in the future, it is likely that the demand for development engineers and physicists at the bachelor and masters level will precede the demand for Ph.D. physicists. Also it must be remembered that even in the United States of America, where industrial research is much more advanced than in Canada, industry employs only about a quarter of the Ph.D. physicists(2). We, therefore, believe that the number of Ph.D. physicists required by Canadian industry in the next five years will represent only a small fraction of those receiving degrees.

Government laboratories have been major employers of physicists. During the past few years there has been rather little growth in government laboratories with only a few departments expanding substantially. Many of the laboratories of the Canadian and of the provincial governments have grown to their present size from a small nuclei in the past twenty-five years and few of the professional staff are near retirement age. Only in the field of atmospheric studies where many of the present staff started in the meteorological service in the wartime and immediate prewar era does there appear to be a need for a significant number of replacements. We have also been informed that there is a small but continuing demand for physicists trained in ionospheric and radio transmission problems. During the past few years, there also has been a demand for physicists in problems relating to atmospheric and water pollution but here the major demand has been

largely for scientists to deal with interdisciplinary problems only a few of whom were physicists. Unless there are substantial changes in the policies of the governments in Canada, we see little probability that there will be an increased demand for physicists in the government departments and agencies in the next five years.

The universities have been the largest employers of Ph.D. physicists in Canada and it appears to us that this condition will continue. Even in the United States with its large numbers of industrial laboratories and research institutes, the colleges and universities employ half of the Ph.D. physicists. In Appendix III we have attached a paper prepared in the ACAP office showing the predicted number of students of university age in Canada and under certain assumptions, the numbers who will be enrolled in university for the next ten years. Since most physicists are employed by universities as teachers, these numbers allow us to estimate the future demand by universities for faculty members in physics. As with all other forecasting, the estimated future demand for physicists by the universities depends upon certain assumptions. First, the paper assumes that the ratio of students to faculty will remain at the present value and second it presents the following two alternative assumptions on student enrolment:

i) the participation rate (i.e. the fraction of the population enrolling in universities) will grow at 0.1% per year.

ii) the participation rate will grow at 0.6% per year as it did in the period 1960-1969.

With assumption (i) a reasonable estimate of the total number of additional faculty members required in physics up to 1983 would be 245 and with assumption (ii) this number becomes 726. Of these Ontario could be expected to contribute somewhat less than half and thus on assumption (i) the growth of physics faculties will require 11 Ph.D. physicists per year from Ontario while on assumption (ii) the number is 32.

It is almost impossible to predict the attitudes of the youth of this country in the future but their attitude will determine the numbers of students who enter university. It does, however, seem reasonable to assume that it will require a few years for the present attitudes to change. Also in comparing the future participation rate with that of the past, certain factors which may influence the rate can be considered. The claims of increased earning power resulting from a university education quite rightly no longer appear and this will discourage many of the less dedicated students. Also the province has built a system of community colleges which attracts a significant portion of the students who formerly attended university. Finally if the entrance standards of the university remain constant, the present higher participation rate leaves a smaller fraction from which to increase the rates compared to that which existed ten years ago. It is

our opinion that a 0.1% increase in participation rate is a realistic assumption and it now would require a rather violent change in public opinion to regain a 0.6% increase.

The first assumption, namely that the student-faculty ratio will remain at the present value is unlikely to prove correct for two reasons. First, we found that several universities believe their physics departments to be overstaffed at the present time. Second, beyond 1984 the decline in population in the 18-24 age group will lead to a substantial reduction in university faculty and it is likely that some years prior to this, universities will be very reluctant to maintain the present student-faculty ratio which would leave them with an excess of faculty at a later date. We therefore believe that, in the paper, the predicted numbers of new faculty members required to meet the growth of the universities are too high and we estimate that these numbers should be about five per year for the Ontario universities.

Replacements necessary in the faculty of universities due to losses by resignations, retirements and other causes must also be estimated. Fig. 2 shows the age distributions of physics faculty for the Ontario universities (1973). It is evident that the faculty has a young average age and retirements are likely to create only one or two vacancies per year for the next ten years. A more significant source of vacancies is the resignation of faculty members who join universities outside the province or government departments or the senior administrative ranks of the universities. We estimate that from all causes there will be a loss of about ten faculty members per year. Thus growth and replacements may require approximately 15 new faculty members per year in the physics departments of Ontario of which approximately 11 are likely to be recent Ph.D. graduates.

Finally there are demands for Ph.D. physicists from a variety of areas, each of which employs few, and there is a loss of physicists by Ph.D. graduates freely choosing to enter some field for which the Ph.D. is not a requirement. Senior positions on the staff of community colleges and high schools and a variety of positions in hospitals and professional organizations often require physicists trained at the Ph.D. level. Upon graduating with a Ph.D. in physics a student is forced to make a choice of a career and it has always been a fact that some choose careers which they could have entered without their Ph.D. training. In considering the demands upon the schools, we must consider this loss from the available force of Ph.D. physicists but all changes in career at a later date will be considered the natural attrition of the labor force.

The best estimate we can make for the annual demand for Ph.D. physicists which can be filled by the Ontario universities, for the next five years, is as follows:

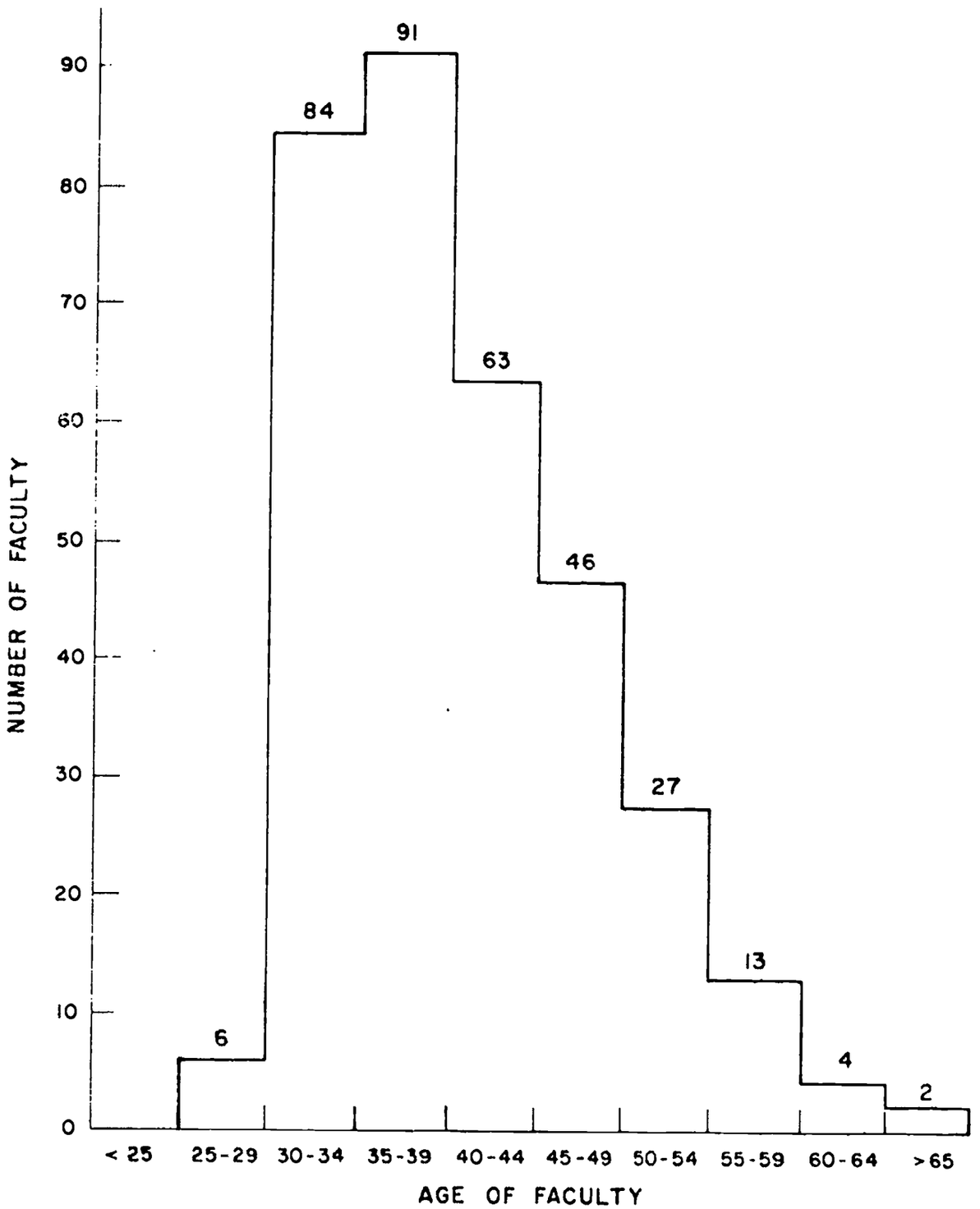

Figure 2 AGE DISTRIBUTION OF THE PHYSICS FACULTY IN THE ONTARIO UNIVERSITIES

Industrial demand	9
Government demand	10
University demand	11
Other demand	7
	37

The demand for physicists at the masters level is even more difficult to estimate than the demand for Ph.D. physicists. Few masters physics graduates find employment at universities but they fill many different types of positions in industry and in government departments. The demand for these graduates is very much influenced by the state of the economy and thus subject to large short-term variations. It appears that the demand for masters graduates in physics is strong at the present time and largely through our faith in the growth of Canadian industry, we believe that the demand will continue to be strong. We, therefore, believe that the number of physicists graduating at the masters level should stay rather close to the present value (110 per year). This estimated demand for "masters" physicists together with our estimate of the demand for Ph.D. physicists implies a change from the present pattern of physics education with far more students terminating their studies at the masters level.

Translating our estimates of the demand for masters and Ph.D. physicists into the numbers of graduate students needed in the Ontario universities to fill the demand by 1978, it appears that the numbers would be 148 Ph.D. students and 165 masters students. To these numbers there must be added the number of foreign students who will be studying in Ontario and returning to their native lands upon graduation. This may be about 30 Ph.D. students and 20 masters students. Thus, on the basis of demand, we estimate that by 1978 the Ontario system should have enrolled 178 doctoral students and 185 masters students.

Student Supply

In attempting to estimate the number of qualified students who will wish to undertake graduate studies in physics, we have taken note of the number of students of the appropriate age in Ontario, the number of nonCanadian students who are likely to enroll, the attitudes of students at present and possible changes in these attitudes. The future attitudes of students is probably the most important factor and the most unpredictable.

The total population in the age group associated with graduate studies will continue to increase, reaching a value 20% higher than the present level (see Appendix III). Given no change in other conditions, we might expect a 20% rise in graduate enrolment over the next ten years. Other conditions are, however, likely to be the controlling factors. For example, the number of physics major and honours students in the years between 1968 and 1972 was nearly constant when the population of the appropriate age increased about 17%.

In our discussions with the faculty and with the graduate students we have attempted to determine the attitudes of the present graduate students to graduate studies in physics. With a few exceptions we found the faculty presented an optimistic picture in which the students are finding satisfactory employment and in which there is an increasing interest in graduate work in physics. Also, with few exceptions, the students presented a much more pessimistic picture in which only a few of the graduates are finding suitable employment and in which only the most dedicated students are being attracted to graduate school. Some part of this difference of opinion arose from a different point of view on postdoctorate fellowships. Faculty members usually regarded fellowships as satisfactory employment while many students, aware of the difficulties in finding employment at the end of these fellowships, regarded them as unsatisfactory positions. While it is probable that the truth lies between the two points of view, there seems little doubt that the pessimism of the graduate students will have a depressing effect on the number of physics major and honours students electing to continue into graduate work. Only a satisfactory employment situation among postdoctorate fellows and Ph.D. graduates is likely to again increase the fraction entering graduate school.

In 1972-73, half of the Ph.D. students were not Canadian citizens. A certain number of these non-Canadians were students who had entered Canada, often with their parents, fully intending to become Canadian citizens whether or not they attended university. There are, however, many non-Canadian students who obtained their bachelors degrees in foreign countries and were attracted to the graduate schools of Ontario by the favorable terms offered. Recent changes in the immigration laws and in the rules governing the funds available for foreign students will substantially reduce the number of such foreign students. We may expect that over 30% of Ph.D. graduate students but a considerably smaller fraction of the masters students to be affected by the changes in the regulation resulting in a 15 or 20% decrease in the numbers of graduate students.

Our survey of the present numbers of undergraduate students in honors and major physics courses and of the attitudes among graduate students lead us to believe that there will be a slow increase in students enrolled in majors and honours courses with no corresponding increase in those continuing on to graduate school. Of those who do enter graduate school a higher fraction are likely to leave after completing their masters degree. The number of non-Canadian students is expected to drop sharply. With these factors in mind, we expect the graduate enrolment in physics to be about 350 in 1978 of which half will be masters students.

We have not attempted to make year-by-year projections of enrolments. A smooth curve with a very flat minimum joining past numbers to the numbers we have predicted for 1978 is our best estimate of the trend. We see no reason for predicting a sharp rise in numbers beyond 1978 and only after 1990 will the rapidly rising numbers of retirements cause a sharp increase in the demand for physicists.

Comments on the Projected Enrolments

We wish to emphasize that we have not endeavoured to determine a desirable enrolment in physics graduate schools nor have we considered the possibility of forcing the enrolment towards some predetermined goal. The numbers we have presented are the numbers of students who might be expected to enroll and the numbers of physicists which Ontario might reasonably contribute to Canadian requirements if present trends continue. Fortunately, it appears to us that the numbers of students will approach the demand and we therefore recommend that no regulations be adopted which would place limits on the total number of students enrolling in graduate programs.

The physics departments of the province supplied the consultants with projected graduate enrolments. For the years 197879 the sum of these projections gives a total enrolment near the 1969 level. This number differs greatly from our projected value. During our discussion with department heads and faculty it became clear that several of the projections represent a desired rather than the expected number of students. Also several departments gave reasons for expecting to enroll an increased fraction of the total number in the Ontario university system but none seemed to expect a smaller fraction. We do not condemn the departments for their optimistic projections but we believe that we understand the reasons for the difference between our projections and those of the physics departments.

It may appear that we are making projections which reflect a very pessimistic outlook for the future of physics. We believe that this is not the case. Compared with the high graduate enrolments of 1969 the predictions may appear gloomy but we believe that this merely reflects the anomalously high enrolment of that time. We believe that Canadian industry will become more technical and that physicists will play a substantial role in this change. We believe that Canadian universities and research institutions will find support in their work advancing the knowledge of physics. The numbers of graduates we predict for the next five years is depressed to some extent by the high enrolment of the present and immediate past and taking this fact into account, we believe that the projected enrolments are numbers which represent a healthy future for physics.

Finally it may be claimed that our projections are presented with little supporting data and no sound theoretical basis. We agree. The projections are nothing more than the conclusion reached by four scientists who have no information beyond that freely available to all and who have no special knowledge of the mystic arts required for infallible forecasting.

IV The Physics Departments of Ontario

In this section we give our impressions of the characteristics of each of the physics graduate schools in Ontario. We have made no attempt to deal in detail with the many research projects of the approximately 300 faculty members but comment on the average of many activities. In so doing, some of the strengths and some of the weaknesses of each department are lost.

At this point it is useful to present summaries of some of the data supplied by the universities which provide useful information on the system of universities and at the same time illustrate the differences between the universities in the system. We shall consider two topics, the Canadian student enrolment and the quality of the student body.

Canadian Content

In section II we have mentioned the fact that about half of the Ph.D. graduate students are non-Canadian. Some of these are landed immigrants of long standing in Canada. Nevertheless, because of recent changes in immigration laws and financial support regulations, it seems probable that the numbers of non-Canadian students will drop in the near future. In Table 2, we show the percentage of the Canadian graduate students at each university. From the entries in this table we can make the following observations:

(a) There is a barely discernable trend toward an increased percentage of Canadian students at the masters level. The Canadian content of the masters programs is sufficiently high that a decline in non-Canadian students will have no serious effects.

(b) At the Ph.D. level the variation in the Canadian content is much greater than at the masters level. It appears that some institutions have had difficulty attracting Canadian students and, at a time of rapidly decreasing enrolment of foreign students, these institutions may be in great difficulty.

(c) Reduced foreign student enrolment will have little influence on astronomy graduate schools.

Student Quality

We know of no simple method of determining the average quality of the graduate student body at a university. Some measure of this quality would be useful as an indication of whether or not the decreasing enrolment since 1971 had caused a university to lower its entrance requirements. We note there that such a lowering of admission standards does not necessarily imply a change in the minimum acceptable standards as specified in the graduate school regulations of the various universities. One measure of the quality of the student body is the fraction of the students holding NRC scholarships. Since

TABLE 2

PERCENTAGE OF CANADIAN GRADUATE STUDENTS

(Landed Immigrants are not included)

UNIVERSITY	1969-70		1970-71		1971-72		1972-73	
	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.
Brock	-	-	100	-	-	-	40	-
Carleton	38	20	50	20	100	67	100	44
Guelph	100	-	100	-	100	-	100	-
Lakehead	50	-	25	-	40	-	50	-
Laurentian	100	-	86	-	63	-	50	-
McMaster	58	59	68	59	63	56	63	53
Ottawa	61	61	79	75	100	71	100	67
Queen's	32	45	32	38	63	26	56	32
Toronto - Phys.	83	66	87	65	82	61	79	61
Astr.	75	67	88	58	82	67	88	78
Trent	100	-	67	-	75	-	67	-
Waterloo - Phys.	68	32	60	36	48	41	63	42
Math.	50	35	100	33	100	20	80	-
Western - Phys.	43	39	40	35	44	33	73	35
Astr.	88	67	91	50	100	50	100	80
Windsor	67	39	50	39	57	63	56	44
York	63	44	33	46	67	41	46	42
System Total:	64	53	66	53	70	52	70	52

TABLE 3

PERCENTAGE OF GRADUATE STUDENTS HOLDING NRC AWARDS

University	1969-70	1970-71	1971-72	1972-73
Brock	-	100	0	0
Carleton	14	16	15	5
Guelph	9	14	23	36
Lakehead	0	0	0	0
Laurentian	50	14	25	17
McMaster	41	36	31	33
Ottawa	28	26	18	16
Queen's	23	20	15	22
Toronto - Phys.	31	37	41	28
- Astr.	60	57	59	50
Trent	0	33	25	0
Waterloo-Phys.	16	16	24	23
-Math.	10	20	44	42
Western - Phys.	23	19	15	22
- Astr.	27	15	11	11
Windsor	29	5	0	4
York	14	26	18	17
System Total	28	28	28	25

students holding these scholarships and bursaries can choose their graduate schools free from the financial pressures which often influence other students, their concentration is a measure of a school's ability to attract students of the highest quality. We have therefore determined the percentage of the graduate students supported by NRC scholarships and bursaries at each university. The results are presented in Table 3 for the four academic years from 1969-70 to 1972-73. As measured by the entries in Table 3, one can make the following comments on the qualities of the various student bodies:

1. The percentages given for the four emergent universities (Brock, Lakehead, Laurentian and Trent) are not statistically significant since the number of graduate students at these institutions is small.

2. Since the percentage of students in the system holding NRC awards has remained nearly constant over the four-year period shown in Table 3, the variations at the individual universities is significant.

3. The quality of the student body at the University of Toronto and at McMaster University is above average in each of the four years. The department of Astronomy at the University of Toronto has a particularly outstanding graduate student body. The department of Applied Mathematics at the University of Waterloo also has an outstanding group of graduate students.

4. The University of Guelph has a student body whose quality is steadily improving and is presently well above the systems average.

5. The quality of the student body, as measured by the statistics in Table 3, has decreased markedly over the four year period for the Physics Department of the University of Windsor. The quality of the student body at Carleton is also well below average.

Assessment of the Departments

In the following paragraphs we present our assessment of the fourteen physics departments of Ontario. The universities are listed in alphabetical order except for the four smaller universities which are grouped together. As a rough measure of the size of the various departments, the number of faculty members in each are listed in Table 4. The numbers in this table should not be used in any detailed evaluation of departments since the method of reporting faculty members is not the same for all universities.

Carleton

Graduate studies at Carleton University have been concentrated to a large extent in the area of high energy physics and it is probable that this is the only area in which Ph.D. training can be expected in the near future. The group of faculty members engaged in high energy research is small by world standards but it has been able to conduct successful experiments at the major accelerator laboratories and the

Table 4

Approximate Numbers of Full-Time Faculty Members

	Full Professors	Associate Professors	Assistant Professors
Carleton	4	8	2
Guelph	7	9	8
McMaster	17	14	2
Ottawa	6	8	2
Queen's	9	13	12
Toronto	23	13	10
Waterloo (Physics	15	17	7
(Mathematics	2	4	2
Western Ontario	12	16	9
Windsor	7	9	1
York	10	11	6
Brock	1	4	2
Lakehead	3	2	5
Laurentian	3	4	4
Trent	1	4	1
Toronto (Astronomy	3	2	8
Western Ontario (Astronomy	1	3	3

students associated with these experiments are in contact with many aspects of physics beyond those at Carleton. Although the department is engaged in only a small research effort, we believe that the strong concentration on high energy physics has allowed it to develop a group of faculty members, postdoctorate fellows and students within which an effective Ph.D. program is being offered to students. In other areas the department is weak. The proposed association with the University of Ottawa should strengthen the course work of the department and have some small advantages in other areas but probably will have little effect on the research activities.

With a considerable portion of the faculty contributing little to the Ph.D. program, it is unlikely that Carleton will emerge as a strong graduate school in physics. The research equipment and other facilities in the department, along with that available from government agencies, are quite sufficient to carry out the present research program. The projected enrolments of the department are reasonable but faced with its difficulty in attracting scholarship students and the probable reduction in non-Canadian students, there may be difficulties in achieving these numbers.

Guelph

Although the University of Guelph is not new, it is only recently that it has attempted to develop a substantial graduate program in physics. During the past few years the department has acquired a faculty up to the standard of some of the well established physics departments and is carrying out research in a number of areas. The greatest strength lies in the studies of amorphous systems and in nuclear physics and in biophysics which will be assessed separately. The faculty is a well balanced mixture of experimental and theoretical physicists. The department is well equipped with experimental apparatus and several faculty members make use of major facilities at other centres.

The physics department was appraised and found competent to undertake Ph.D. training in physics. Subsequently an embargo prevented the university from implementing its Ph.D. program but some doctoral students from other universities are supervised by the members of the Guelph faculty. It is difficult to judge the effects of the embargo. We found a number of faculty members progressing effectively and enthusiastically with their research programs but we were told that the embargo reduced morale and created hardship and injustice. It is clear however that the university and the department of physics very strongly favour the development of a Ph.D. program. (For a further discussion of this embargo see page A-40.)

A plan for an industrial Ph.D. program in physics has been proposed in which a candidate may conduct all research at an off campus industrial research laboratory. It appears that the course requirement for this type of Ph.D. may differ from that of the usual degree. While

approving close collaboration with industrial laboratories, we believe that the university should take great care in maintaining standards and, in particular, in retaining sufficient breadth in this industrial Ph.D. program.

McMaster University

McMaster University has an excellent physics department which has achieved international recognition in its two areas of specialization, nuclear physics and solid state physics. The fraction of outstanding faculty members in physics is in our opinion higher than at any other university in Ontario. The university has benefitted for many years from the enlightened leadership of its senior administrative officers. Interdisciplinary research, particularly in materials science has flourished at McMaster. Physical support facilities are excellent, and the physics department is probably the best supported department in Canada. The department however, has a relatively weak undergraduate student base and is experiencing some difficulty in attracting a reasonable number of qualified graduate students. Ph.D. numbers have fallen from a high of 90 in 1969-70 to a low of 49 in 1973-74. This drop is greater than for the Ontario system as a whole. During the same period, the quality of graduate students at McMaster, as measured by the percentage of NRC award winners, has dropped from 41% in 1969-70 to 33% in 1972-73. This decrease in student quality is greater than that for the Ontario system as a whole, but the quality of the McMaster student body is still better than the average system quality. The university is evidently aware of this problem and its projections for the future are entirely reasonable.

Ottawa University

The primary strength of the physics department lies in the area of solid state physics. The department is small (14 faculty members) and is likely to remain so for the next five years. On the basis of the stringent criteria which we have adopted we have identified only two outstanding faculty members in this group. We would therefore project a desirable Ph.D. enrolment which is smaller than the present actual enrolment. However the University of Ottawa has unique characteristics which we believe must be taken into account in planning future enrolments. This matter is discussed in the next chapter (page A-40)

The department is proposing a formal amalgamation with the physics department of Carleton University. The proposed arrangement may be useful with regard to graduate course work but will probably not have a significant impact on research programs since the programs at these institutions do not overlap significantly.

Other matters in the department (research facilities, technical support, morale) are judged satisfactory.

Queen's University

The physics department at Queen's specializes in nuclear physics, astronomy and astrophysics and in solid state physics. We judge the experimental nuclear physics research to be of good quality, well balanced and well supported by theoretical research in related areas. The research in astronomy and astrophysics is strongly concentrated in radioastronomy. Although the radioastronomy group has no local facilities, it has access to a number of major installations and has contributed research of good quality, some of it imaginative. The solid state research effort appears to be somewhat fragmented and of variable quality with the best work being concentrated in the area of metal physics. The department has also initiated work in applied physics. Some of this work appears to be entirely developmental in character and might be more appropriate for an engineering department. A rationale of the role of applied physics is needed at Queen's.

On the basis of faculty quality we have assigned 9.6% of the total Ontario Ph.D. enrolment to Queen's. This fraction is larger than that which describes the actual enrolment in any recent year. We note that the Queen's student body has a low Canadian content and it appears unlikely that the department will realize its own predictions regarding graduate student numbers. Nevertheless, the department should plan on the basis that it will not share in the anticipated further reduction of Ph.D. students in Ontario.

University of Toronto

The department of physics of the University of Toronto is the largest in the province and its research activities cover the broadest range of subject matter. The quality of the faculty is good, although not uniformly good in all areas, and we find that the department has the largest number of well qualified Ph.D. supervisors of any physics department in Ontario. Several members of the faculty have achieved a truly international reputation.

The strongest research group in the department is not clearly apparent in the listing of subdivisions of research on the submissions to ACAP by the university since it bridges the divisions of atomic and molecular collisions, molecular spectra and crystal physics. In this area, close collaboration between excellent experimental and theoretical research has resulted in significant and well recognized advances in the understanding of long range molecular interactions. Nuclear physics has had an unusual history at Toronto since the university has never had a large nuclear accelerator which has proved effective in substantially advancing nuclear physics. The nuclear physics group nevertheless has worked effectively, to a large extent with accelerators at other centres. The quality of the faculty in this area ranges from excellent to average. Elementary particle physics, both experimental and theoretical, is carried forward effectively by the largest group in that field in Canada. In this difficult area where the work must be compared with that of some of the world's largest and best financed groups of

experimental physicists who are supported by theoretical groups of the highest quality, we feel that the department can claim only moderate success. For many years, solid state physics, in the usual sense, was not strong in the department although there were notable individual efforts in the field. Much of the present strength of the group is of recent origin and at the present time the quality of the faculty in this area ranges from excellent to below average. The atmospheric physics group is small but of high quality. As we have noted earlier, atmospheric physics is an area where the demand for trained personnel is high and will likely remain high for many years. We believe that the department and the university have acted wisely in planning to expand this field of graduate studies. There is a good mix of theoretical and experimental work in all areas but it appears that aside from the atomic and molecular field, the collaboration between the theoretical and experimental groups is limited. All of the above comments should be read remembering that we find the department has the largest number of qualified Ph.D. supervisors of any department in the province.

The weakness of the physics department lies not in the scientific competence, but in the fact that it appears to consist of a number of noninteracting or even conflicting groups. For example, the students reported rather sharp boundaries to their range of interactions, evidently limited by the boundaries of the various groups of the department. One must conclude that at present the department gains little by its large size. With its present high quality faculty, with its excellent research facilities and with its central location, the department should look forward to a future in which it could become a truly great department as measured against the best in the world. Without continuous effective leadership and the active cooperation of all parts of the department, such success is unlikely.

Graduate work on the Scarborough and Erindale campuses of the University of Toronto is an integral part of the overall graduate program of the University of Toronto. Entrance and degree regulations are identical with those of the St. George campus, and the faculty competence is comparable for the three campuses. Facilities for experimental research are very good on the Erindale campus but are more limited at Scarborough. The latter campus is improving the balance between theoretical and experimental work by adding another experimentalist to its faculty. (This is primarily relevant to the undergraduate program, since the graduate program draws on the full strength of the three campuses.) Commuting is a problem for students as well as for faculty but the benefits of associating with the St. George campus certainly outweigh the disadvantages associated with frequent travel. The university is to be commended for maintaining the graduate work of the three campuses in a single graduate school.

Waterloo

The physics department at the University of Waterloo specializes in condensed matter physics. The quality of faculty in this department is somewhat disappointing and except for two senior members who hold administrative posts, the department lacks a "star".

The quality of the student body, as measured by NRC awards, was below average during 1969-71 but has recently improved and is now average. The Canadian content of the student body is somewhat below average.

The department has a strong undergraduate base. General backup facilities are good, computing facilities excellent. The department plans some applied research, but is aware of the need for balance. In view of the presence of a large engineering faculty, this view seems entirely appropriate.

The applied mathematics department engages in some physics-related activity which at a different institution might be an integral part of the physics department. We judge the physics-related faculty to be good to outstanding. The group consistently attracts an outstanding student body and the size of the graduate student activity appears to be entirely determined by the availability of first class students. Our projections for this group closely coincide with their own estimates.

Western Ontario*

Taking into account the members of the applied mathematics department who are working in theoretical physics, the University of Western Ontario has one of the largest physics departments in the province. The major areas of research are physics of the atmosphere, atomic and molecular physics and theoretical physics. In these areas the department has adequate facilities for a high quality Ph.D. program.

The University of Western Ontario was well established before the post-war explosive growth of the universities began. From this firm base one might have expected the physics department to grow to be one of the strongest in the province. Unfortunately we find that the graduate school in physics is one of the weakest among departments of comparable size. In every physics department there are a few faculty members who contribute little or nothing to research and graduate studies but in this department the number of such faculty members is unusually large. We found the ionospheric research to be of good quality, the atomic and molecular research to be highly variable in quality and the physics-related research in the department of applied mathematics to be of inadequate quality. There appears to be little unity in the department and it lacks the atmosphere of enthusiasm and stimulation which are characteristic of a good graduate school.

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*The University of Western Ontario made a single submission for the Department of Physics and the theoretical physics work in the Department of Applied Mathematics. Accordingly, we have treated the two together in our assessment.

The future course of the physics department is somewhat unclear. On the one hand, it appears that promotions in the past have had little relationship to excellence in research and the department now has a considerable number of faculty members in positions with tenure who contribute little or nothing to research or graduate studies. On the other hand, the university now seems well aware of the weakness of the department and has expressed a determination to strengthen it. There are a number of able young men in the department who could add to its future strength. It will require very firm policies over a period of years on the part of the administration to ensure the advancement of the most able faculty members. In the immediate future we believe that recovery from the recent substantial reduction in the size of the physics graduate school will be slow.

Windsor

The physics department of the University of Windsor awarded its first M.Sc. degree twelve years ago and the department has grown to its present size only very recently. The department is engaged in graduate studies in atomic and molecular physics, relativity, solid state physics and nuclear physics. Without doubt the strength of the department lies in the atomic and molecular field where special emphasis has been placed on the studies of collisions. In this area and in relativistic physics where it is normal to find only two or three members of a department knowledgable in the subject, the department of physics has considerable strength.

Beyond doubt, five years ago the physics department would have been judged very weak. The additions to the staff of the past five years have done much to strengthen the department and the university is to be commended for the quality of the new staff. We found the quality of the research in the area of the major activity of the department (atomic and molecular physics) to be very good. Apart from the depressing effects of the employment situation, the morale and enthusiasm in the department are high. Careful selection and building, starting from the recent additions to the staff, should assure the department a good standing in any rating based on quality.

In spite of the quality of the present work in the department, graduate studies in physics at Windsor are in a precarious position. The student body has a large non-Canadian content and the university has failed to attract students of the highest quality. With an overall decline in graduate student numbers and with this decline being greatest among non-Canadian students, the department may find itself in a difficult position. It is most unlikely that the department will achieve the projected 30-50% increase in graduate enrolment over the next five years.

York

The graduate school at York University is the most recently developed large school of physics in Ontario. The department has specialized in atomic and molecular physics with particular emphasis on atmospheric and astronomical studies. Much of the strength of the department comes from its coherent structure and from the cooperation between the physics and chemistry departments. The demand for physicists trained in these areas for work in environmental control has made this graduate program particularly valuable. Space, research equipment, library and computer facilities are quite adequate for a high quality Ph.D. program.

Insofar as graduate studies are concerned, the average quality of the faculty is somewhat disappointing. Although high quality reliable work is carried on by some members of the faculty, this is diluted by much which is peripheral to physics. The volume of publications is high but rather too large a fraction of it is either of a routine nature or is related more closely to engineering than physics. The enthusiasm and atmosphere of the department are good and it appears that the quality of the department has been improving. With a greater concentration on the core material of physics, the department could become one of the stronger departments in Ontario in a few years.

York University is well located in Ontario and some growth in undergraduate enrolment should be expected over the next five years. Among the physics graduate students, there is a large non-Canadian content and the University should prepare for a decreased enrolment as the forces reducing the number of foreign students become stronger. It is also unlikely that the sudden burst of activity in environmental control which has occurred in Canada in the past few years, will continue very far into the future. The forecast by the university of 30 Ph.D. students and 25 masters students in 1978 therefore appears unrealistic.

Brock University

The physics department offers an M.Sc. degree in the area of solid state physics. The faculty is more than adequate for this purpose. The department attracts a small number (less than 5) of M.Sc. students each year. We think that the department can not realistically expect this number to change in the near future. The department wisely does not anticipate initiating Ph.D. studies. Faculty teaching loads are high but most faculty members are struggling to keep abreast in their fields of research in spite of this. The proximity of Brock to major research centres facilitates cooperative research programs and the department is taking advantage of this situation.

Physical facilities are modest but adequate and the university is evidently struggling financially.

Lakehead University

The physics department at Lakehead offers an M.Sc. degree in Physics with primary specialization in condensed matter physics. The faculty competence is adequate for this purpose but the department is not a strong one. Technical backup facilities are excellent. The department wisely does not contemplate the introduction of a Ph.D. program in the near future. The department should take care to protect existing research competence in a period of financial stress.

Students and faculty complain about isolation, and the University should consider ways and means of counteracting this effect of geographic isolation. Students also complain about a lack of course offerings at the M.Sc. level and the department should attempt to extend the list of available courses.

Laurentian University

Laurentian offers an M.Sc. program in physics with concentration on fine particle physics and solid state physics. There is no graduate program in astronomy although this subject is taught at the undergraduate level. The faculty is adequate to offer M.Sc. work in the two above mentioned fields but the program offered is weak in the core subjects. There is too much emphasis on applied research and technology and because of the personalities involved, this aspect of the program completely dominates the department. In our view, the department should strive to achieve a more appropriate balance. It appears that the department is torn by internal strife and the entire situation is unstable. The department is struggling with faculty redundancy and may be asked to release faculty members. The M.Sc. program, as well as the honors program in physics, may have to be abandoned if this occurs. We recommend an early reappraisal of the M.Sc. program at Laurentian.

We note that the department is participating in M.Sc. and Ph.D. work under the auspices of Bradford University, England. A review of the graduate work of this institution is fortunately outside our terms of reference, but we do not think that the Bradford-Laurentian arrangement should receive provincial support.

Trent University

Trent University has the smallest physics department of any university in Ontario (6 faculty members). Although the faculty has adequate competence to offer an M.Sc. degree, *it is clear that* a department of this size is marginal even if the institution were to confine its attention to undergraduate activities. We firmly believe, however, that faculty research activity is essential, even at an undergraduate institution. At the present time, research funding is coupled to graduate training. If this situation were altered, we would

not hesitate to recommend that the M.Sc. program at Trent be discontinued - at least until this university has a more substantial student base. We amplify further on these remarks in the general section dealing with the four emergent universities (page A-55)

V Distribution of Physics Graduate Students Among the Universities

Having determined that the quality of the physics graduate schools should serve as the basis for the distribution of students among the universities, we now turn our attention to the evaluation of this quality. As discussed in section II, the most important factor in the evaluation of quality is the competence of the faculty as supervisors of doctoral students; a factor directly related to the competence of faculty members in their research activities. The atmosphere within the department is given considerably less importance in reaching our conclusions since it is much more difficult to evaluate and also, over a period of time, it is reflected in the number of competent research supervisors. We are very much aware of our limitations in attempting to assess the many activities of the physics departments. We have, however, relied heavily on other relevant assessments in reaching our conclusions and thus have had access to far more than our own expertise. We also find comfort in the fact that though our assessment leads to some adjustment in the present distribution of students, it does not result in drastic and irreversible changes in any of the physics departments. Furthermore, we recommend an evaluation of the departments in the near future which should lead to a more precise assessment of their qualities.

Much of our assessment of the quality of faculty members is based on NRC grants but in all cases other indicators such as prestigious fellowships and publication records were considered. The NRC physics grants selection committee has for many years used excellence as its main criterion for making research awards. Other granting agencies, and indeed other grant selection committees within NRC, do not necessarily place the same weight on the excellence of the scientist and for this reason we have not included research funds from other sources, or other NRC committees, in our evaluation. In order to use the NRC grants in this exercise we established a scale of grants which acceptable supervisors should attain. Several scales were set up and tested independently by the consultants in order to determine the sensitivity of the final result to our assumptions. The application of a scale of grants leads to many borderline cases and for these, other factors were used as the bases for our decisions.

The records of some faculty members show that their NRC physics grants do not give a true measure of their quality. Also a considerable fraction of the physics faculty receive their grants through the NRC Space and Astronomy Committee or through large grants which support accelerators or elementary particle physics. In dealing with these faculty members, we have attempted to rate them on a scale comparable to that used by the Physics Grant Selection Committee.

Counting the number of competent Ph.D. supervisors* does not give a true comparison of the merits of the various departments. Some faculty members barely meet our standards for acceptability whereas

*Please see discussion of this term in the addendum to this report.

others are scientists with international reputations who far exceed the minimum standard. In order to take into account the greater value of these outstanding physicists, we have given them double weight in determining a weighted number of Ph.D. supervisors. In all, we found that 92 faculty members met the standards we had set for Ph.D. supervisors and of these we assigned 23 double weight.

We have not presented a list of the names of faculty members whom we consider to be competent Ph.D. supervisors. To do so might imply that we favor some central authority which determines who among faculty members will be allowed to supervise Ph.D. students. We believe this authority should continue to reside within the universities and we wish to emphasize that we have used the number of competent supervisors in each department only as a measure of quality. Since such men, through a variety of interactions and committees, have a large influence on all graduate work in a department, they do much to assure suitable standards even when the department may, for good reason, assign a Ph.D. student to a faculty member whom we have not counted as a leading research scientist.

In the second column of Table 5 we have listed the weighted number of competent Ph.D. supervisors which we have identified at each university. In column three we have given the distribution of students which follows from the numbers in the second column. The last two columns give the distributions of students in the years 1973-74 and 1972-73. Actual numbers of students which we estimate may be obtained by combining the figures in Table 5 with those obtained from Fig. 1. We have purposely given percentage figures rather than numbers of students in Table 5 since we believe these percentages should be retained even if our projected total enrolment proves to be in error.

Year by year planning numbers for each university may be obtained by a smooth interpolation from the present numbers to those shown in Table 5. Beyond 1978 we have made no projections and, with new data, the periodic reviews which we have recommended will achieve much more meaningful projections. At the present time, we could not support any plan based on the assumption that there will be a rapid rise in the number of graduate students in the 1978-1983 period. We have made no projections of the numbers of masters students at each university since we believe all departments can present satisfactory masters programs to the students who will enroll.

It would be disastrous to accept the planning numbers we have presented in Table 5, or any other similar set of numbers, without provisions for periodic reviews. Many different review procedures are possible and probably the only inviolable rule should be a requirement that the review be carried out by impartial competent physicists in a manner which does not generate a new large bureaucracy. The physics discipline group should study and recommend to ACAP, procedures to be followed in periodic reviews of planning numbers. Since over the next

TABLE 5

HIGHLY-QUALIFIED Ph.D. SUPERVISORS AND DESIRABLE DISTRIBUTION OF Ph.D. STUDENTS

University	Weighted Numbers of competent Ph.D. Supervisors	1978-79* Student Distribution %	1973-74 Student Distribution %	1972-73 Student Distribution %
Carleton	5	4.3	3.2	3.0
Guelph†	5	4.3	0.0	0.0
McMaster	24	20.9	19.5	20.2
Ottawa†	2	1.7	4.0	5.0
Queen's	11	9.6	5.2	6.3
Toronto	32	27.8	32.7	28.8
Waterloo-Phys.	8	7.0	12.4	10.9
-Math.	4	3.5	0.4	1.7
Western	8	7.0	5.2	8.6
Windsor	8	7.0	5.5	5.3
York	8	7.0	12.0	10.3
	115			

†See notes on page 40 regarding the numbers at Guelph and Ottawa.

*The consultants have assumed that these numbers are not rigid but will be used in manner described in the ACAP document "Planning Technique".

few years both the standings of the many young professors in the departments and the total enrolment will change rapidly, we recommend that the first of these periodic reviews take place within two years.

Two universities, Guelph and Ottawa, require special comments dealing with special local conditions.

Guelph

Prior to our visits to the physics department at the University of Guelph, it had been appraised and found competent to undertake a Ph.D. program. Subsequently an embargo prevented the university from starting a Ph.D. program and this situation exists at the present time. The most important factors bearing on this situation, as we see them, are as follows:

We agree with the decision of the appraisal committee that the University of Guelph is competent to grant Ph.D. degrees in physics. We note that the undergraduate population at Guelph has expanded in recent years at a higher rate than the system average so leading to an increase in its physics faculty. The department is not a strong one but certainly no weaker than others which now have Ph.D. programs. Our rating of the strength of the department is given in Table 5. We have noted earlier (page A-28) that there is a feeling in the department that the embargo created "hardship and injustice". Based on our method of assessing departments and assigning planning numbers of Ph.D. students, Guelph has been assigned a small number of students. On the question of whether or not the embargo, which is largely a financial matter, should be lifted we make no recommendations.

Ottawa

In our opinion the Ph.D. program of the University of Ottawa is the weakest physics program in the province. The number of students we have assigned in Table 2 is too small to justify the continuation of the program. The University of Ottawa does, however, have a special place among Ontario Universities since it has the only Ph.D. program conducted in a department where both the English and French languages are commonly used. The student body reflects this bilingual atmosphere and we believe it should be preserved.

The association of bilingualism with a lower quality in physics education would be very harmful and in our opinion even less desirable than discontinuing the Ph.D. program at the University of Ottawa. We therefore strongly urge the university to strengthen the physics department and suggest that ACAP take no action with respect to the present Ph.D. program until the University has had time to consider this matter. We therefore recommend that the University of Ottawa be permitted to plan for a number of Ph.D. students higher than that which we have assigned in Table 5 but if future assessments find no substantial improvement in the quality of the faculty, the Ph.D. program be discontinued.

VI Graduate Work in Astronomy in Ontario

It is one of the paradoxes of mankind that the most significant advances in modern astronomy tend to be made by groups living in (astronomically speaking) abominable climates, whereas civilizations favored by clear skies have often contributed virtually nothing. In this context one need only compare Northern Europe, and in particular the Netherlands with Spain and Portugal. In the forefront of advances have been the United Kingdom and France and the countries associated politically and culturally with them in distant continents, particularly Canada and Australia.

Canada has played a distinguished role in the development of modern astronomy - one thinks of the contributions of Plaskett, Pearce, Petrie, and their associates of the Dominion Astrophysical Observatory in Victoria to our understanding of the rotation and structure of the galaxy, stellar atmospheres, and binary stars, Covington's pioneer work in solar radio astronomy, Millman's radar and optical studies of meteors and fundamental studies at David Dunlap Observatory of stellar motions by Jack Heard, Frank Hogg, Young, and others, and of variables in star clusters by Mrs. Hogg.

More recently, there have been great strides forward in the new fields of radio astronomy at Algonquin Park and Penticton, in extragalactic studies, in the development of new data acquisition systems, and in theoretical work. In all of these areas, astronomers and astrophysicists at Ontario universities have played leading roles. It is important that Canadian astronomy take advantage of this strong background and maintain leadership in areas in which they have chosen to work, e.g., high spatial resolution radio astronomy, including interferometry, structures of galaxies and cosmology, stellar motions, photometry, and high resolution stellar spectroscopy. Above all, it is important that bright young Canadians have opportunities to participate in these exciting endeavors.

Astronomy is often grouped with physics for good reasons. Qualifications for distinguished work in astrophysics are the same as for similar work in physics; one cannot do astronomy without a thorough knowledge of physics. Until recently, progress in astronomy depended on the application of newly acquired knowledge in physics, e.g., optics, atomic and molecular structure but now some of the most exciting problems in physics are posed by astronomical phenomena, pulsars, quasars, black holes, cosmology, etc. Inexplicable sources of tremendous amounts of energy in quasars and galactic nuclei pose challenging fundamental problems.

Except for limited amounts of data of specialized types acquired by radar and by probes in the solar system and data on the moon, meteors and meteorites, all astronomical knowledge depends on the detection and measurement of extremely weak electromagnetic waves reaching us from distant sources. Hence, insofar as ground-based measurements are concerned, advances in astrophysics depend on acquisition of faint radio-frequency or optical signals with reliable equipment. On the one hand, this means radio-telescopes of adequate antenna size equipped with sensitive detectors located in noise-free environments, and on the other optical telescopes of sufficient size and versatility in good locations free from lights and with an adequate amount of clear skies.

Since radio waves easily penetrate clouds, and many noise-free sites exist, Canada is in an advantageous position for radio astronomy - except perhaps for its northern latitude. For optical astronomy, the situation is otherwise. In Ontario there are really no good locations for an optical observatory. Like Lick and Mt. Wilson Observatories in the USA, the David Dunlap Observatory is grievously affected by light pollution. University of Western Ontario has established its medium-sized reflector in a light-free site, but of course is still affected by adverse weather conditions.

Although small instruments are needed to develop and check out new equipment and experimental ideas, and particularly to train students, most of the serious research work by Ontario optical astronomers has to be done elsewhere, outside of Canada.

Many of the most important and exciting problems in astronomy can be studied only in the southern hemisphere, which contains among others the following important objects:

(a) The centre of the galaxy which passes overhead at latitude $-28°$.

(b) The southern Milky Way (most interesting parts of which are at $-50°$ to $-65°$ declination) and which contains a number of unique and very interesting stellar associations and nebulae, variable stars, etc.

(c) The best examples of a number of remarkable stars are found in the southern hemisphere, e.g., eta Carinae (possibly an old supernova), stars with remarkable mass loss, e.g., γ^2 Velorum.

(d) The brightest and nearest globular star clusters, ω Centauri and 47 Tucanae are found in the southern hemisphere.

(e) The nearest of all external galaxies, the Magellanic Clouds, are observable only from the southern hemisphere. Since they are an order of magnitude closer than the nearest northern hemisphere galaxies, a 24-inch telescope is equivalent to a 240-inch northern hemisphere telescope for many projects.

The development of a joint French-Canadian large reflecting telescope for Hawaii is a big step in the right direction but this instrument will not reach the Magellanic Clouds nor the great globular cluster, 47 Tucanae. The University of Toronto has wisely placed a 24-inch reflector in a good site in Chile; this instrument is already yielding rich dividends. Also there is being planned for Australia, a 50-inch reflector designed particularly for coudé spectroscopy. This instrument, to be financed and operated by a non-government, private group will be available to both Canadians and Americans.

Repeated mention has been made of cooperation between Ontario astronomers and their counterparts in the USA whereby the Canadians are able to work with the 200-inch telescope, the Kitt Peak equipment, etc. It cannot be over-emphasized that for the 200-inch telescope and other Hale Observatory equipment, arrangements are made on a person-to-person basis. If time is made available for one astronomer, it does not necessarily mean that it will be available for another, less-known but perhaps equally competent investigator. Such a man might have an easier task getting time on the Kitt Peak or Cerro Tololo equipment, but he might still have severe difficulty in getting enough time to complete a significant program.

It is unrealistic to suppose that many Ontario astronomers can count on continuing, viable research programs that can be carried out with American equipment. The reason is that all these large and effective optical telescopes are heavily oversubscribed; larger and larger numbers of American astronomers are submitting good to excellent observing programs. Although the American observatories will be able to accommodate occasional visitors from Canada, they will be unable to supply large-telescope time sufficient for the types of programs that ought to be developed.

This means that continuing emphasis must be placed on developing optical instruments in locations in Hawaii and the southern hemisphere. Larger, more effective and specialized radio telescopes should be provided for Canadian sites for two reasons - to provide Canadian astronomers with adequate equipment and also to enable them to "trade time" with radio groups in other lands. In particular, Ontario radio astronomers should be encouraged to cooperate with their Australian colleagues. One thinks of the excellent instrumentation developed by the University of Sydney, for example, which has not been used to a degree commensurate with its possibilities because of lack of manpower, funding, etc., in the Australian scene.

To summarize, then, a portion of the vigorous program of Ontario astronomy will have to be carried out at facilities outside of Canada, e.g., in the USA and in the southern hemisphere. At least some of these stations will have to be built and operated by Canadians or partially supported by them. Cooperative programs in radio astronomy would appear to be particularly promising, especially since some radio facilities, e.g., in Australia, are not saturated as are the optical facilities.

Much of the Canadian effort in astronomy and astrophysics is concentrated in the Province of Ontario, particularly at the universities of Toronto and Western Ontario in optical astronomy, and at Toronto, Queens and York Universities in radio astronomy. In addition, Waterloo is upgrading its modest astronomical program; there are small efforts at Guelph, while Lakehead and Laurentian also have astronomers. For many years, Toronto was the only place in Canada offering advanced educational opportunities in astronomy. It has retained its preeminent position in Ontario.

Only the universities of Toronto and Western Ontario have separate departments of astronomy; in all other institutions, where it exists, astronomy is included as part of the physics program. Occasionally, efforts of considerable astronomical interest are included in departments of applied mathematics; applied mathematicians may often interest themselves in celestial mechanics, relativity, and other branches of theoretical astrophysics, including high-energy astrophysics.

At some Ontario universities where no work in astronomy is attempted, experimental and theoretical programs often embrace topics of considerable astrophysical interest. Work on spectral line broadening, autoionization and atomic and molecular collisions at Windsor is significant for interpretation of solar and stellar spectra. Likewise, nuclear physics efforts at McMaster have a bearing on nucleosynthesis in late stages of stellar evolution. Unfortunately, local staff astrophysicists are not available to take advantage of these worthy enterprises.

The range in astronomical specialties and interests is as extensive as that of traditional fields of physics but departments are usually very small. Not only is there no single Canadian institution that covers all important branches of contemporary astronomy, but in all of Canada some important domains of research are scarcely touched in university research endeavours; two examples are solar physics and meteor astronomy. Canadian astronomers should not attempt to dabble in every active area of astronomical significance, but rather they should concentrate their efforts on a few selected fields, as indeed has been done.

All important branches in astronomy can be examined at least briefly in a core curriculum at the fourth year or first year graduate level, although on any one staff there are specialists in only a very few of them. Such curricula of core courses are in fact given at Toronto and Western Ontario.

Only these two universities give a Ph.D. in astronomy, and for reasons noted below, no new Ph.D. programs in astronomy should be initiated in Ontario for the foreseeable future. On the other hand, it is possible for a student in physics to obtain a Ph.D. with a thesis on

some astrophysical topic. Such programs seem eminently practical for universities such as Queens, where viable research endeavours exist in radio astronomy, or York with specialized activities in dynamical astronomy, radio astronomy, and specialized areas in astrophysics, or perhaps eventually at Windsor in laboratory astrophysics or calculations of atomic properties of primarily astrophysical interest. Although alumni of such programs emerge as physicists, their exposure to astrophysical problems and research should enable them to bring to students and colleagues, broader insights in some of the most exciting domains in physical science.

Every university should have an astronomer to teach courses in astronomy. Otherwise, presentations usually tend to become lop-sided with heavy emphasis on the special interests of the particular teacher who happens to be giving the course at that epoch. Astronomy teachers need to be trained in departments such as Toronto or Western Ontario where full-fledged astronomy programs are offered, or at York or Queens where the physics staffs include a number of astronomers and offer contact with practicing astronomers from other groups.

The astronomical profession has been characterised traditionally by small numbers. Hence, requirements for numbers of students in an M.Sc. or Ph.D. program that are appropriate for a field like chemistry or engineering are inappropriate in astronomy. One of the most prestigious graduate schools in astronomy in the entire world, that at Princeton, admits only three students per year!

Because of the small size of astronomy departments, mobility is absolutely essential for all except the very largest places. In Ontario, a student seriously interested in astronomy would normally go to Toronto for his graduate work, unless he wishes to do high dispersion stellar spectroscopy, laboratory astrophysics, or certain aspects of radio astronomy in which event he might choose to go respectively to Western Ontario, York or Windsor, or Queens. A student who receives his honours or M.Sc. degree from Toronto would be well advised to go elsewhere for at least one of his three degrees, although if his interests are in galaxies, globular cluster variable stars, stellar motions, and certain theoretical problems, he might prefer to take his Ph.D. at Toronto. Although an astronomy student could take all three degrees at Toronto, in today's highly competitive environment, he would be well advised to strive for versatility by taking an M.Sc. with a thesis on one topic at one university and a Ph.D. in a different topic at a second university. Thus, he should not take all three degrees at Toronto, in spite of the latter's preeminence.

As far as enrollment distribution is concerned, again referring to the tyranny of small number statistics, we note that though in recent years the number of M.Sc. students in Toronto and Western Ontario differ by less than a factor of two (in favor of Toronto), the ratio of Ph.D. students is closer to five in favor of Toronto. This ratio reflects the greater opportunities available in Toronto as well as the greater distinction of its staff.

At other universities, students whose theses involve astrophysical topics are included in the physics statistics (since they actually gain their degrees in physics). At Guelph and Waterloo, staff and facilities are available to permit a student to undertake an M.Sc. thesis on an astronomical topic in a physics department, while at York and Queens a physics student could prepare a Ph.D. thesis on an astrophysical topic.

Figure 3 shows the full-time graduate enrollment in astronomy. Notice that to within the inevitable fluctuation of $\sqrt{n}$, the total enrolment is remarkably constant. We expect the Ph.D. enrolment to decline to 15 by 1978 and the number of masters students to remain approximately constant at the present level.

The situation with respect to employment opportunities in astronomy in Canada probably parallels that in the USA where there exists a large over-supply of astronomy Ph.D.'s. From an examination of the then available data, Roeder(4) concluded that the supply exceeded the demand by a factor in excess of two. By now, the situation is probably even more severe.

Employment opportunities for astronomers are mostly in the field of education -- teaching in universities and colleges, in planetaria, in science museums, and as science writers. Those who specialize in instrumentation may find opportunities in other fields and in industry, while those who are computer experts may likewise find jobs. In such instances, it is not the knowledge of astronomy that pays off, but rather the skills that had to be acquired in order to do astronomy. For example, remote sensing techniques may be applied to environmental studies.

With respect to university positions, the physics situations may serve as a useful model. In the period of expansion, many posts were filled with and tenure was granted to undistinguished individuals. This phenomenon happened to some extent in astronomy. These same institutions were thus caught in a trap of inflexibility when opportunites did come to hire really first rate people. Very few new university positions are likely to develop in the system during the next few years. A diagram qualitatively similar to that of Fig. 2 holds in astronomy as well as in physics. The number of new university positions in Canada for astronomers each year is probably of the order of 2 to 5 (depending on one's optimism) and the current production is of the order of 6 Ph.D.'s. Our recommended planning numbers of graduate students up till 1978 are shown in Fig. 3 and it is expected that these numbers will change only slightly in the five years following 1978. The current estimate is that four out of every five astronomy Ph.D.'s in the USA will have to find employment in other than

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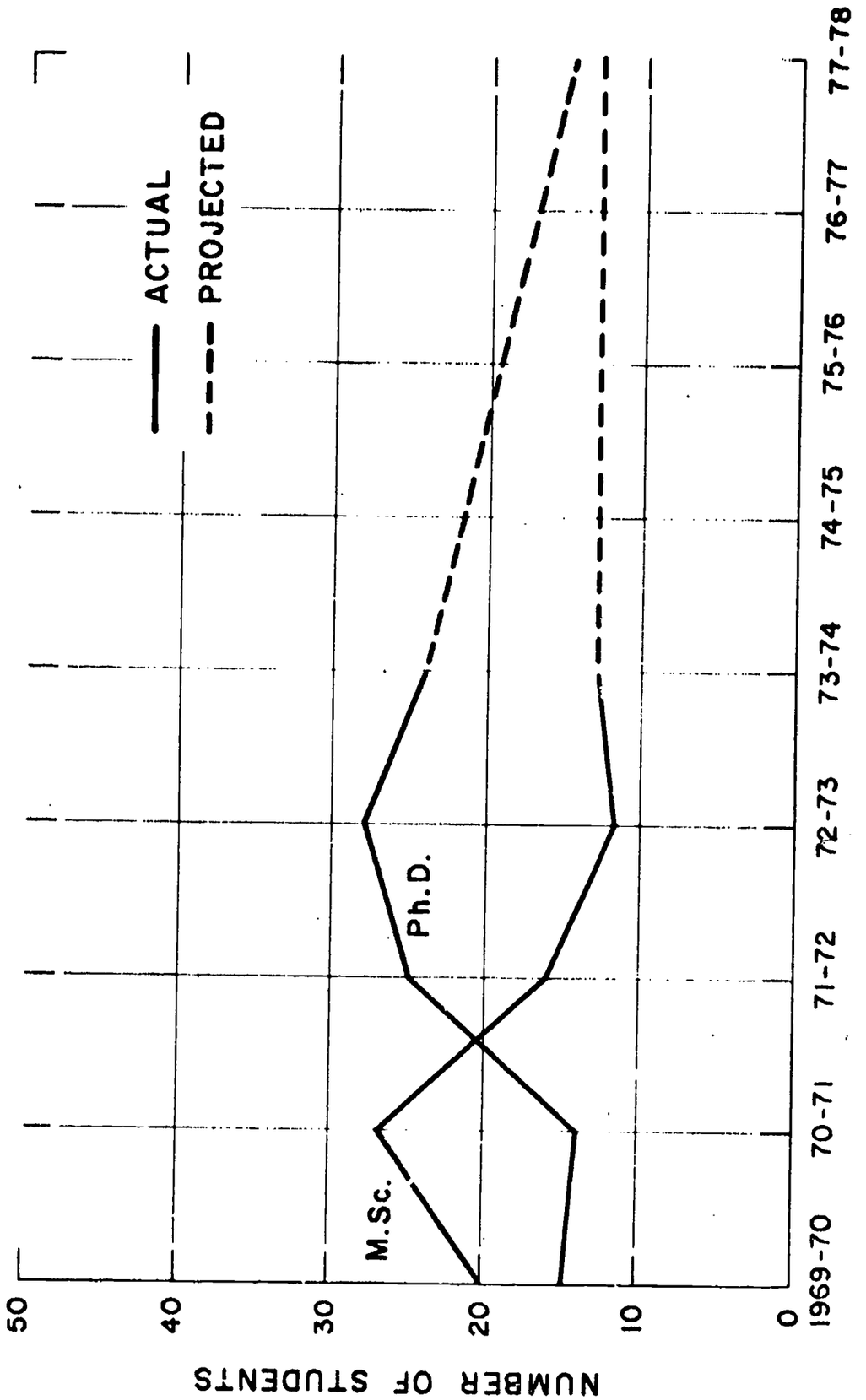
(4) Roeder, R.C., Annals New York Academy of Sciences, 77 (1972).



BEST COPY AVAILABLE Figure 3 ASTRONOMY ENROLMENT PROJECTIONS, ONTARIO

research-oriented teaching institutions or astronomical research groups. That is, they will have to seek jobs for which much of their advanced training is superfluous. In Canada, as in the USA, other jobs may be generated at lower echelons of the educational system.

Popularization of astronomy via planetaria, public lectures, star-parties, and amateur astronomy clubs has generated a fair amount of public interest in the field and should provide impetus for appointments of astronomers in educational positions in high schools, and in preparing material for presentation in grade schools. In this respect, bilingual astronomers might enjoy a distinct advantage. The potential astronomical "market" has never been developed properly among French-speaking Canadians.

Astronomy differs from physics in that it has virtually no industrial applications, although as noted above, there are many skills a competent astronomer must know that do have industrial applications, e.g., computing expertise, but these opportunities are the same as those available to physicists.

What can be made in the way of general recommendations for astronomy in Ontario? As noted above, demand for people trained in this field is likely to remain low for some years to come. Hence an annual production of six Ph.D.'s in astronomy and related fields in physics should certainly be sufficient for the foreseeable future. No new Ph.D. programs should be initiated and those currently in operation should be tightened in the sense that only the best students should be allowed to continue. One might argue that all programs save that at Toronto should be phased out, but we feel that such an action would be very unwise. Some important areas in astronomy and astrophysics simply are not covered at Toronto but are handled elsewhere, e.g., high dispersion stellar spectroscopy and laboratory astrophysics. Important radio astronomy work is being done elsewhere, particularly at Queens. Any student who intends to specialize in astronomy should get one degree in a bona fide astronomy department in Ontario or elsewhere.

Astronomy at the University of Toronto

Toronto has an excellent astronomy department, comparable with the better graduate schools in Britain, Australia, or the USA. In spite of poor observing conditions for optical work in Ontario, the Toronto people have made outstanding contributions in the fields of stellar velocities, variable stars, galaxies, and in dove-tailing advances in optical and radio astronomy. This has been accomplished largely by cooperative arrangements, often on a person-to-person basis between Toronto personnel and staffs of institutions such as the Hale Observatory and Kitt Peak National Observatory. They have also done outstanding work in high-resolution radio astronomy.

By appointing only good people to tenure positions, Toronto has tried to maintain high standards. On the other hand, the department suffers from geographical dispersion throughout the Toronto area. Key people are located at Erindale and Scarborough; the large telescope (and most of the smaller telescopes as well) and the library are located at Richmond Hill, some distance from the centre of the city, while the teaching and some research activity is concentrated at the St. George campus. The students find this scattering of staff and facilities very frustrating.

The quality of the astronomy graduate student body at Toronto is very high and will not be appreciably affected by a decline in the number of foreign students (see Tables 2 and 3). Their appraisal of the strengths and shortcomings of the department were penetrating. For example, they were aware that an increased effort in theoretical astrophysics is indicated. Toronto also needs sustained support for its efforts in instrumentation and data acquisition techniques, areas fundamental to success in the highly competitive fields of astronomy and astrophysics. The administration is aware of these matters and is making efforts to solve these problems. As we found elsewhere, the main concern of the students was that jobs would not be available when they finished their studies.

Astronomy Program at the University of Western Ontario

The University of Western Ontario has a Ph.D. program in astronomy emphasizing the use of its 50-inch telescope and coude spectrograph. They are making a significant attempt to modernize their detection equipment by developing an image dissector device similar to that used in the Wampler-Robinson scanner in use at Lick Observatory. This innovation should enormously increase the efficiency and output of their equipment in order to obtain good line profiles for detailed studies of the structures of stellar atmospheres, chemical compositions of unusual stars, etc.

Although some of the staff members are good, capable people in their own specialties, the department has some entrenched mediocrity as a consequence of policies which led to the granting of tenure where tenure was not deserved. The department appears to be frozen into its present level of quality; improvements will have to come from efforts made by its own present staff.

The ratio of Ph.D. students between Toronto and Western Ontario should be five to one in favor of Toronto but no similar ratio should be applied for masters students.

Astrophysical Programs in Physics Departments

At Queens University, an impressive effort in radio astronomy is being made by a small, capable, enthusiastic staff. Endeavours include not only "classical" but important types of problems such as

galactic clouds of neutral and ionized hydrogen, cooperative sky surveys, and radio-frequency spectral energy distributions, but also engaging new studies on radio stars (presumably close binaries), radio emission from clusters of galaxies that emit X-rays (!) and cosmological problems. The observational programs are supported by a theoretical effort involving studies of gravitational radiation, relativistic stellar structure, pulsars, and X-rays. This well-integrated effort constitutes a virtually unique effort in Ontario in an astrophysical area of rising importance. It should be encouraged as one of the outstanding programs of the physics department. The course offerings are geared to the fields of interest of the staff members and do not consititute a complete core curriculum as found in Toronto, but this is not necessary for a physics department.

A varied astrophysical interest exists in the physics department of York University; optical studies of short-period fluctuations in hot variable stars, radio studies of remarkable binary systems, planetary nebulae, and X-ray sources, and theoretical investigations of galactic dynamics. Related work in physics includes studies of atomic and molecular structure and geophysical investigations of auroral radiations from the ISIS satellite. Although the quality of many of the individual efforts is high, the dispersion of effort among very diverse programs has disadvantages, even though it may offer students a variety of choices. Close cooperation with the astronomy program at the University of Toronto would minimize many of the adverse effects of excellent efforts that are spread too thin at times.

As far as planning numbers are concerned, the prospective students who would concentrate on astrophysical theses at York, Queens, or elsewhere are included in the physics planning numbers. It is to be understood that Ph.D.'s in these programs are physicists, even though their main research interests may centre in astrophysics.

VII Comments

In this section we deal with a variety of topics which are related only in that they are matters contributing to the quality of the physics and astronomy graduate schools.

Mobility of Graduate Students

From our discussions with deans and department heads, we found that almost unanimously they agreed that it is undesirable for a student to receive all his graduate and undergraduate training at the same university. An investigation of the student bodies of the various physics departments showed that, at almost all universities, a significant fraction of the Ph.D. students had not changed universities. We must therefore conclude that, although the university authorities see the disadvantages of a Ph.D. student remaining at the university of his bachelor's degree, they are not prepared to take strong measures to discourage the practice. In our discussions with Ph.D. students we found that the reasons for continuing work at the university of their bachelor's degree were often trivial. A few stated that they remained in the same department because it was the best department for the studies they wished to pursue. Even with these students one might wonder if their reason was sound or if the undergraduate program had so limited their view that the specialty of the department was the only one they could pursue conveniently.

We believe that a student should not remain at the same university for the bachelor's, master's and doctor's degree. The change of universities is beneficial to the university system. When a student changes from one university to another, he looks at the quality of several before making his choice and when a university accepts a graduate student from elsewhere, it questions the quality of the student's earlier training. More important, however, a change of universities is beneficial to the student since he meets new professors, new students and new ideas and often enters a new life style. A broad outlook is essential since the employment situation of the future will differ considerably from that of the 60's when large numbers of Ph.D. students found employment as faculty members in a rapidly growing university system. The successful applicant in the past was often the man who specialized in some area of research for his M.Sc., Ph.D. and postdoctoral studies. The employer of the future is not likely to favour an applicant whose background indicates this degree of specialization. Instead, it may be better for the student to study a number of different areas in order to maximize his opportunities for the new employment market whose characteristics are largely unknown. For this reason we think it essential that the practice of a student taking all of his degrees at one institution be discouraged. Ideally, the student should work in different research areas for his M.Sc., Ph.D. and postdoctoral studies. Although this is in principle possible at a single institution, it tends not to happen unless the student changes universities.

As noted above we found none who actually favours the practice of keeping a student at one institution but we found many students who did not change. We suspect that the financial pressures arising from decreasing enrolments has tended to limit student mobility. It is evident that further declarations that student mobility should be encouraged will no nothing to alter the present situation since all university authorities already accept tnis principle. We recognize that, for a few students, there may be compelling reasons for remaining at one university. We therefore recommend that a university receive no provincial financial support for any Ph.D. student who has received a bachelor degree from the same university unless the student holds a master's degree from another institution or the university receives special permission from the Ontario Council of Universities. It seems appropriate that the Ontario Council of Universities act on the advice of the discipline group in this matter.

The Role of Applied Physics

The hoped for growth of applied physics in Canadian industry has produced applied physics research programs in the graduate schools of a number of institutions. This trend has been greatly accelerated because of the availability of research funds for applied projects at a time when conventional sources of research funds (mainly NRC) have remained largely static. It is clearly in the national interest to instill in our graduates an awareness of the problems of applied research. For this reason we feel that efforts to establish some applied physics research in graduate schools should be encouraged. Ultimately, however, there is the question of balance. Clearly the physics department should not attempt to become an engineering department. We feel very strongly that applied activities should never constitute more than a small fraction (say 25%) of a physics department's research activity. Otherwise the variable and diverse nature of applied projects may well endanger the health of the core physics program.

The conduct of applied research contains a number of additional pitfalls which appear to have been largely overlooked by Ontario universities. Certainly we have not encountered a definitive statement or rationalization of applied research in the university during our visits. The university, as a public institution, should not engage in proprietary research activity. The freedom of the student to publish his research findings should remain sacrosanct, students should be free to pursue interesting but unforeseen changes in their research project and this "academic freedom" of the student is often difficult to reconcile with a strictly mission oriented project which may involve a definite time scale. Proprietary research activities limit the free flow of information between faculty members and break a department into non-interacting research groups. If not checked this could lead to a situation ominously reminiscent of the situation which existed in some United States universities during the last decade. At one university the consultants were denied a list of the research grants of one faculty member "because the information is proprietary".

We recommend that all universities formulate policies governing applied research in the physics graduate program with particular attention being paid to the questions of academic freedom and the coherence of the departments.

Tenure and Promotions

Universities are notable among human institutions for their stability. In spite of the difficulties within the universities over the past few years, they have suffered little compared to industrial and government research institutions. Not only are universities stable but individual faculty members have secure positions through tenure. When correctly used, the granting of tenure is the most powerful means available for selecting a faculty of the highest quality and the stability of the universities provides an ideal atmosphere for high intellectual achievements. When misused these same factors of tenure and stability provide an atmosphere for complacency and mediocrity. We feel that, at a number of universities, the tenure system has been misused.

It appears to us that, at some Ontario universities, physicists and astronomers were hired at a time when there were no acceptable standards for the granting of tenure and later, often as the result of faculty pressure, all were granted tenure. Thus whole departments have been built up and the faculty members given secure positions for life without having faced any severe test of their competence. The pressure for promotion based on length of service and the maintenance of relative positions in weak faculties has further weakened the system.

The standards for the granting of tenure at universities where high quality is valued, are well known. Generally they involve a long pre-tenure period where the scientist must prove to persons outside his department and outside his field that he is a highly qualified teacher and research scientist. Applications of these standards result in many appointments being terminated after three or five years. The maintenance of these standards requires a strong authority at the highest level within the university which will resist the many pressures to reduce the standards. The weakness of many existing departments appears to have resulted from the lack of such a strong authority and the necessarily long and slow progress toward strength in these departments can only start when this authority is established.

Many of the weaknesses of some university departments, arising from the inadequate tenure regulations of the past, will remain with the departments for many years. If, as we believe, some growth will occur in the next ten years and, at the same time, many talented young scientists will be available, then substantial improvements in quality are possible. We therefore recommend that all universities review their tenure and promotion practices to assure a standard up to that adopted by universities which have achieved well-deserved reputations for high quality.

Present Programs and New Requirements

We have noted earlier that the graduate study programs of the Ontario universities cover a broad front in physics. Taking into account the ability of physicists to change fields and the various programs in the other provinces, we believe that the needs of the country have been met. For this reason rather little of the report has dealt with programs. We also believe that it would create an unnecessarily rigid system if particular fields of physics were assigned to each university. The various programs are already related through the activities of the discipline group which exchanges information on existing programs and discusses possible changes. We therefore recommend that there be no assignment of the responsibilities for specific fields of physics to each department but that the coordination of the research activities of the departments by the discipline group be continued.

We have pointed out that there will be few openings at the universities in the next ten years and that physics graduates will have to find employment in industry or other areas. In the USA, which might serve as a model of the more highly industrialized Canada of the future, almost a quarter of the physicists employed by industry are in the fields of optics and acoustics(2). No Ontario university has graduate programs in these areas. With the exception of Laval, which has a strong optics program, no Canadian university outside of Ontario has such programs. Optics and acoustics are not fashionable topics in physics but in preparing graduate students to meet industrial needs it would seem wise for some university to develop graduate work in these areas. We recognize the difficulties faced by universities in undertaking new programs at this time but we recommend that serious consideration be given to developing graduate programs in optics and acoustics in Ontario.

The question of whether or not controls should be placed on the movement of departments into new areas of science has been considered. The departments and the faculty members in considering this matter may be subject to two conflicting forces. On the one hand, from time to time certain areas of science become well explored and it is profitable for some of the established scientists in these areas to change their fields. These scientists find that the apparatus in their laboratory, their own expertise, their ability to publish and their contacts with other scientists all tend to discourage the change. No additional barriers should be erected in the paths of established scientists who attempt to change their fields of research. On the other hand, at various times governments make large sums of money available to deal with urgent technical problems. There may be some tendency for faculty members who have no established reputation as research scientists to undertake these well financed projects and by their strong financial position, to attract students. We believe that it would be harmful to establish rigid rules or to establish some central control over new

programs but we believe it is most important that students work with the most able faculty members. We recommend that no limitations be placed on the movement of departments into new areas of research but that in the periodic reviews of graduate programs special attention be directed to new areas of research which have been started to ascertain that students are under the guidance of well qualified supervisors.

Graduate School Entrance Requirements

In section IV we noted that the fraction of the graduate students in the physics departments holding NRC scholarships and bursaries varied greatly from one university to another and we speculated that this might be a reflection of the varying qualities of the student bodies. We also noted that the quality of the student body is not simply related to the minimum acceptable entrance standards as specified in the graduate school regulations of the various universities. We believe that each university should retain control of its own entrance procedures in order to deal quickly and effectively with students from many different backgrounds. At the same time, it is most important that the entrance requirements for all graduate schools be maintained at a high level. A graduate school which cannot attract first class students and maintains its enrolment with those of a lower standard, serves no good purpose and reflects badly on all universities in the province.

Various means of achieving a high and uniform entrance standard have been suggested. A central registration and screening committee which will deal with all applications for entrance to the graduate schools of Ontario has been suggested. This appears to be a slow procedure which would prevent the individual universities taking the rapid action which is often necessary. While the committee deliberated, the students may enter schools outside Ontario. Variations of this procedure which give the universities more freedom have also been suggested. At present we have insufficient information to recommend an improvement on present procedures or even to be certain that any change in these procedures is necessary. This question is one which deserves careful consideration and we believe that the discipline group could act effectively. We recommend that the discipline group annually review and grade the applications of physics graduate students who have been accepted by the universities of Ontario and that the results of this review be made available to the committees which will make future surveys of the physics graduate schools.

The Emergent Universities

The four emergent universities (Brock, Lakehead, Laurentian and Trent) have a number of problems in common. At each institution the faculty teaching leads are abnormally high and, in spite of this, these institutions are in severe financial difficulties. These difficulties arise from the present small enrolments and the earlier projections of

much larger enrolments. Institutions with small numbers of students are unable to take advantage of certain economies of scale and suffer when financing is based on student numbers. The earlier plans for a much larger number of students have left these universities with overly large administrative structures and physical plants. In spite of these difficulties, the faculties at each of these institutions are anxious to participate in research and graduate training thereby increasing their already high teaching load.

We feel that the desire by most members of the faculty to participate in research and graduate training stems from their conviction that, in the long term, the quality of their academic work requires an active participation in research. We have noted in section 2 of this report that we believe it is essential that members of the faculty should be engaged in research but we have also noted that we do not believe that it is necessary for the faculty to be engaged in graduate training. Unfortunately research activity and graduate training are coupled by present means of financing. If other means could be found for financing research at these universities, the pressure to maintain graduate programs which are small and costly in administration and in faculty time, would be largely eliminated. We therefore recommend that, at the four emergent universities, the income from the province for graduate students should not be proportional to the number of students but a special fund be set up at these universities to support their research programs.

Cooperative Programs Between the Universities

During our visits to the physics departments we discussed the usefulness of cooperative programs involving two or more universities as a means of improving the quality of the graduate schools and solving some of the present problems. We noted that there were numerous examples of cooperation in course work and that various experimental groups from different universities, particularly in nuclear physics, worked together. These cooperative efforts have been helpful but in the overall effort of the Ontario universities in physics, they have played a rather small role.

The two areas where cooperation is likely to prove most profitable are in course work and in the use of expensive equipment. With reduced total numbers of graduate students, the enrolments in courses at many universities are small. There can be a considerable gain in efficiency and sometimes an improvement in the quality of courses through cooperative programs in which students and professors travel between universities to reduce the teaching load. Although there are difficulties, useful cooperation has been achieved and further similar developments are possible. The use of the major research facilities at one university by the faculty and students of another is a well established practice among physicists and we feel we can make no useful comments on this matter.

The heart of a Ph.D. program is the student-supervisor interaction and the research. We have noted earlier that the average student has rather limited interactions with other professors. Also aside from the numerous informal exchanges of information, pieces of equipment and the like, between faculty members of different universities, most thesis research can be handled adequately within one university. Although we believe cooperative programs will be valuable and the Ontario Council on Graduate Studies should guard against financial and administrative practices which hinder cooperation, in the overall effort of the Ontario graduate schools in physics, these programs are likely to continue to play a small role.

In astronomy where the number of students and faculty members is small and large observatories are essential, the need for cooperation between departments is evident. For many years astronomers have cooperated on a national and international scale. We feel that these well established patterns of cooperation will change only slowly in the future.

Appendix I

(Terms of Reference of Consultants)

1 Consider the materials prepared by the discipline groups and the universities and obtain other data they may require to carry out the tasks detailed below. They may obtain data and views from any relevant source; such as, employers of holders of graduate degrees, professional and learned societies, federal agencies. The campus of each interested university shall be visited by at least two consultants. After discussion with the discipline groups, consultants shall arrange their schedule of visits to the universities in consultation with ACAP to ensure uniformity. Reports of appraisal consultants are privileged documents and are not to be made available to ACAP consultants. Consultants shall consult with the discipline groups near the beginning of the work, during the work as they consider necessary, and immediately before preparing their final report.

In order to obtain a fuller impression of graduate work intimately related to physics and astronomy, the consultants may request information from universities concerning work in related departments, such as: chemistry, mathematics, electrical engineering, metallurgy, etc.

2 Report on the adequacy of the present state of graduate work in physics and astronomy in the province in general and in each university where applicable, discussing the following:

a. coverage of core elements and specialities, and extent of activity in each;

b. faculty quality and quantity;

c. nature of programmes offered;

d. enrolment size and distribution amongst universities;

e. quality of student body; admission requirements;

f. relationship to related disciplines;

g. physical facilities;

h. other matters considered by the consultants to be significant.

3 Make recommendations for the development of graduate work in physics and astronomy in Ontario between 1973 and 1983, but in more detail for 1973 through 1978, and, without limiting the generality of the foregoing, dealing with the following points:

a. Desirable programmes to be offered in the province, considering both possible limitations or reductions of existing programmes and creation of new programmes and new kinds of programmes including the appropriateness of part-time programmes. In particular, consider possible new fields in physics and astronomy and training of students for work in application-oriented and inter-disciplinary work in which physics and astronomy should be involved.

b. Desirable provincial enrolments, year by year, in the various levels of graduate study, and specialties where appropriate. One should consider the need for highly trained manpower and also the general cultural and societal factors which may lead students to pursue graduate work. In considering manpower needs, one should take account of the "market" available to graduates (at least all of Canada) and of other sources of supply for that market. Results of forecasts of high level manpower employment should be treated with due caution and only in a clearly balanced relationship with cultural and societal needs.

c. Distribution amongst the universities of responsibility for programmes and/or specialties where appropriate, including consideration of the need for any increase or decrease in the number of departments offering doctoral work and including consideration of areas of collaboration and sharing of facilities at regional level and across the province.

d. Distribution of enrolment amongst the universities, showing desirable ranges of enrolment.

e. Desirable extent of involvement with related disciplines, identifying any suggested areas for greater collaboration.

In all cases, it is important that the rationale for the recommendations be clear; this is especially important for items c. and d. Consultants are asked to comment on advantages and disadvantages of various techniques for arranging that their recommendations become effective.

4. It is permissable for consultants to recommend appraisals of individual programmes. This would arise if consultants were to suspect that a programme would be found to be wholly or in part below minimum acceptable standards; an appraisal by the Appraisals Committee is the means of settling the question. It is recognized that this action would be infrequent. Perhaps more likely, in planning assessments in some disciplines, consultants may find an excess of programmes in the same area of study, all of which could pass an appraisal; they would then have to make their own judgments of relative quality (a task outside the terms of reference of the

Appraisals Committee), and guided by this judgment and other factors, the ACAP consultants would have to recommend where enrolment should be curtailed or eliminated.

5. The major divisions for the planning study are:

Astronomy and Astrophysics
Atomic and Molecular Physics
- Atomic and Molecular Collisions
- Atomic and Molecular Spectra
- Quantum Electronics

Elementary Particles
Nuclear Physics
Atmospheric and Earth Physics
Condensed Matter
- Crystal Physics
- Electronic Properties
- Amorphous Systems

Basic Theory
Other

Solid earth geophysics is specifically excluded as it has been studied already in the solid earth sciences planning assessment.

Biophysics will be more appropriately planned in connection with life sciences planning; it should be considered only marginally by the consultants in order to obtain a picture of the total effort of some physics departments. This planning assessment is not directed towards removal of the embargo on biophysics.

Although it may be important for consultants to obtain information about some of the graduate work in engineering departments, it is not part of their duties to make recommendations about the size of engineering doctoral programmes.

With the above exceptions, full recommendations are expected on work in the major divisions specified, no matter where it is located in a university's internal administrative structure.

Appendix II

Basic Commitments Vital to Meaningful Graduate Studies and Research

A. The Commitment by Society

Any program based on public support must be relevant to the philosophical and pragmatic needs of the community that provides the support. There are many facets to this problems with the following perhaps being the most important and requiring positive action and firm priorities set by the community.

1. The community realizes and accepts a responsibility for the maintenance and improvement of world knowledge and includes the discipline of chemistry in this regard.

2. The community needs to demand the best intellectual environment that it can afford for the higher education of its talented citizens by realizing the importance of such activity for the general material and cultural welfare, economic independence and security of its citizens.

3. The community appreciates the high cost of the pursuit of knowledge at the best world standards and accepts the sacrifice necessary for its maintenance and promotion recognizing that chemistry, as a rapidly developing science, must play a central role in this activity and indeed is deserving of preferential treatment as one of the hard core subjects of human knowledge of direct relevance to its survival as a socioeconomic unit.

4. The community appreciates that the achievement of its goals must be in the control and trust of proven experts maintained in a competitive environment with external reference as to performance and guarded thereby against unwitting deterioration of standards.

B. Commitments Within the University

1. To develop with care powers for introspection that enable it to discern the real value of its activities through dispassionate, objective evaluation of the performance of its staff members.

2. To develop procedures for appointment and promotion which reliably accumulate thoroughly competent, dedicated and exceptionally talented staff members who are thereby fit to lead the intellectual elite of the society through teaching, but more importantly through example in the conduct by direct involvement of scholarly activities at the forefront of knowledge.

3. To maintain an administration that is appreciative of true scholarship and dedicated to the concept that those staff members, who possess a degree of expertise dely acknowledged by their peers outside the university and throughout the world as being relevant to the improvement of knowledge at the best world standards, are the mainstay of the university and that the maintenance of graduate programs is largely predicated to this end.

4. To maintain an administration that realized through personal experience the great demands in talent, energy and drive required for the maintenance of scholarship at truly meaningful levels and is therefore sympathetic to and in support of those measures needed to ensure the necessary levels of performance by its professional staff.

Given the above indicated community with proper commitment of its politicians and an enlightened university administration from the Board to the president and to the level of deans, it is possible for a given department to aspire to a meaningful graduate program. In the absence of these basic commitments, it is best to do nothing since the existence of inferior programs for graduate study and research represents a hazard and handicap while being a serious drain on the economy.

To embark profitably on programs of graduate study and research also requires clear appreciation by those direclty involved of their responsibilities (a) to the university (b) to the general community and, especially, (c) to the students enrolled in the program. These responsibilities can only be met under the following conditions.

1. The department has documentable reasons for believing that its staff members can provide a Ph.D. candidate with a truly meaningful experience in higher education. To do otherwise, especially to an inadequately talented student is tantamount to sentencing the individual to second-rate citizenship in his profession and to doing great harm to the community which becomes dependent on his professional services.

2. The department must have what is required in terms of staff and facilities to attract a substantial number of absolutely first-rate students. Student bodies, like departments, need leaders to set the standards for others (and to prod professors) and unless a university has acquired staff that can dependably attract excellence to its student body, it must not assume responsibility for graduate work, especially a Ph.D. program.

3. The department must have sound reason to expect that it is sufficiently well-based financially to provide the equipment, supplies, laboratory, shops and library needed for proper engagement of a Ph.D. program with adequate secretarial, clerical, technical and maintenance personnel to make the effort meaningful.

4. The department must appreciate and be mindful of the rather large financial burden placed on society by Ph.D. programs and to participate in such activity in a thoroughly responsible manner. The responsibilities go far beyond the personal stature and ambitions of the individuals involved - matters which are very secondary to societal needs in terms of the contribution of the Ph.D. program to quality teaching throughout the undergraduate programs of the university, the career and employment opportunities within the immediate society for at the least a substantial part of its graduates, the need (actual or anticipated) for the type of specialized expertise represented by its outstanding chemist-professors to local industry, government and colleagues in other disciplines, especially on campus.

Appendix III

An Approach to Estimating Faculty Requirements: The Example of Physics

This approach to estimating faculty demand can be applied to any discipline: physics will serve only as an example. An estimate of the number of faculty required in physics in the future is based on a number of variables - both measurable and not. This paper is an attempt to identify and quantify as many of these variables as possible in order to present reasonable estimates of the demand in Canadian universities of Ph.D.s in physics.

A forecast of the number of university faculty required in the future is dependent upon:

1) Pool of People as Potential Studuents

The basic demographic trends relating to the size of the age group from which most university students are drawn sets the limit for the size of the potential university population. The majority of university students have continued their education immediately after high school and thus fall within the 18-24 age group. However, with the shift towards more part-time or "continuing" education, this relevant age group may also shift. This shift will likely be very gradual and it seems reasonable to assume that most students will fall within the 18-24 age group for the next decade.

2) Interest in University Education

The second step narrows this potential population by making assumptions about participation rates of the 18-24 age group in university education. The limits of the range of university enrolment are set by these alternative assumptions.

3) Interest in Physics

To narrow the relevant population even further, alternative assumptions about the fraction of university students interested in physics need to be made.

4) Staff-Student Ratio

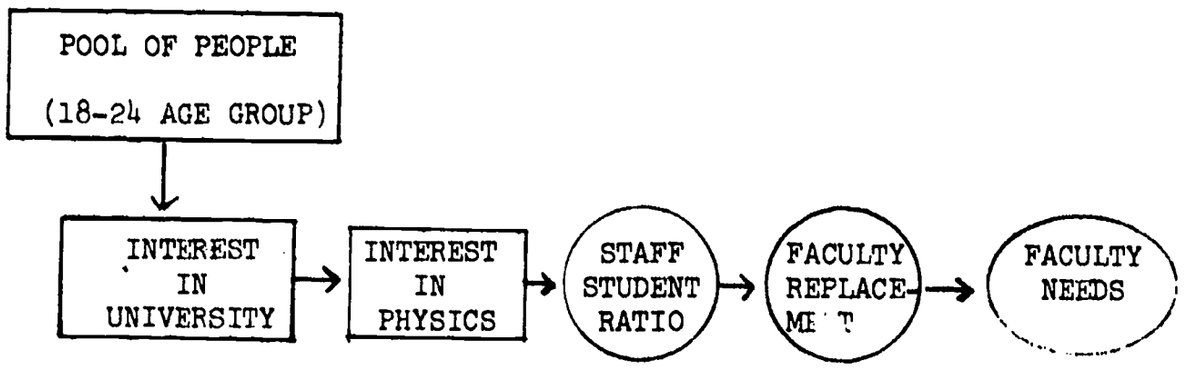
The staff-student ratio links the student data with faculty numbers. Assumptions concerning the staff-student ratio lead to estimates of faculty needs as a result of growth in physics enrolment.

5) Faculty Replacement Rate

The final step in estimating faculty requirements concerns assumptions about rates of replacement of faculty.

The progression through these five steps leads to estimates of demand for physics in universities. The process can be presented graphically.

Schema of Process to Estimate Faculty Demand



1. Pool of People as Potential Students

An estimate of the size of the 18-24 age group in the future has a fairly high degree of accuracy. Those who will make up this age group in the 1980s have already been born. The mortality rate for this age group is very low. As a result, 95% of those born in a current time period can be expected to survive to age 25. The net migration effect is probably of some importance but it is impossible to measure with any degree of accuracy. It is dependent on so many internal and external forces, that it would be positive or negative in the future. The age group projections do not take into account additions due to net migration or subtractions for mortality in the intervening period. Thus, the size of the 18-24 age group for the year 1971 + 'x' is equal to the size of the 18 - 'x' to 24 - 'x' age group in 1971. For example, the size of the 18-24 age group for 1980 is simply the number of people in the 9-15 age group in 1971. It should be noted that those in the age group are changing continuously and while some are entering the group at age 18 others are exiting at age 25.

The pattern of growth in the size of the 18-24 age group from 1960 to 1987 can be separated into four stages.

a) The first stage, which lasted from 1960 to 1969 saw a large year to year increase in the size of the age group. This came about largely as a result of the post-war "baby boom" entering the 18-24 age group. (A relatively even rate of exit from the group compared to a rising rate of entry.)

b) During the second stage, from 1970-1972, a sharp drop in the net increase of the size of the age group occurred. This drop reflected the end of the "baby boom" in 1952.

c) It is expected that the third stage, between 1972-1977, will be one of relatively stable growth in the size of the age group.

d) Finally the fourth stage, beginning in 1978, will see the impact of the sharp drop in the birth rate which began in 1960 and continued throughout the decade. After 1982, the total size of the age group will begin to decrease as those entering the age group become much fewer than those leaving it.

Fig. 4 at the end of this report shows the growth in the size of the 18-24 age group. Data for this chart is found in Table 10.

2. Interest in University Education

Forecasts of university enrolment don't have the same degree of accuracy as age group projections since students can decide whether or not they want to attend university. Assumptions about participation rates (% of 18-24 age group enrolled in university) can be used to bracket the probable range of university enrolment.

During the 1960s university enrolment grew at a rapid rate. Coupled with the growth in the 18-24 age group was a year to year increase in the participation rate. Changes in the participation rate are based to a large extent upon students' attitudes and perceptions. In the 1960s, there was an awareness that high economic returns could be gained from a university education. Also lack of funds was no longer a major stumbling block to attendance at a university since many forms of financial assistance became available.

From 1969 to 1971, the participation rate grew at a much slower rate than it did during the 1960s. University enrolment became stabilized. Students' attitudes and perceptions were again changing. There were more alternative forms of education (eg. community colleges) which appeared to be more rewarding than a university education. Employment prospects for graduates seemed to be poor. Societal values about a university education were changing. Societal values are difficult to measure but the interplay of these factors resulted in a change in the pattern of the growth of the participation rate.

What about future enrolment?

From the projection of the 18-24 age group, it seems likely that enrolment will increase slowly and then begin to decline in the 1980s. Using two assumptions about participation rates, possible future university enrolments can be projected.

Assumption I

It is assumed that the recent reduction in participation rate growth reflects a permanent shift in expectations or other factors affecting student choices. Thus participation rates will continue to grow at only 0.1 percentage points each year. (During the 1960s the participation rate grew on average 0.6% a year. However, the average between 1969 and 1971 was only 0.1%.)

Assumption II

It is assumed that the recent reduction in participation rate growth is only a short-term phenomenon reflecting in part uncertain economic prospects (eg. employment for graduates). Thus participation rate growth will soon resume its longer term trend of approximately 0.6 percentage points a year. (During the 1960s the participation rate grew on average 0.6% a year. However, the average between 1969 and 1971 was only 0.1%)

These two participation rate assumptions set the probable limits of the range of growth in enrolment.

The growth in participation rates under Assumptions I and II is shown in Fig. 5 at the end of this report. The corresponding growth in university enrolment is shown in Fig. 6 which is also at the end of the report. Data for these charts is found in the appendix.

3. Interest in Physics

The future interest in physics by university students is impossible to predict quantitatively. The historical pattern is not available since undergraduate physics enrolment figures are not collected on a national basis. Any estimate about the likely future enrolment in physics must be based on qualitative, intuitive judgements.

For this paper, it is assumed that enrolment in physics remains a constant fraction of university enrolment as a whole. By using the two assumptions for projecting university enrolment, it seems likely that the probable ranges of enrolment in physics are covered. However, different rates of growth can easily be substituted.

4. Staff-Student Ratio

The staff-student ratio forms the link between enrolment and faculty. Here again it is difficult to determine this ratio. The number of physics students is not known but the current number of faculty in physics is. Thus by assuming that the relationship of the staff-student ratio will remain at its current value, the requirement for physics faculty as a result of growth in university enrolment can be calculated. (The growth in university enrolment is shown in Fig. 6 and

the projections for university enrolment were calculated on the basis of two alternative participation rates, Assumptions I and II). Again one could make a different assumption. For example, if university enrolment grows as a result of a .6% annual increase in the participation rate but it is felt that the staff-student ratio will worsen, one could use a rate of annual increase for staff which is less than the annual increase in enrolment.

Table 6 at the end of this report shows the growth in physics faculty in Canada under Assumptions I and II.

5. Faculty Replacement Rate

Besides the demand for faculty which results from growth in enrolment, there are also faculty openings which are due to replacement. Net resignation and retirement accounts for a very small part of the demand for faculty. It seems reasonable to assume a net resignation rate of 1% for physics faculty in Canadian universities. (Net resignation refers to departures either to universities outside Canada or outside the world itself.) Thirty-one of 883 physics faculty in Canada in 1971-72 and 5 in 351 Ontario faculty in 1972-73 are 60 years of age or over. Thus the retirement rate for the next five years was averaged as 0.5%. This rate will be used for the years 1972-73 to 1987-88.

Physics faculty requirements for Canada which are due to replacement using Assumptions I and II are shown in Table 7 at the end of the report.

Table 8 at the end of the report represents the annual requirements for physics faculty in Canadian universities. It is a summation of faculty needs due to growth (Table 6) and faculty needs due to replacement (Table 7).

It seems likely that 80% of annual hiring will be junior faculty and that of these, 95% will have their Ph.D. Therefore, 76% of annual hiring in physics will be openings for Ph.D.s. The results of these calculations is shown in Table 9 which is also at the end of this report.

Historically, Ontario produces 45% of the Ph.D.s awarded in physics in Canada over the three years 1969-1971. (Canadian Association of Graduate Schools, 1972 Statistical Report.) Thus, on Assumption I for the years up to 1980, 16 Ph.D.s awarded from Ontario universities per year would be the province's contribution towards filling university teaching posts in Canada. On Assumption II, the corresponding number would be 33. Of course, some of these people will take positions outside Canada and some graduates (possible Canadians) from non-Canadian universities will accept positions in Canada. But if one feels that Canada should at least produce a sufficient number of Ph.D.s to man its own universities, this analysis will help indicate the necessary scale.

SOURCFS OF DATA

1. Data on the size of the 18-24 age group from 1960 to 1970 was obtained from Statistics Canada. The figure for 1971 was obtained from the Census of Canada publication, Population - Single Years of Age. 92-716 Vol. 1, Part 2. (Bulletin 1.2-4).

2. Data on university enrolment from 1960-1961 to 1971-1972 was obtained from Statistics Canada publication 81-204, Fall Enrolment in Universities and Colleges (various years).

3. Canadian Association of Graduate Schools. 1972 Statistical Report.

4. Statistics Canada. Salaries and Qualifications of Teachers in Universities and Colleges, 1970-1971 (81-203) 1971-1972 (unpublished).

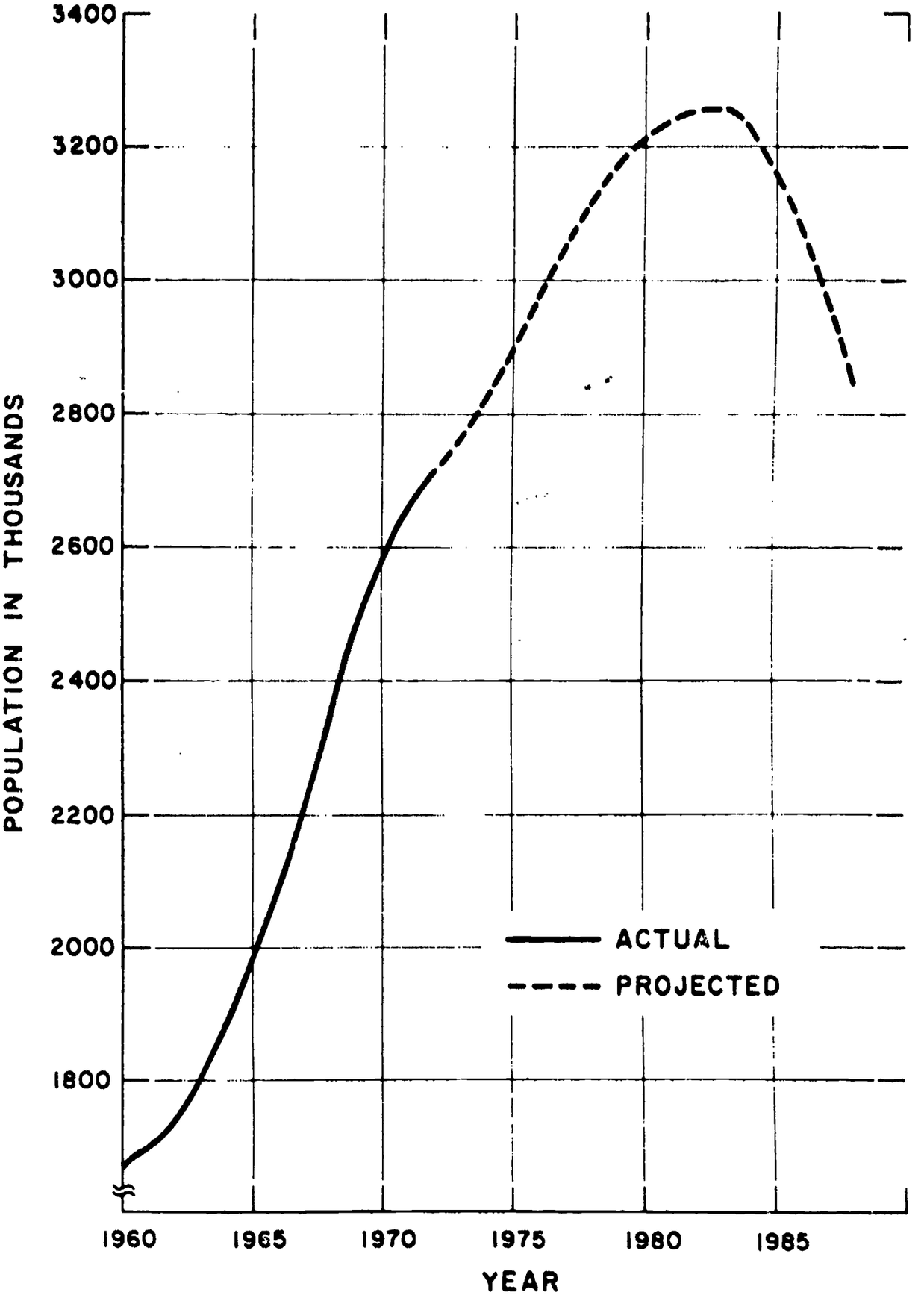


Figure 4 POPULATION OF 18-24 AGE GROUP CANADA, 1960-1987

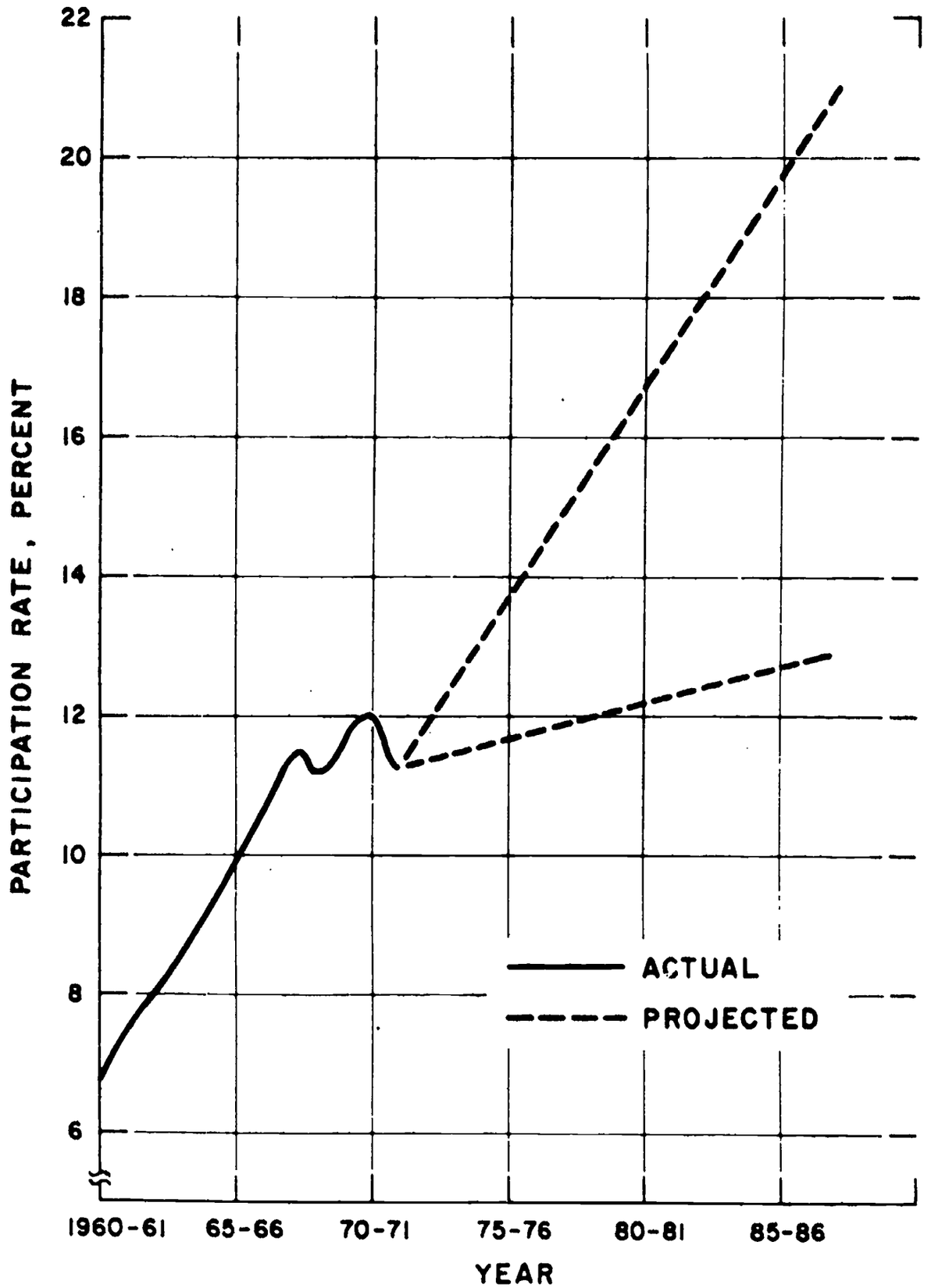


Figure 5 UNIVERSITY PARTICIPATION RATES, FULL-TIME STUDENTS CANADA, 1960-61 TO 1985-86

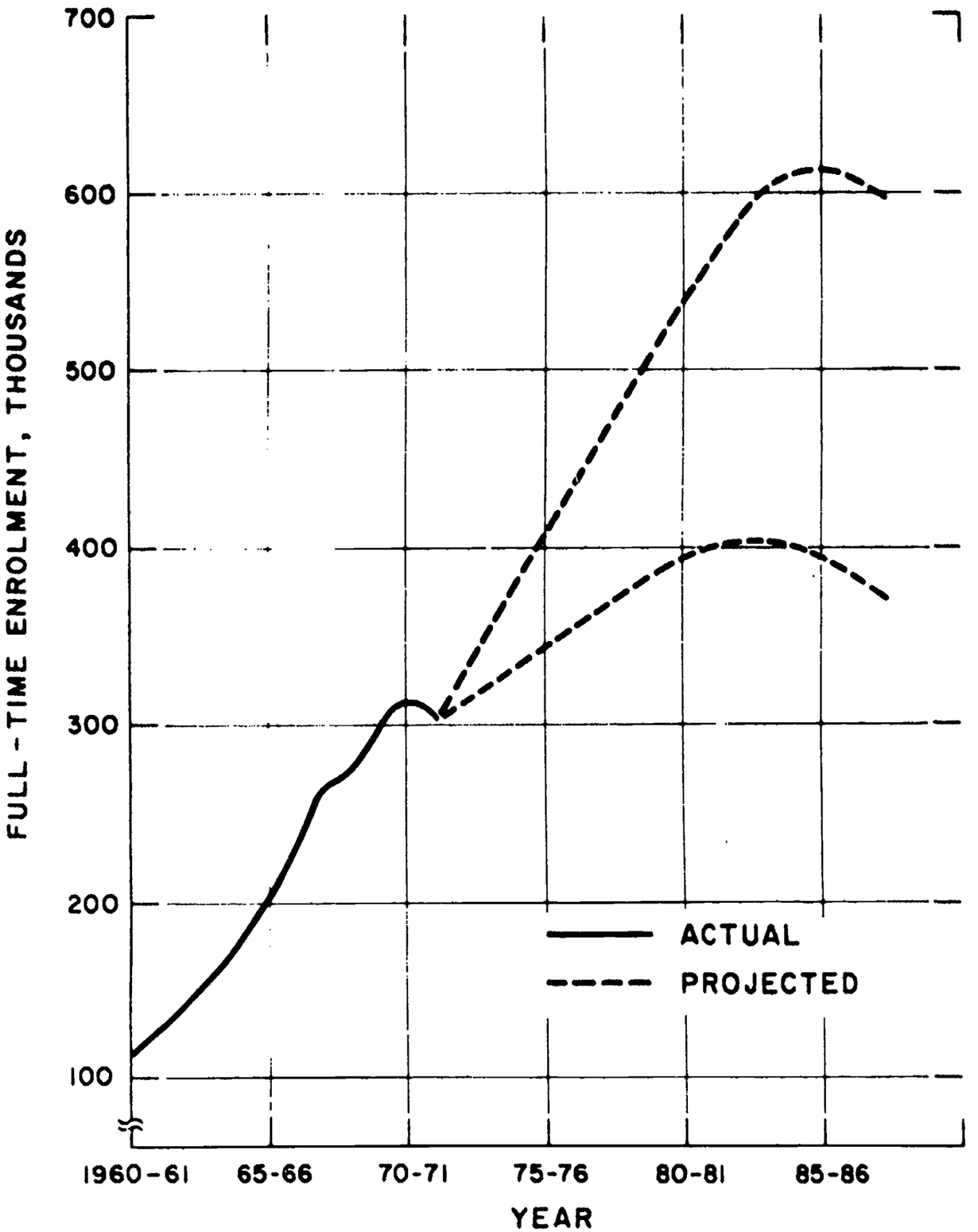


Figure 6 UNIVERSITY ENROLMENT, FULL-TIME CANADA, 1960-61 TO 1985-86

TABLE 6

ANNUAL FACULTY REQUIREMENTS IN PHYSICS

DUE TO GROWTH[1] IN ENROLMENT, CANADA

1970-1971 to 1987-1988

	ASSUMPTION I		ASSUMPTION II	
	TOTAL FACULTY	ANNUAL INCREASE	TOTAL FACULTY	ANNUAL INCREASE
1970-71	871[2]	-	871[2]	-
1971-72	883[2]	12	883[2]	12
1972-73	901	18	940	57
1973-74	931	30	1013	73
1974-75	965	34	1090	77
1975-76	1000	35	1171	81
1976-77	1035	35	1256	85
1977-78	1069	34	1339	83
1978-79	1099	30	1419	80
1979-80	1124	25	1496	77
1980-81	1141	17	1561	65
1981-82	1159	18	1630	69
1982-83	1172	13	1690	60
1983-84	1176	4	1739	49
1984-85	1168	-8	1769	30
1985-86	1146	-22	1778	9
1986-87	1114	-32	1765	-13
1987-88	1080	-34	1750	-15

[1]The projected rate of growth in enrolment resulting from growth in the participation rate (under Assumptions I and II) is found in the appendix.

[2]There were 871 full-time physics faculty in Canadian universities in 1970-71 and 883 in 1971-72. Salaries and qualifications of teachers in universities and colleges, 1970-71. Statistics Canada. 1971-72 unpublished data.

TABLE 7

ANNUAL FACULTY REQUIREMENTS IN PHYSICS

DUE TO REPLACEMENT, CANADA

1972-1973 to 1987-1988

(1.5% of Total Faculty in Table I)

	ASSUMPTION I	ASSUMPTION II
1972-73	13	14
1973-74	14	15
1974-75	14	16
1975-76	15	18
1976-77	15	19
1977-78	16	20
1978-79	16	21
1979-80	17	22
1980-81	17	23
1981-82	17	24
1982-83	18	25
1983-84	18	26
1984-85	17	26
1985-86	17	27
1986-87	17	26
1987-88	16	26

TABLE 8

ANNUAL FACULTY REQUIREMENTS IN PHYSICS
DUE TO GROWTH AND REPLACEMENT, CANADA
1972-1973 to 1987-1988
(Table 1 + Table 2 = Table 3)

	ASSUMPTION I	ASSUMPTION II
1972-73	31	71
1973-74	44	88
1974-75	48	93
1975-76	50	99
1976-77	50	104
1977-78	50	103
1978-79	46	101
1979-80	42	99
1980-81	34	88
1981-82	35	93
1982-83	31	85
1983-84	22	75
1984-85	9	56
1985-86	-5	36
1986-87	-15	13
1987-88	-18	11

TABLE 9

ANNUAL FACULTY OPENINGS IN PHYSICS

FOR NEW Ph.D.'s, CANADA

1972-1973 to 1987-1988

(Table 4 = 76% of Annual Faculty Requirements, Table 3)

	ASSUMPTION I	ASSUMPTION II
1972-73	24	54
1973-74	33	67
1974-75	36	71
1975-76	38	75
1976-77	38	79
1977-78	38	78
1978-79	35	77
1979-80	32	75
1980-81	26	67
1981-82	27	71
1982-83	24	65
1983-84	17	57
1984-85	7	43
1985-86	-4	27
1986-87	-11	10
1987-88	-14	8

TABLE 10

Actual and Projected University Full-time Enrolments, Canada

1960-61 to 1987-88

YEAR	18-24 AGE GROUP (thousands)	PARTICIPATION RATES (%)		UNIVERSITY FULL-TIME ENROLMENT (thousands)		INCREASE IN ENROLMENT (%)	
1960-61	1689.1	6.7		113.9		--	
1961-62	1712.5	7.5		128.9		13.1	
1962-63	1770.1	8.0		141.4		9.6	
1963-64	1848.8	8.6		158.4		12.0	
1964-65	1941.7	9.2		178.2		12.5	
1965-66	2039.5	10.1		205.9		12.5	
1966-67	2154.8	10.8		232.7		13.0	
1967-68	2290.2	11.4		261.2		12.2	
1968-69	2419.4	11.2		270.1		3.4	
1969-70	2543.5	11.7		298.5		10.5	
1970-71	2622.7	12.0		315.7		5.7	
1971-72	2688.8	11.3		304.4		-3.6	
		I	II	I	II	I	II
1972-73	2723.9	11.4	11.9	310.5	324.1	2.0	6.5
1973-74	2792.0	11.5	12.5	321.1	349.0	3.4	7.7
1974-75	2866.8	11.6	13.1	332.5	375.6	3.6	7.6
1975-76	2946.2	11.7	13.7	344.7	403.6	3.7	7.5
1976-77	3024.2	11.8	14.3	356.9	432.5	3.5	7.2
1977-78	3094.3	11.9	14.9	368.2	461.1	3.2	6.6
1978-79	3154.4	12.0	15.5	378.5	488.9	2.8	6.0
1979-80	3200.2	12.1	16.1	387.2	515.2	2.3	5.4
1980-81	3221.9	12.2	16.7	393.1	538.1	1.5	4.4
1981-82	3247.6	12.3	17.3	399.5	561.8	1.6	4.4
1982-83	3256.2	12.4	17.9	403.8	582.9	1.1	3.7
1983-84	3243.5	12.5	18.5	405.4	600.0	0.4	2.9
1984-85	3193.3	12.6	19.1	402.4	609.9	-0.7	1.7
1985-86	3111.1	12.7	19.7	395.1	612.9	-1.8	0.5
1986-87	2998.9	12.8	20.3	383.9	608.8	-2.8	-0.7
1987-88	2887.2	12.9	20.9	372.4	603.4	-3.0	-0.9

ADVISORY COMMITTEE ON ACADEMIC PLANNING
Ontario Council on Graduate Studies

Professor M. A. Preston
Executive Vice-Chairman

COUNCIL OF ONTARIO UNIVERSITIES
130 ST. GEORGE STREET, SUITE 8039
TORONTO, ONTARIO M5S 2T4
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June 11, 1974

M E M O R A N D U M

TO: R. R. Haering, University of British Columbia
A. E. Douglas, National Research Council of Canada
L. H. Aller, University of California
P. Nikiforuk, University of Saskatchewan

FROM: M. A. Preston

Let me thank Dr. Douglas, Dr. Haering and Dr. Nikiforuk for agreeing to meet with four members of ACAP last week in order to discuss various difficulties with your report which have been pointed out by the universities and in ACAP's own preliminary study of it. The ACAP members found the hours involved in discussion with you to be valuable, and were pleased with your agreement to prepare an addendum to your report in order to clarify some points and to answer some questions. You requested a letter from ACAP mentioning the more important points and asking the specific questions to which we need answers.

1. A discussion of the significance of "competent PhD supervisors" will be important. You mentioned to us that you felt a more accurate phrase might have been used; the number is a kind of index of quality (so is its ratio to total staff). You intend that other members of a department besides those counted (particularly younger ones) will supervise doctoral students, but you feel that a department without a reasonable number of the highly competent ought not to be offering a PhD. You recognize that some of those counted may not themselves supervise many students. You feel that the quality of education is a function of not just one person but of a whole department.

   The above is a summary of your remarks as we understood them, which we ask you to confirm, correct, or put in your own words.

2. We discussed "critical mass". You emphasized that the number 6 or 8 in your report referred to the "interaction sphere" of an individual student and that is is certainly too small to be treated as an enrolment figure. You mentioned that, in considering the student's academic milieu, one must take account of postdoctoral fellows, research

associates and sometimes students in other departments. You mentioned that smaller departments have difficulty in attracting seminar speakers. You mentioned that courses can be made more valuable (by having a greater enrolment) when two universities can pool such offerings. During the remainder of our discussion we often spoke as though a graduate enrolment of less than 30 would be a prima facie reason to examine in detail whether the necessary milieu were in fact provided by PDF's, other departments or cooperative arrangements.

Again your confirmation, correction, or restatement of the above summary is sought.

3. On the matter of applied physics, you stated your view that research in university physics departments should be directed to advance physics, although it is a good thing if a scientist pursues practical applications of his basic research. My notes on this are not very complete, and I suggest you enlarge on this point.

4. We described for you the established arrangements in Ontario in connection with the appraisal of major additions or changes in a department's offerings. Firstly, there is the situation you described where a professor will occasionally pursue a research topic (and employ a student) in a field bordering on the one in which he concentrates. Secondly, there is the situation where a department wishes to offer a new research area for thesis work in a formal way, e.g. by mentioning it in brochures for intending students. The members of ACAP pointed out that, when it is proposed to change a graduate programme by adding a new research field, the matter is referred to the Appraisals Committee of OCGS. This Committee may decide that the development is a natural and limited extension of work underway and that earlier investigations by the Appraisals Committee (or by a planning assessment) give sufficient assurance of quality that no appraisal is necessary. Alternatively, they may decide that the new field is sufficiently unrelated to the old ones (in personnel, facilities, or scientific interconnections) that an appraisal to establish quality is required. It is understood that universities refer such questions to the Appraisals Committee if there is any doubt as to the category into which it would fall; the occasional excursion of a professor's research interest would not normally even be discussed with the Appraisals Committee. The more major changes would be referred and might or might not lead to an appraisal.

5. The above remarks refer to checks for quality. We ask you to discuss the extent to which a department should consciously select (i.e. plan) the areas it maintains and/or develops for doctoral thesis research.

6. The report mentions some areas in which each department works, but, as you remarked, the list is incomplete. We do need your views about the adequacy of each university for doctoral thesis work in each of the areas that the

university has specified in its plans submitted for this assessment. I list these areas in the attached Annex 1. We suggest you indicate one of four categories: centre of strength, adequate, doubtful or inadequate, together with any comments you may wish to make. The Physics Discipline Group defines centre of strength as "a group having a world class status in one area of physics. In a university department such a group may be expected to attract high quality students and generate a stimulating intellectual atmosphere in its field". It is recognized by all concerned that your judgements are made on the basis of the information available to you and are not the equivalent of Appraisal Committee findings; if in some cases it seems appropriate, a university may subsequently obtain an appraisal. In general we ask you to base your reply on the present situation and whatever you may know of the future development of each department for three years or so.

M. A. Preston

MAP:kw

ANNEX I : Doctoral Fields Proposed or Suggested in University Plans (Astrophysics, Biophysics and Geophysics are not listed)

(The format of many of the university statements makes it difficult to ensure that the fields listed are in all cases really intended by the University, but in the circumstances of each case it has seemed desirable to request the consultants' evaluation.)

CARLETON

1. High Energy Physics - Experimental and Applied
   - Theoretical
2. Nuclear Physics - Experimental and Applied
   - Theoretical

GUELPH

1. Condensed Matter Physics
2. Molecular Physics
3. Nuclear Physics

Theoretical Physics (a separate listing in the paragraph B1d of the Guelph submission)

Note: Favourable appraisal, to begin in the fall of 1971, was obtained for specialization in "molecular and solid-state physics and low energy nuclear physics".

MCMASTER

1. Nuclear Physics - Experimental and Applied
2. Solid State Physics - Experimental and Applied
3. Theoretical Physics
4. Quantum Optics

OTTAWA

1. Solid State Physics - Experimental
   - Theoretical
2. Atomic and Nuclear Physics - Experimental
   - Theoretical
3. High Energy Physics

QUEEN'S

1. Molecular Physics
2. Nuclear Physics
3. Solid State Physics
4. Theoretical Physics

TORONTO

1. Elementary Particle Physics - Experimental
   - Theoretical
2. Nuclear Physics - Experimental
   - Theoretical
3. Molecular Physics (primarily Molecular dynamics)
   - Experimental
   - Theoretical
4. Solid State Physics (primarily electronic properties of metals) - Experimental
   - Theoretical
5. Atmospheric Physics

WATERLOO	1.	Solid State Physics - Experimental - Theoretical
	2.	Theoretical Physics (Applied Mathematics)
WESTERN ONTARIO	1.	Chemical Physics
	2.	Atmospheric Science
	3.	Theoretical Physics
	4.	Atomic Physics
WINDSOR	1.	Atomic and Molecular Physics - Experimental - Theoretical
	2.	Nuclear Physics - Experimental - Theoretical
	3.	Relativistic Physics
	4.	Solid State Physics
YORK	1.	Atomic and Molecular Collesions and Structures
	2.	Chemical Physics
	3.	Atmospheric Physics (Earth and Planetary)

MAP/edh

THE UNIVERSITY OF BRITISH COLUMBIA

VANCOUVER 8, CANADA

DEPARTMENT OF PHYSICS

June 25th, 1974

Dr. M.A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning
Council of Ontario Universities,
130 St. George St., Suite #8039,
Toronto, Ontario,
M5S 2T4

Dear Dr. Preston,

Thank you for your letter dated June 11th, 1974, in which you ask us to clarify certain aspects of our report. The following remarks are intended to summarize and amplify the discussion we had on June 5th regarding the six points mentioned in your letter.

(1) Our use of the term "competent Ph.D. supervisor" appears to require additional clarification in spite of the comments on page 38 of our report. We have tried to identify in each department, those outstanding individuals who, in our opinion, are the backbone of the Ph.D. program. The number and fraction of faculty who are "competent Ph.D. supervisors", determine the quality of the Ph.D. students' experience in the department. We do not wish to imply that all other faculty members are incompetent to supervise Ph.D. students and believe that, in the stimulating atmosphere generated by those we have identified as competent Ph.D. supervisors, there will be a considerable number of other faculty members (particularly younger members) who can adequately supervise Ph.D. students.

(2) On page 9 of our report we discuss the question of the minimum size of a viable graduate school. We feel that for the reasons stated it is not possible to give a definite number below which the program is no longer viable. Certainly the total number of graduate students (M.Sc. plus Ph.D.) should be larger than the number of 5 or 6, which we have found to be the typical size of the "interaction sphere". How much larger would depend on the degree of research specialization in the department and on the many other factors mentioned on pages 9 and 10 of our report. We do not feel that a discontinuation of some Ph.D. programs in Physics would at this time be in the best interest of the Ontario Universities. The fact that two or three Universities could in principle accommodate all the Ph.D. students in Ontario is irrelevant. This fact might have been reason for not expanding the University system to its present size, but such a concentration of students does not represent the optimum use of the presently existing University system. Nevertheless, we state on page 10 of our report that some contraction of Ph.D. programs may have to occur if our predictions on

enrollments are too optimistic.

(3) In assessing the suitability of an applied Physics project we feel that one should distinguish between a Physicist who sees a practical application for some of his fundamental work and the person who proposes to undertake some applied project simply because he knows that funding is available. The former is an intellectual leader, even when engaged in applied work. The latter is simply getting on a bandwagon. Our critical comments regarding applied research are directed at those who follow instead of lead.

(4) We understand the procedure which you outline in item (4) of your letter dated June 11th. It is clear however, that the degree of control exercised by the Appraisals Committee depends strongly upon their interpretation of the terms "natural extension of work underway" and "occasional excursion of a professor's research interests". Our recommendations 4 and 5 may be considered as recommendations that these terms be given the broadest possible interpretation such that departments retain a large measure of freedom to determine their own programs.

(5) With the possible exception of the University of Toronto, no Ontario University is large enough to cover adequately every field of research. A small institution must specialize if it is to achieve excellence - unless its faculty members have close working contacts with larger groups elsewhere. Specialization of course, does not by itself guarantee excellence. Each department should carefully consider its options whenever it has an opportunity to modify its composition.

(6) We have attempted to summarize our impressions regarding the adequacy, by subfield, of each department's Ph.D. program (see attached sheet). The judgements we have made in this connection are in many instances based on a superficial examination of the available evidence. In some cases, we are making evaluations of matters which fall outside our own competence. In all cases we are using primarily written information supplied by the University, together with our own (imperfect) knowledge of the department. Time did not permit an in depth look at each area of activity in each department. The following comments should therefore be interpreted as <u>impressions</u>, and <u>not</u> as an appraisal of the various activities.

In evaluating the subfields we have followed the format of Appendix i of your letter of June 11th. We do so with great reluctance for the following reasons:

(a) The names of the subfields often give little information on the graduate programs of the departments and it is clear that the same name is interpreted differently in different departments. For example, if we judge by the contents of the well known journal "The Journal of Chemical Physics", the term chemical physics overlaps to a large extent the fields of atomic and molecular physics, condensed matter physics and theoretical physics. The problem of definitions of subfields is particularly acute in the division between theoretical and experimental studies where some universities have listed theoretical physics as a separate subfield,

others have listed the theoretical and experimental work separately under each subfield of physics while still others have made no separation. It appears to us that the large variation in the terms used to describe the current research programs does not reflect the nature of the programs or the organization of the departments but results from a poor definition of terms and a lack of a clear understanding by the departments of the way in which these terms will be used in assessing their programs.

(b) It is difficult and perhaps meaningless to give a single rating to a department in a subfield wherein we find two or three men of outstanding ability and several of questionable ability.

Yours sincerely,

A.E. Douglas

R.R. Haering

P.N. Nikiforuk

RRH/lh

Enclosure

COMMENTS BY SUBFIELD[1,2] AS IDENTIFIED BY EACH UNIVERSITY

CARLETON	1. High Energy Physics - Experimental and Applied - Theoretical	B
	2. Nuclear Physics - Experimental and Applied - Theoretical	C
GUELPH [3]	1. Condensed Matter Physics	A
	2. Molecular Physics	C
	3. Nuclear Physics	B
	4. Theoretical Physics	B
McMASTER	1. Nuclear Physics - Experimental and Applied	A
	2. Solid State Physics - Experimental and Applied	A
	3. Theoretical Physics	A
	4. Quantum Optics	C
OTTAWA	1. Solid State Physics - Experimental - Theoretical	B
	2. Atomic and Nuclear Physics - Experimental - Theoretical	C
	3. High Energy Physics	C
QUEEN'S	1. Molecular Physics	C
	2. Nuclear Physics	A
	3. Solid State Physics	A
	4. Theoretical Physics	B
TORONTO	1. Elementary Particle Physics - Experimental - Theoretical	B
	2. Nuclear Physics - Experimental - Theoretical	A
	3. Molecular Physics (primarily Molecular dynamics) - Experimental - Theoretical	A
	4. Solid State Physics (primarily electronic properties of metals) - Experimental - Theoretical	A
	5. Atmospheric Physics	A
WATERLOO	1. Solid State Physics - Experimental - Theoretical	B[6]
	2. Theoretical Physics (Applied Mathematics)	B[4]

WESTERN ONTARIO	1. Chemical Physics 2. Atomic Physics	B
	3. Atmospheric Science	B
	4. Theoretical Physics (total)	C [5]
WINDSOR	1. Atomic and Molecular Physics - Experimental - Theoretical	A
	2. Nuclear Physics - Experimental - Theoretical	C
	3. Relativistic Physics	B
	4. Solid State Physics	B
YORK	1. Atomic and Molecular Collisions and Structures 2. Chemical Physics	B
	3. Atmospheric Physics (Earth and Planetary)	A

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[1] EXPLANATION:

A centre of strength, as defined below.

B good, adequate

C doubtful or inadequate or ill-defined

A "centre of strength" is "a group having a world class status in one area of physics. In a university department such a group may be expected to attract high quality students and generate a stimulating intellectural atmosphere in its field".

[2] Astrophysics is excluded

[3] We suggest that the report of the Appraisals Committee be used to evaluate this department

[4] Rated B because of its limited range of interests; the quality of the faculty is very good

5 It is difficult to assess theoretical physics at this university, since a single submission was made covering the Department of Physics and the physics related activities of the Department of Applied Mathematics but it is not clear to the consultants that these two departments act as a unit.

6 This includes limited amount of molecular physics now being done

A P P E N D I X B

DISCIPLINE GROUP RESPONSE

These comments were submitted before the addendum to the consultants' report (pages A-78 to A-88) was requested.

RESPONSE OF THE PHYSICS DISCIPLINE GROUP

to the

A.C.A.P. CONSULTANTS' REPORT

on

PHYSICS AND ASTRONOMY

SUMMARY

The Discipline Group recommends that: THE CONSULTANTS' PLAN, AS DESCRIBED IN THEIR REPORT AND REVIEWED IN OUR RESPONSE, BE ADOPTED.

INTRODUCTION

The Consultants' Report lays down sound principles for tne evaluation and administration of Ph.D. studies in Ontario. Their recommendations are designed to preserve the excellence and strengths which exist in the whole system of Ontario Universities, and to improve the system in the future.

The Consultants' criteria of quality set a high and salutary standard of excellence whose consistent attainment in the universities would surely benefit both the institutions themselves and the people of Ontario. We strongly support the Consultants' view that such high standards are more likely to be achieved by vigorous competition between universities than by administrative edict or by the restriction of Ph.D. studies to a small elite group of institutions.

The Discipline Group recognizes that even to maintain the present standards and particularly to improve them will require that future decisions of the universities will be difficult and painful. It is appropriate, therefore, to conclude this Introduction with two quotations from p. A-6 and 7 which we support:

"...designating particular universities as the homes of high quality graduate schools may lead to complacency and a decline in quality."

"...only a few universities will make the painful decisions necessary to achieve the highest quality in their physics departments and if departments are supported (by their universities) according to their quality, these will emerge as the major graduate schools in physics in Ontario."

THE CONSULTANTS' PLAN

Although the Consultants have taken the view that freedom in numbers and areas is an essential feature of the development of a high quality Physics programme in Ontario, they have been specific in assessing the current situation. It is, therefore, possible from their report (figure 1 and table 5 and p. A 26-34) to give the numbers of Ph.D. students which universities should plan for in the coming academic year and the areas in which departments are competent. Over the years some natural re-arrangement of numbers and areas is envisaged in the plan, and this re-arrangement should be supervised by the Discipline Group. It is even possible that the competition, which the consultants propose, may lead to such small enrollments in some universities that they may temporarily suspend their Ph.D. programmes.

The Consultants' Plan is based upon their measure of the relative numbers of highly qualified Ph.D. supervisors† in each department. (These numbers are not to be interpreted as meaning that other faculty are not qualified to supervise students, since the consultants state that "the authority to specify supervisors should continue to reside within the universities". p. A-38). It can be seen from their Table 5 that they find highly qualified supervisors broadly spread over very many Physics Departments in Ontario. Thus we agree with the Consultants that all ten universities should continue their Ph.D. programmes. As they point

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† We prefer "highly qualified" to "competent" - see our comment on Recommendation 2.

out, quality not size is the important criterion: "In our discussions with students we found that at all graduate schools, both large and small, a student had profitable interactions with only five or six other students. Students also usually had close contacts with their supervisor and one or two other professors."

An essential feature of the plan is the development of the Discipline Group into a type of Ontario Physics Graduate Committee to oversee the provincial programme. We felt it worthwhile to tabulate the tasks assigned to us by the Consultants and this is done in Table 1.

Table 1. TASKS ASSIGNED TO THE DISCIPLINE GROUP

1. To ensure the effective use of all faculty of quality in a province-wide competitive system of graduate programmes.

2. To review the standards of quality for faculty and to apply them in planning every two to three years.

3. To review the areas of physics covered in each department, to ensure broad educational opportunities.

4. To review the enrollment standards for Ph.D. students on an annual basis.

5. To recommend ways of maintaining vitality and a "stimulating intellectual atmosphere".

It will be seen that these tasks are consistent with the quotation (given below) from the Discipline Group's document of Nov. 5, 1973 entitled "Statement of Principles".

QUOTATION

"The Physics Discipline Group favours a flexible approach to the planning of Ph.D. programmes in Physics. Physics has always developed in unexpected ways and in unexpected places. If we wish our students to be equipped to work in the leading areas of the subject, we must take account of the unexpected. For this reason the best system is one in which departments can act flexibly. Thus the Discipline Group advocates collaboration and self-control by the physics community as the method of handling planning problems. This system should include:-

(i) standards of quality for students,

(ii) appropriate coverage of relevant areas of physics, and

(iii) standards of quality for supervisors of Ph.D. students."

In summary, it is clear that the Consultants' Plan and the Discipline Group's philosophy merge. We expect that the Group should slowly grow in authority by undertaking new tasks in a responsible and systematic manner.

DISCUSSION OF CENTRES OF EXCELLENCE AND OF STRENGTH

We define a "centre of excellence" in physics as being an institute with world class achievements in many areas of physics. If such an institute accepted Ph.D. students it could attract the best in Canada who might otherwise go to other countries. It could also set a standard in physics for university departments and other laboratories.

We define a "centre of strength" in physics as a group having a world class status in one area of physics. In a university department such a group may be expected to attract high quality students and generate a stimulating intellectual atmosphere in its field.

Over the next few years it appears that only a few new appointments in physics are likely to be made, so that the present faculty will be largely unchanged. Those departments in which there are now a number of young faculty who are still developing, may show an improvement while others may even decline in quality. These factors are independent of the organization of Ph.D. work. Thus the Discipline Group concludes that the present system will not lead to a centre of excellence in Ontario within a "decade or two". This conclusion is consistent with the Consultants' argument on p. A-6 and 7, since they imply tnat such a centre would emerge only if university administrators took extreme measures to support their physics departments and the departments concentrated their development in this direction only. However the Consultants found centres of strength in

a number of physics departments. Many are of relatively small size involving only a few professors and students and often centre about one or two strong individuals. In assessing the strengths of departments the Consultants identified a score or more of "scientists with international reputations", (p. A-38), and the distribution of centers of strength naturally follows the distribution of these outstanding physicists. These groups are a valuable asset to the people and universities of Ontario. Their continued activities in the training of Ph.D. students and their research viability should be assured.

THE RECOMMENDATIONS

1. *"No regulations be adopted which would place limits on the total number of graduate students. (page A-22)"*

Concur. There is no need at present to place any limits on numbers. Quite the contrary, the universities should try to compensate for the over-correcting influences of the market place by reducing excessive upward and downward swings in enrollments.

2. *"The Ph.D. students of the province be distributed among the universities according to the numbers of faculty members who are found to be competent Ph.D. supervisors in the various physics departments. A recommended initial distribution is shown in Table 5. (page A-59)"*

The principle of encouraging a distribution which parallels that of highly qualified supervisors is wise. Our recent experience indicates that free movement of students brings this about, and that artificial regulation is unnecessary. (We use "highly

qualified" rather than the Consultants' word "competent", because the expression "competent" was used only as a convenient measure of a department's strength and not to imply also non-competence).

3. *"the projected enrollments and distribution of Ph.D. students be revised every two or three years. (page A-40)"*

Concur. In the light of our comments on Recommendations 1 and 2 periodic review of changes in departmental strength and in student enrollment patterns are essential - perhaps every three years.

4. *"there be no assignment of responsibilities for specific fields of physics to particular departments, but that the co-ordination of research activities of the departments be continued by the discipline group. (page A-54)"*

Concur.

5. *"no limitations be placed on the movement of departments into new areas of research, but that in the periodic review (see Recommendation 3) of graduate programs, special attention be directed to new areas of research which have been started to ascertain that the students are under the guidance of well-qualified supervisors. (page A-54)"*

Concur.

6. *"a university receive no provincial financial support for any Ph.D. student who has received a bachelor degree from the same university unless that student holds a masters degree from another institution or the university receives special permission from the Ontario Council of Universities. (page A-51)"*

We support the principle that students should move, but reject the need to enforce it by B.I.U. regulations. The Discipline Group should monitor the proportion of students that do not move to another university and ensure that this fraction remains reasonably small - less than 25%.

7. *"all universities formulate policies governing applied research in physics graduate programs with particular attention being paid to the questions of the academic freedom, balance and coherence of the departments. (page A-52)"*

Concur.

8. *"all universities review their tenure and promotion practices to assure a standard up to that adopted by universities which have achieved a well-deserved reputation for high quality graduate work and research. (page A-53)"*

Concur.

9. *"serious consideration be given to developing graduate programmes in optics and acoustics. (page A-54)"*

Other fields too should be considered., eg. plasma physics, etc.

10. *"the discipline group annually review and grade the applications of graduate students who have been accepted by the universities and that the results of this review be made available to the appropriate committees for evaluation and planning purposes. (page A-55)"*

Concur. The Discipline Group has already set up, in C.O.U.Ph.D., a mechanism to follow the spirit of this recommendation.

11. *"at the four emergent universities the income from the province for graduate students should not be proportional to student numbers, but a special fund be set up at these universities to support their research programmes. (page A-55)"*

The problem, in part, of higher teaching loads at these four universities, cannot be isolated from other problems of the B.I.U. system of financing.

12. *"in order that the University of Ottawa be given an opportunity to develop a high quality bilingual graduate school in physics, the University be allowed to plan for a number of Ph.D. students higher than that assigned, but if future assessments find no substantial improvement in the quality of the faculty, consideration be given to having the Ph.D. programme discontinued. (page A-40)"*

The Discipline Group's position is that any body that makes a condemnatory recommendation is obligated to give detailed reasons before any such statement can be seen to be just.

13. *"an appraisal of the M.Sc. programme at Laurentian University be carried out in the near future. (page A-35)"*

The Discipline Group has heard that the situation at Laurentian was misunderstood by the Consultants and the Group supports any action that Laurentian may wish to take for re-evaluation.

SUMMARY

The Discipline Group recommends that: THE CONSULTANTS' PLAN, AS DESCRIBED IN THEIR REPORT AND REVIEWED IN THIS RESPONSE, BE ADOPTED.

COMMENTS OF THE ASTRONOMY DISCIPLINE GROUP ON THE ACAP CONSULTANTS' REPORT ON PHYSICS AND ASTRONOMY RADUATE WORK IN THE PROVINCE OF ONTARIO

General comments

The members of the discipline group endorse in general the wise and thoughtful comments of the consultants on graduate work in astronomy which are made in pages A41-48 of their report.

Although not directly related to graduate needs we specifically endorse the consultants' comments on page A-45.

> "Every university should have an astronomer to teach courses in astronomy. Otherwise, presentations tend to become lopsided with heavy emphasis on the particular teacher who happens to be giving the course at that epoch."

We feel a responsibility to ensure that astronomy (which is a very fine vehicle of education in science for many types of student) should be well taught in the province. The Canada-France-Hawaii telescope and other anticipated developments in astronomy will stimulate demand for courses in astronomy.

Specific comments

The specific comments of the discipline group on the recommendations Astronomy 1,2,3 on page A-3 of the consultants' report are as follows:

1: NO NEW GRADUATE PROGRAMS IN ASTRONOMY BE ESTABLISHED IN ONTARIO, BUT THIS IS NOT TO BE CONSTRUED THAT A THESIS ON AN ASTRONOMICAL TOPIC IN AN EXISTING DEPARTMENT OF

PHYSICS BE INTERDICTED. (See Page A-48)

Comment: No plans for new graduate programs in Astronomy are known to the discipline group. We concur that theses on astronomical topics may be appropriate parts of Ph.D. work in the existing physics departments.

2: FOR PLANNING PURPOSES THE PROJECTED ENROLMENT OF PH.D. STUDENTS IN ASTRONOMY BE REDUCED TO 15 BY THE YEAR 1978-79 AND THAT THESE STUDENTS BE DISTRIBUTED BETWEEN THE UNIVERSITY OF TORONTO AND THE UNIVERSITY OF WESTERN ONTARIO IN THE RATIO OF NOT LESS THAN 5:1 IN FAVOR OF THE UNIVERSITY OF TORONTO (See Pages A-47 and A-50)

Comment:

a) We see no valid reason why the recommendation (Physics 1) for physics graduate enrolment should not apply equally to astronomy graduate enrolments.

b) We disagree with the imposition of an arbitrary fixed ratio of students in the astronomy graduate programs at the University of Western Ontario and the University of Toronto. The principle of encouraging a distribution which parallels that of highly qualified supervisors is wise. Our recent experience indicates that free movement of students brings this about, and that artificial regulation is unnecessary.

3: RECOMMENDATIONS 3,4,5,6,8,10 UNDER "PHYSICS" ALSO APPLY TO ASTRONOMY DEPARTMENTS.

Comment: Our response to recommendations 3,4,5,6,8, and 10 of the Physics document are:

3: We concur. In the light of our comments 2 a) and 2 b) above, periodic review of changes in departmental strength and in student enrolment patterns are essential - perhaps once every three years.

4: We concur.

5: We concur.

6: We support the principle that students should move, but reject the need to enforce it by SIU regulations. The Discipline Group should monitor the proportion of students that do not move to another university and ensure that this fraction remains reasonably small - less than 25%.

8: We concur.

10: With small numbers of departments and students involved it is unnecessarily cumbersome to set up formal review mechanisms.

A P P E N D I X C

UNIVERSITY COMMENTS

Comments appear from Brock, Carleton, Guelph, Lakehead, Laurentian, McMaster, Ottawa, Queen's, Toronto, Trent, Waterloo, Western Ontario, Windsor and York.

These comments were submitted before the addendum to the consultants' report (pages A-78 to A-88) was requested.

RESPONSE TO THE

A.C.A.P. CONSULTANTS REPORT ON PHYSICS

BY BROCK UNIVERSITY

The major portion of this report is concerned with Ph.D. programs; consequently most of the recommendations, if implemented, would have only secondary effects on Brock. Nevertheless, we feel the exercise to have been worthwhile, if only as a means of providing a focus for the deliberations of the Discipline Group.

In assessing the summary of recommendations, we have kept in mind that the Terms of Reference for the Consultants were set up by ACAP in close consultation with the Discipline Group. In several instances the Consultants have rejected the terms of reference, although they were careful to state their reasons for doing so. In other instances they have made specific recommendations but have not indicated how they should or could be implemented.

There were two aspects of the report that were not directly called for in the Terms of Reference, but which could have the most lasting value. The first of these is the careful delineation of the need for excellence in at least some of the Ph.D. programs of the province and some suggestions as to how it might be achieved. The second is the accumulation and assessment of data concerning the age distribution of members of Physics faculty. This has subsequently been recognized by the Discipline Group as a particularly severe problem for those Departments who aim to maintain their present level of vigor in research, let alone improve upon it.

Our responses to the recommendations are given below:

1. *no regulations be adopted which would place limits on the total number of graduate students. (page A-22)*

(i) Agreed.

2. *the Ph.D. students of the province be distributed among the universities according to the numbers of faculty members who are found to be competent Ph.D. supervisors in the various physics departments. A recommended initial distribution is shown in Table 5. (page A-39)*

(i') The use of the term "competent" is unfortunate in that it carries connotations other than those intended by the Consultants. Recommendation 2 suggests an a priori distribution of students; it is difficult to conceive of a mechanism that is both workable and acceptable

3. *the projected enrolments and distribution of Ph.D. students be revised every two or three years. (page A-40)*

(iii) A revision in less than 3 years we believe to be unnecessary and excessive.

4. *there be no assignment of responsibilities for specific fields of physics to particular departments but that the coordination of research activities of the departments be continued by the discipline group. (page A-54)*

(iv) Agreed.

5. *no limitations be placed on the movement of departments into new areas of research but that, in the periodic reviews (see recommendation 3) of graduate programs, special attention be directed to new areas of research which have been started to ascertain that the students are under the guidance of well qualified supervisors. (page A-54)*

(v) Agreed.

6. *a university receive no provincial financial support for any Ph.D. student who has received a bachelor degree from the same university unless that student holds a masters degree from another institution or the university receives special permission from the Ontario Council of Universities. (page A-54)*

(vi) We support the intent of this recommendation without qualification. While its implementation may be resisted by some Departments, largely for purposes of self interest, we feel the long term interests of the studen's would best be served by its adoption.

7. *all universities formulate policies governing applied research in physics graduate programs with particular attention being paid to the questions of the academic freedom, balance and coherence of the departments. (page A-55)*

(vii) Agreed.

8. *all universities review their tenure and promotion practices to assure a standard up to that adopted by universities which have achieved a well-deserved reputation for high quality graduate work and research (page A-55)*

(viii) Agreed. This recommendatic n appears to be the only means proposed, whereby the centers of excellence could be established.

9. *serious consideration be given to developing graduate programs in optics and acoustics. (page A-54)*

(ix) This recommendation is based largely on a situation existing in the U.S. While it may have merit, other areas, for example, Plasma Physics are equally neglected and deserving.

10. *a discipline group annually review and grade the applications of graduate students who have been accepted by the universities and that the results of this review be made available to the appropriate committees for consideration during planning exercises. (page A-55)*

(x) Agreed.

11. *[illegible] universities the income from the provision for graduate students should not be proportional to student numbers but a special fund [illegible] universities to support their research programs. (page A-55)*

(xi) Recognition of the special difficulties associated with maintaining research within small Departments heavily committed to the Undergraduate program is welcomed. It echoes a comment in the ACAP report to C.O.U. of 1971-72 (p. 11) where again, the proposal of a special fund to support professors in departments with restricted graduate programs. There is a concern, however, that the implementation of recommendation 11, as stated, may work to the ultimate disadvantage of a small Department, if the B.I.U.'s generated by M.Sc. students were jeopardized. Internal pressures within a University inevitably lead to considerations of "income generated" vs operating costs, etc. We feel, therefore, that whereas special support, in addition to B.I.U.'s, would be welcomed, we would choose to retain the B.I.U.'s if a choice must be made.

12. in order that the University of Ottawa be given an opportunity to develop a high quality bilingual graduate school in physics, the University be allowed to plan for a number of Ph.D. students higher than that assigned, but if future assessments find no substantial improvement in the quality of the faculty, consideration be given to having the Ph.D. program discontinued. (page A-40)

(xii) No comment.

13. an appraisal of the M.Sc. program at Laurentian University be carried out in the near future. (page A-35)

(xiii) No comment.

CARLETON UNIVERSITY

RESPONSE TO THE FINAL CONSULTANTS' REPORT ON THE PHYSICS AND ASTRONOMY PLANNING ASSESSMENT

In general, Carleton is in agreement with the spirit and intent behind many of the consultants' recommendations concerning Physics. We support the emphasis on quality and the proposition that it cannot simply be regulated into being, the enrolment trends projected by the consultants, and their views on the size of a graduate school and coverage of fields. There are, however, four matters on which we would wish to comment specifically and these are set out below.

1) Carleton has noted with interest the expanded role for the discipline group recommended by the consultants. However, some difficulties in implementing such a regulatory role for discipline groups were discerned. Regulatory functions in the university system may come from departments, from individual universities, from groups of universities or from discipline groups. It would appear essential to examine which aspects of the regulatory process should be allocated to each level. The consultants have elected to refer almost exclusively to one of them.

2) Carleton has always insisted on the viability and academic plausibility of small, highly focused programmes at the graduate level. Indeed, in the case of Physics it may be said that Carleton, more than any other university in Ontario, has developed such a well defined focus. There is, however, a danger that having done so a department could be restricted ad infinitum to such a focus by ACAP. In this case, the decision to define sharply the focus of the programme could impair the possibility of a department to evolve a new focus in future. It should be clearly understood, therefore, that the condoning of any small, specialized programme does not imply that the department might not legitimately aspire, in time, to develop one or more other foci.

3) Carleton has noted with interest the recommendation that basic income units not be provided for doctoral students at a given university if they had done all previous university work at the same institution. While we concur with the spirit of the recommendation

which calls for some diversification in the university education of students, we are wondering if there is a need to legislate what would recommend itself as a most natural practice. However, if consultants have discovered in their assessment some important violation of such a natural practice, we would respect their recommendation.

4) Finally, we must express some disappointment in the consultants' report for not having provided much in the nature of information and recommendations likely to help individual universities in their institutional planning. It would have been most helpful if the consultants had chosen to indicate more precisely the areas of greater promise for future development at each university and if they had chosen to propose some precise trimming of existing programmes.

University of Guelph

PHYSICS AND ASTRONOMY PLANNING ASSESSMENT

Comments on Consultants' Report

The University of Guelph considers the report of the consultants to be an acceptable one. There are some matters, however, on which we wish to make comment.

We find in Chapter II a useful statement, supporting, as it does, the proposition that opportunities should be available to students of high quality to pursue graduate studies with research supervisors of high quality. In that context we endorse recommendation 1 that "no regulations be adopted which would place limits on the total number of graduate students". We endorse, also, the proposal (pages A-54, 55) that the discipline group maintain a review function at the Ph.D. level for some time.

Specifically with regard to the University of Guelph we are pleased that the consultants support (page A-40) the decision of the appraisals committee that our department is competent to offer Ph.D. studies in physics. It should be noted that ours is the only such program in Ontario which has sustained an appraisal. Their assignment of "a small number of(Ph.D.) students" to Guelph we take to imply the consultants' general support of the lifting of the present embargo which has, indeed, created a sense of injustice and of frustration. We urge upon AC.P and COU such action as will support

the University in seeking relief from this imposition.

We note, further, the consultants' recognition of the fact that our undergraduate population has been growing at a higher rate than the system average and that our faculty numbers have been increasing accordingly. We point out that the latter growth could well serve to justify some increase in the number of "competent Ph.D. supervisors" set out in Table 5, where the number, being based upon the 1971-72 grant distribution by NRC, reflects our 1971-72 faculty rather than the current faculty.

With regard to cooperative activities (page A-56) we are able to report our arrangements with Toronto and Waterloo for graduate work, and with McMaster and Toronto for research. We plan to continue with these collaborative programs and to develop them where appropriate. Such programs could be adversely affected by rigid planning numbers; accordingly, we are pleased to note that the consultants do not advocate rigid planning numbers.

We record here the fact that we have submitted for appraisal our proposed M.Sc. and Ph.D. work in biophysics. The mutually supportive relationship between physics and biophysics is an additional reason for our welcoming the view of the consultants that Guelph should continue to develop its quality Ph.D. program in physics.

The consultants (page A-46) have noted that Guelph provides for M.Sc. research "on an astronomical topic" within the physics program. We propose to continue this work at the present level and to continue, also, our collaboration with Toronto in this

general area.

On more general matters we assert our concurrence with what we take to be the consultants' opinion (pages A-9, 10) that six or seven students commonly form the critical size for graduate work in physics. Our experience at Guelph confirms this opinion and we find that this appears to be the operational number at some of the other universities.

We support the concept of student mobility (page A-51), but we reject recommendation 6 which invites government sanction. The universities themselves can encourage mobility, but we consider hard-and-fast rules to be impracticable. The discipline group could play a useful role in this matter.

Recommendation 7 and the statement on applied physics (page A-52) presumably refer to research that is peripheral to physics as a whole. We agree that such peripheral activities ought not to comprise more than 25% of a department's research effort. But we would be concerned if the consultants' remarks were interpreted to refer to applied research in which there is a sound physics core.

We consider that the consultants are to be commended for preparing a report which should be a useful basis for planning in this important discipline.

*****

April 30, 1974

TELEPHONE 345 2121
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Lakehead University
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OFFICE OF THE PRESIDENT

May 15th, 1974.

Dr. M. A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Ontario Council on Graduate Studies,
Council of Ontario Universities,
Suite 8039,
130 St. George Street,
TORONTO, Ontario. M5S 2T4

Dear Dr. Preston:

With regard to the Discipline Assessment in Physics, the University does not wish any official response to be included in the report.

Yours sincerely,

ANDREW D. BOOTH,
President.

/lp

LAURENTIAN UNIVERSITY RESPONSE
TO THE
ADVISORY COMMITTEE ON ACADEMIC PLANNING
REPORT FOR PHYSICS AND ASTRONOMY
OCTOBER 1974

It is clear that a large fraction of the report deals only with PhD - granting institutions, and we make no comments on these sections.

We agree strongly with recommendation C3 dealing with alternate sources of funding for university departments which do not offer graduate programmes. We feel, however, that further details should be specified with respect to what group is to give "urgent attention" to this question.

We feel that recommendation C18 which concerns the Department of Physics at Laurentian was developed because, unfortunately, there was a lack of full information: this is discussed later. But we would also like to comment on a general principle involved. It is difficult for us to understand why any university just completing its fifth year of an MSc programme should be asked for a complete reappraisal, given support for the programme by the university, a series of good theses in the past (as judged in all cases, by competent external examiners), and continued enrolment in the programme.

Since our original appraisal in 1969, our staff has increased both in size and qualifications*, and our research support and facilities have been substantially increased.

We are aware, of course, that Laurentian's five year plan calls for planning to create an interdisciplinary programme in Physics and Chemistry, and that such a programme would naturally involve a new appraisal. However, planning for such a programme is still at a very early stage. Provision is already made for the university to re-examine the desirability of continuing with its Physics MSc programme in the light of developments within the Five Year Plan. We feel that such a provision already allows equitable consideration of present and projected programme development. Any term

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* The Department has increased from nine to twelve faculty members, and two of these have recently received PhD degrees.

approval, with its consequent provisional termination date, will inevitably create the possibility of an adverse steering effect on potential students at a time when the programme is in the process of establishing itself.

It is difficult for us to comment in further detail, since phrases in the report such as "the questionable quality of the present physics master's programme" and "the programme is weak in core subjects" in connection with Laurentian's programme, have not been given a basis. However, it appears likely that the consultants' recommendations formed a general framework for the report. Our original response to the consultant's report was not distributed along with the other responses. We would therefore simply point out that we have compared the courses required of our MSc candidates with those listed by other Physics departments in Ontario, and conclude that the statement that our MSc core course porgrmme is weak, should either be rejected, or applied to most other departments as well.

We feel strongly that a reappraisal should only be carried out on a basis of reasonably well-defined and documented problems with the current programme, not largely on the basis of impressions from a half-day visit by part of the consultants' team.

The immediately relevant details which relate to the main comments of the consultants are on the first two pages of the attached copy of our response.

The above comments should not be interpreted as revealing apprehension about any reappraisal of our programme. Rather, they simply express our view that the brief reasons outlined in the report, concerning the recommendation for reappraisal of our programme are neither justified nor sufficient.

LAURENTIAN UNIVERSITY RESPONSE TO REPORT ON GRADUATE STUDIES IN PHYSICS AND ASTRONOMY (SUBMITTED BY CONSULTANTS TO ADVISORY COUNCIL ON ACADEMIC PLANNING, ONTARIO COUNCIL OF GRADUATE STUDIES, COUNCIL OF ONTARIO UNIVERSITIES).

Laurentian University

May 1974

Our remarks will refer in turn to:

(a) specific comments made by the consultants concerning the MSc programme in Physics at Laurentian University.

(b) the general recommendations which relate to MSc programmes within the province.

Comments Specific to Laurentian University

We dismiss, as being without foundation, the suggestion that the department of Physics is "torn by internal strife". The department, as a whole, has taken its many major decisions of the past years with near unanimity. In the main, disagreements within the university and instability within the university result from the instability of the overall university B.I.U. - based income and from pressures to balance the university budget.

Furthermore, it was the decision of the entire department to emphasize the field of Fine Particle Physics. This decision was taken for several important reasons, including the following:

(a) Laurentian researchers have made major contributions in this field;

(b) the specialization in this field is unique in Canada:

(c) the field is a branch of science having many important applications.

For the consultants to say that our research emphases result from "personality domination" rather than from our "strengths" and then to say, in the same report (page A31) that another university "lacks a 'star'" appears to us to be inconsistent.

The consultants have referred to "applied research" in their report and in meetings with the Physics Discipline Group as meaning 'proprietary research' or 'research begun through interest in money rather than through interest in science'. We agree that safeguards are necessary for the protection of students involved in contract research. On the other hand, we make no apology for the fact that the Physics Department of Laurentian University is engaged in many research projects which have application. In the range of projects undertaken here we emphasize, too, that there is

a laudable spectrum of theoretical and experimental approaches with a very successful liaison between individual researchers.

We have compared the courses required of our MSc candidates with those listed by other Physics Departments in Ontario (using data submitted to ACAP). We conclude that the claim by the consultants, that our MSc core course programme is weak, should either be rejected or applied to most of the other Physics Departments in the province as well.

The consultants have mentioned that the faculty is adequate to offer MSc work in the fields of Fine Particle Physics and Solid State Physics. That our responsibilities have been effectively carried out is probably best judged in assessing our graduate students, their research, and their present abilities. We are proud of their accomplishments, and of their acceptance and recognition following graduation. External examiners have commended the research of all the students who have received the MSc degree in Physics at Laurentian University.

Recommendations of Consultants Relating to MSc Programmes

We agree with many of the recommendations made affecting us, and comment only on the few mentioned below.

Recommendation 7

We agree that policies to protect the interests of students should be formulated at any university at which students are engaged in proprietary research or contract research. (However we object to having the term "applied research" used in this connection alone.)

Recommendation 9

We point out in connection with the suggestion that research in optics be supported that optical information processing and a variety of holographic techniques are being investigated at Laurentian University. It should also be noted that Dr. B. J. Thompson, Director of the Institute of Optics, Rochester University, acts in the capacity of visiting professor to Laurentian University.

Recommendation 11

While a B.I.U. - based income at Ontario Universities can lead to intolerably unstable income and to distorted funding patterns within the universities, we do not view the "patchwork" solution proposed in recommendation 11 as one that is likely to be acceptable in the near future.

Recommendation 13

We cannot agree that any special reappraisal of the department is necessary. The consultants have commented favourably on the competence of the department in the research fields in which we involve MSc students and the quality of our students is excellent.

McMASTER UNIVERSITY RESPONSE TO THE ACAP CONSULTANTS' REPORT ON GRADUATE STUDIES IN PHYSICS AND ASTRONOMY

While we believe that the physics consultants have produced a report which gives a reasonably accurate picture of the state of physics in Ontario in 1973 and which expresses a philosophy of physics education which would be accepted as reasonable by academic scientists the world over, we are disappointed that they did not make any hard specific recommendations. Unless some other bodies are prepared to put some teeth into the recommendations, the report will remain as a "consumer report" of the state of affairs in 1973 which will gather dust on library shelves. The report essentially suggests a maintaining of the status quo in regard to the existence of doctoral programmes throughout the Province and in this regard it presents a sharp contrast with many of the earlier ACAP consultants' reports.

The Question of Quality

On page A6, the consultants state that none of the graduate schools in physics within the province achieves the standards of high quality that are the marks of a great department. They rate two of the sixteen as approaching that standard and suggest that both might achieve it in a decade or so - given the correct conditions. They go on to say that the province cannot have three or four, much less nine or ten really outstanding graduate schools in physics and that an equal division of facilities, funds and talented physicists among all existing schools will assure the existence of none of outstanding quality. Having said this they proceed to make a series of recommendations that make

the emergence of one or two outstanding graduate schools well nigh impossible.

Of the thirteen recommendations regarding physics, only number two and number six address themselves to the problem of building a few centers of excellence and neither of these two offers more than general principles. Number two proposes to distribute graduate students among universities according to the number of "competent" Ph.D. supervisors but proposes no mechanism for achieving this distribution.

It is clear from the philosophy of the consultants' report that the number of "competent supervisors" is being used only as a rough measure of the strength of a department and that there is no intent to limit graduate student supervision to faculty members who have been declared "competent". The intent of the recommendation is to distribute the physics graduate student enrolment among departments roughly according to the relative strengths of the departments. Although no mechanism for policing their recommendation is proposed, the stress in their report on self-discipline suggests that they believe this policing can be done by the Discipline Group in Physics. This belief is probably justified so long as only a rough equivalence between "strength" and student numbers is asked for. However, if rigid planning numbers are required and if these are coupled mathematically to "strengths", the exercise of determining the relative strengths of the departments in the province would place impossible strains on the Discipline Group and destroy all possibility of cooperation between the physics departments of the province.

Recommendation number two is designed to maintain vitality where it exists in the provincial system. It will do nothing to build the strength required in the stronger departments if they are to compete on the world

scene as "great departments". Indeed, it is probably unrealistic to assume that any BIU financing system which is tied closely to student enrolments will allow for the creation of such centers of excellence.

Recommendation six, which attempts to combat the growing tendency of students to take all their degrees at one institution, is a good recommendation. Implementation of this regulation across all fields of Science and Engineering would do a great deal to break down the insularity which characterizes the Ontario universities. We believe that the recommendation in its present form is administratively awkward and unlikely to be acceptable to many of the universities. Rather than asking that special permission be required for each student wishing to stay at the same university for all of his degrees, we believe that it would be much better to have a regulation that would require each university to limit the number of its own B.Sc. graduates in any of its own Ph.D. programs to 25% of the total enrolment in that program.

Recommendation ten deals with the question of student quality by proposing that the discipline group annually review and grade the applications of graduate students who have been accepted by the universities. Attempts by COUPHD, the Committee of Chairmen of the Ontario University Physics Departments, to implement such a recommendation have floundered in the past because of the reluctance of some university administrations to release copies of transcripts and letters of recommendation to the COUPHD committee on admissions. All that has been made available are the names of the institutions which students attended and the B.Sc. or M.Sc. standings which they obtained. Unless the universities are prepared to offer more detailed information to the proposed discipline group committee on admissions than have been provided to COUPHD, the committee will not be in a position to carry out its function properly. Although

we are not convinced that there are wide disparities in admission standards in different physics departments, we support this recommendation as academically and politically desirable.

Vitality, Student Numbers and Support for Research

If one accepts the predictions of graduate student enrolments contained in the report as reasonable and adopts the 'laissez-faire' philosophy of the report, all the universities in the province will be short of graduate students during the next decade and all faculty will face the problem of maintaining lively and active research programs in an academic milieu in which undergraduate teaching and committee involvement assume greater and greater importance. Without the presence of graduate students or other persons who can give full time to research, it will be the exceptional faculty member who can maintain a vigorous research programe over a long period of time. While an active department can tolerate the death of a few active research groups, even the most research-oriented department is reduced to non-effectiveness when the mood of the department is determined by a faculty majority who have lost interest in research. This dry rot threatens every department in the province - and, judging by the consultants' report, has already overwhelmed some.

We believe that the excitement of science cannot be maintained without the steady injection of new blood into the system. An alternative to graduate students as a means of injecting new blood into the system would seem to be postdoctorate fellows. However, the existing mechanism of support for young Ph.D.'s on a short term basis (one or two years) from annually awarded research grants does not provide the continuity that is needed to meet either the demands of an ongoing research program or the personal requirements of young scientists who are at the "family-building" stage of their lives. Now

that two-year postdoctoral fellowships are unlikely to develop into faculty positions, postdoctoral appointments have lost a great deal of their appeal and many of the young scientists with the greatest potential for research and teaching are turning away from the university to accept positions with no research potential in order to achieve financial security. If Ontario intends to have good universities in the 1980's, the province cannot afford to waste their talents now.

Recommendation 11 proposes that there be a decoupling of research support from the income received from graduate student basic income units in the four small emergent universities who do not now have Ph.D. programs. It seems to us that this recommendation should be modified so that it can be applied to all universities in the province. If this were done, we would have a mechanism for relaxing the overly-tight coupling which now exists between research and graduate student training in this province. It would free the universities to make hybrid faculty-postdoctoral appointments with a longer term job security than is now available to young scientists in the 25-35 age bracket. At the present time 25% of the faculty in Ontario physics departments is in the 30-35 age group; in five years this fraction will drop to something less than 5% while the fraction of those over 50 will nearly double. The 5% figure could be raised quite significantly if a relatively small injection of non BIU generated money was made available to the universities to create faculty-postdoctoral positions half supported by research grants and half supported by university funds.

The Copse report and others have recognized that in some of the Ontario universities, and McMaster,we submit, is a good example, there exists a potential for highly creative pure and applied research that goes far beyond the immediate needs of undergraduate or graduate education but which must be developed if any school is to provide the excitement for students that at all

levels is the mark of a great university. Despite the recognition of the need, it has proven very difficult for the universities to develop a system of funding which takes cognizance of this important extra dimension of university activity. It is important that the province should begin to take seriously its responsibility to support research independently of the perceived needs of undergraduate or graduate students.

The McMaster Situation

The members of the physics department at McMaster have taken very little comfort from the ACAP report. Although complimenting McMaster on the wise use of the resources given to it during the days of rapid expansion and easy money, and recognizing the outstanding achievements of its faculty, the report offers no suggestions by way of its recommendations as to how the department is to maintain the high quality of its graduate program, or to secure the resources to achieve the goals which the document suggests are within its grasp. The Department insists that what it needs most of all are appointments on a regular basis and that without this injection of new blood the danger exists that the natural process of aging will first change the mood and then the effectiveness of the group. The consultants have identified two physics departments in Ontario that have the potential to "make" it in the world league during the next decades. We believe that some positive steps should now be taken to make this development possible.

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May 10, 1974.

University of Ottawa response to ACAP Assessment in Physics

1. Introduction

In their report, the consultants make thirteen recommendations, many of which have general application but one, #12, applying specifically to the University of Ottawa. The present report will discuss that particular recommendation only, together with the various considerations which the consultants quote to support it. We question the validity of the basis for this recommendation and particularly the low evaluation of the quality of the Physics Department at the University of Ottawa. Our purpose here is to show that the Department does, in fact, compare favourably with many of the other nine Physics Departments in the province which have a Ph.D. programme.

. Criteria used by consultants

The consultants' determination of the quality of a Department has been based almost completely on a single criterion of the number of outstanding faculty or 'stars' in the field of research. This number, in turn, has been determined in the main by a single measure of the size of the individual NRC operating grant. It is on the resultant allocation to Ottawa of only two stars

plus the factor of the small size of the Physics Department (discussed further below) that the consultants have rated Ottawa the lowest of the ten Departments with Ph.D. programmes.

3. Other Possible Criteria

Many other criteria are available to assess the quality of the faculty of a Department as can be seen from the consultants' reports in other disciplines. Thus in Chemistry, the NRC operating grant has been used, but not in the 'go - no go' fashion used for Physics. We wish therefore to discuss operating grants in more detail. Throughout this discussion, we will concern ourselves with the NRC operating grants only and will not include major equipment, A.E.C.B., high energy physics grants etc. This is consistent with the choice of the consultants in both Chemistry and Physics.

3.1 N.R.C. Operating Grants

Eleven of the fourteen faculty members of the Ottawa Physics Department receive NRC operating grants. This proportion of grant recipients (11/14 = 0.79) is effectively that for the ten departments in the province with Ph.D. programmes (241/315 = 0.76). To assess the value of these operating grants, in Table I we present for each of the ten departments figures for (a) the total of all operating grants in Physics, Nuclear Physics, Space Research and Astronomy for 1972-73 (the year considered by the consultants), (b) the number of recipients and (c) the average grant per recipient. It is seen that for this average figure, Ottawa is sixth out of the ten departments considered.

Further points with regard to these grants are:-

(a) the average value for Ottawa ($9,091.) exceeds the national average in Physics and Nuclear Physics ($8,450.) by 7%.

(b) the averages in Table I are biased to some extent by the inclusion of Space Research and Astronomy operating grants which are on average 25% larger than those in Physics. If only Physics operating grants are considered, Ottawa moves up to fifth position in the list.

(c) with regard to future figures, since 1972-73 the average NRC operating grant to Ottawa has increased more rapidly than the national average for Physics, so that in the present grant year the Ottawa average exceeds the national value by 15%.

3.2 Publications

A further criterion frequently used in Universities and elsewhere to assess quality is publication of research papers. Two factors need to be considered here, firstly the standard of the papers, which should be published in reputable journals employing a referee system and secondly, the interest which the scientific community shows in the work.

To assess publications in terms of the first of these requirements, we have counted only those papers mentioned in Physics Abstracts. In Table II, we give figures for the average number of papers per full time member of Department over the 3½ year period covered by the Physics Abstract volumes for 70,71, 72 and the first half of 1973. It is seen that in this case Ottawa is above the halfway position in the Table.

To assess the interest in these publications, we present in Table III data taken from the Science Citation Index volumes for 1970,71 and 72. Here the average number of citations per faculty member over the three years have been calculated. It is seen that in this case, Ottawa is at the halfway position in the Table.

4. Reasons for discrepancy in assessments

The statistics produced above would appear to indicate that Ottawa should be considered to be on a par with such Universities as Queen's, Waterloo, Western, Windsor, etc. It is of interest therefore to ask if there are any clear reasons why the criteria used by the consultants should give a very different results. Several points may be mentioned here.

(a) One important factor is the Dynamitron programme. In 1966, Ottawa and Carleton Physics Departments launched a low energy nuclear physics programme with a novel but untested type of machine (Dynamitron). This particular model proved to be a dismal failure. Considerable effort was invested by two members of Carleton and three members of the Ottawa faculty to make use of this machine. Finally, despite some success, the programme was terminated in 1971. Residual funds from the "core" grant were allocated for phasing out and for initiating other projects, with the consent of NRC. As a consequence, the NRC operating grants awarded to the members of this group for the year 1972-73 were correspondingly reduced, each recipient concerned being so notified by NRC.

(b) As indicated above, DRB research grants have not been considered here or by the consultants. However, because of the small size of the Ottawa Department,

a relatively high percentage (3/11) of those faculty receiving NRC operating grants were also receiving DRB grants. Since the NRC requires applicants to indicate the level of support they receive from other agencies, it may be argued that the NRC grants take such extra sources into account and are correspondingly reduced.

(c) One obvious factor is that because of the small size of the Department, the numbers are not really statistically significant, particularly with the 'go - no go' form of the consultants' criterion. It would appear from a study of the grant data that there could be four or five cases at Ottawa where a faculty member was almost on or just below the critical grant value. While in a larger department, statistical fluctuations might be expected to cancel out, the smaller number of faculty at Ottawa could allow an adverse statistical fluctuation to give an appreciable deviation in the final number of 'stars' assessed.

(d) One other parameter mentioned by the consultants was the quality of the graduate student body as measured by the percentage holding NRC or similar scholarships. Again, statistical fluctuations can appreciably affect the result in smaller departments. Thus, in the case of Ottawa, the consultants quote figure of 18% for 1971-72 and 16% for 1972-73. However, at the present time, this figure has increased to 30% and compares well with those of other Departments.

5. Conclusions

From the above considerations, it would appear that the Physics Department at Ottawa can be considered to be in the same category as the corresponding Departments in Queen's, Waterloo, Western, Windsor, etc , despite the adverse comments of the consultants. We request therefore that when student numbers are allocated in the fashion suggested by the consultants and the discipline group, Ottawa be given an allocation similar to those of these Universities and not the small number proposed in the consultants report.

Table I

1972-73 NRC Operating Grants in Physics, Nuclear Physics, Space Research and Astronomy*

University	Total Grant	No. of Recipients	Average Grant per Recipient
McMaster	$361,500.	27	$13,389.
Toronto	$670,550.	60	$11,176.
York	$210,750.	20	$10,537.
Queen's	$210,550.	21	$10,026.
Windsor	$137,450	14	$9,818.
Ottawa	$100,000.	11	$9,091.
Western	$246,300.	29	$8,493.
Guelph	$123,300.	15	$8,220.
Waterloo	$257,950.	34	$7,587.
Carleton	$45,700.	9	$5,078.

* Major equipment, AECB, High energy physics etc grants not included.

Table II

Publications in a 3½ year period (Physics Abstracts 1970,1971,1972 and January-July 1973)

University	Faculty	Total Publications	Publications per faculty member
McMaster	30	404	13.5
Toronto	49	489	10.0
Windsor	17	147	8.6
Ottawa	14	107	7.6
York	27	205	7.6
Queen's	35	260	7.4
Waterloo	39	230	5.9
Guelph	25	144	5.8
Western	28	129	4.6
Carleton	14	57	4.1

Note: To simplify counting, any paper with two (or more) authors from the same department has been counted as two (or more) publications in the above table.

Table III

Citations in a three year period (Science Citation Index 1970, 1971 and 1972)

University	Faculty	Total Citations	Citation per Faculty Member
Toronto	49	3243	66
McMaster	30	1845	62
Guelph	25	912	37
Queen's	35	1200	34
Windsor	17	559	33
Ottawa	14	446	32
York	27	784	29
Waterloo	39	966	25
Western	28	512	18
Carleton	14	203	15

Notes: a) In S.C.I., only the name of the first author is indexed. Hence in all cases, the above figures will be smaller than the actual citation values because only faculty and not other members of departments have been included.

b) Only research papers and not books have been counted.

QUEEN'S RESPONSE TO THE A.C.A.P. CONSULTANTS' REPORT ON PHYSICS

INTRODUCTION

The consultants' report embraces wise and well-reasoned principles for the assessment and administration of Ph.D. studies in Ontario. Their discussion of the conditions necessary to promote excellence in the graduate schools deserves serious study. While most of the recommendations are well-founded and constructive, a few appear inadequately to reflect the consultants' own guiding principles. We therefore discuss the report in some detail.

GENERAL DISCUSSION

A commonsense but useful definition of the purpose of a graduate school has led the consultants to identify stimulating atmosphere, faculty excellence and originality as essential requirements for a viable graduate school. The criteria of quality arising from their discussion set a high but salutary standard of excellence whose consistent attainment in the universities would surely benefit both the institutions themselves and the people of Ontario. We strongly support the consultants' view that such high standards are more likely to be achieved by vigorous competition between universities than by administrative edict or by the restriction of Ph.D. studies to a small elite group of institutions. The consultants stress the subtleties of achieving excellence in a graduate school and we endorse their statement that policies stemming from a desire for administrative efficiency would be unlikely to promote excellence in the graduate schools.

In emphasising that no university in Ontario presently has a graduate school in physics or astronomy attaining the standards they discuss, the consultants have drawn attention to the desirability of academic planning that will foster the improvement of the quality of all such schools in the province. They realistically assess that such planning should presently consist of the application of gentle but continuing pressure for improvement rather than sudden, dramatic measures. The consultants propose that even the most outstanding Ontario department would require a decade or more for this improvement and recommend that actual discontinuation of existing programs be the subject of future review after a period of "guided competition" among the existing schools. We endorse their view that precipitate administrative action is unlikely to bring about constructive improvement. Although the recommended student distribution (and its justification) may well be subject to detailed criticism, its similarity to the status quo shows that further regulation of graduate enrolment is unnecessary.

As well as supporting the consultants' general view of how their declared ideals might be attained, we agree with their basic commentary on what features of a department contribute significantly to excellence in the graduate school. In particular we support the view that departmental size alone does not promote interaction among faculty and students and may indeed contribute to fragmentation of a department and narrowness of outlook within its parts.

The consultants have rightly given considerable attention to the question of demand for Ph. D.'s in physics and astronomy. Their statement that there is no good basis for determining desirable enrolments, and their explicit commentary on the unreliability of demand predictions,

are well founded. Rare and possibly unattainable wisdom would be necessary to forecast accurately society's future need for so potentially flexible a graduate as a modern Ph.D. physicist or astronomer. Consequently the consultants' approach to numerical enrolment matters is basically realistic. Their recognition of the constructive adaptability of the well-trained graduate provides a sound basis for not setting any numerical targets for enrolment in the individuals subfields of physics or in astronomy.

The consultants have also recognised that the quality of the large number of junior faculty across the province cannot be assessed reliably at the present time. The age profile of Ontario physics faculty (p.A-19) indicates that there are almost as many faculty of age below 35 as there are faculty who presently meet the consultants' standard of excellence. We therefore support the consultants' view that future reassessment of the physics graduate schools will be of great importance and urge that no administrative measures be adopted which would pre-empt such reassessment. It is Queen's considered view that reassessments can be carried out without the permanent establishment of the present unwieldly bureaucracy.

Despite the wisdom of the consultants' overview of graduate education in Ontario, there is in the report disturbing evidence of restricted vision in the assessment of certain areas of physics and astronomy. The distinction between pure and applied physics is not clearly discussed although the latter is implied to be uniformly second-rate. A restricted and outmoded notion of the profession of "astronomer" has apparently been adopted, resulting in an anomalous discussion of graduate studies in astronomy. Theoretical work in physics or astronomy is accorded no assessment in its own right and is treated as a mere adjunct to experi-

mental programs. The assessment of nuclear and particle physics is uneven. For example the particle physics program at Carleton receives less attention than it deserves and the world stature of Litherland's nuclear physics research although unequalled in Canada is given no prominence.

COMMENTS ON APPLIED PHYSICS AND ASTRONOMY

1. APPLIED PHYSICS

The consultants give qualified encouragement to the development of applied physics research in Ontario universities, quite properly expressing concern for balance between pure and applied research and for freedom to publish (p. A-52). They do not delineate the role of applied physics but convey the apparent prejudice that when physics research becomes sufficiently useful to border on engineering it is ipso facto second-rate. The absence of even faint praise for any of the existing or planned applied physics or Engineering Physics programs in Ontario universities is surprising, to say the least. These aspects of the consultants' report should be contrasted with the following recommendation of the Rose Report (p. 56):

"A very great difficulty in meeting the necessary demands for manpower in this field lies in the fact that classical physics or applied physics has no proper 'home' in the majority of universities. All students of physics must study classical physics in their basic program, but the research interests in most universities have swept classical physics aside in their reach for newer and more exciting fields. In fact, of the money spent by universities for research in this field, only 9% was spent in physics departments, the balance was

spent in engineering departments. We recommend strongly that at least some universities be encouraged to develop centers of strength in classical physics, and that adequate research funds be especially earmarked for basic and applied research oriented toward the special problems and development of Canadian technology."

The consultants are of the opinion (p. A-30) that "a rationale of the role of applied physics is needed at Queen's". A clear rationale for graduate studies in applied physics, and indeed in applied science, has existed at Queen's for 50 years. The physics department is a full member of the Applied Science Faculty and of the Engineering Sciences Division of the Graduate School. Much of its teaching is directed to engineering students, it has graduated B.Sc. Engineering Physicists since 1920, and it has from time to time graduated students with advanced degrees in Engineering Physics. We are thus an Engineering Physics department as well as a conventional one, and as such view applied physics as an important function of the department, although it constitutes only a modest fraction of our research effort.

Applied physics research falls into two categories. The first applies new results in pure physics to areas of potential technical importance and to other scientific disciplines. These activities are in harmony with the consultants' implied view of applied physics. In the second category lies the engineering-oriented research ("developmental in character" p. A-30) which demands the combined skills of physics and engineering. Since research of the first type is carried out even in conventional physics departments, research of the second type is surely a proper activity for the department at Queen's. The

consultants' remark that such work "might be more appropriate for an engineering department" is itself inappropriate.

2. ASTRONOMY

The report has not rationalised the relationship of different subfields of modern astronomy to one another or to physics. In places (e.g. p. A-49) radio astronomy and astrophysics have been equated to one another and to any astronomy that is not "traditional", i.e. optical astronomy. While recognising (p. A-41) that "the qualifications for distinguished work in astrophysics are the same as for similar work in physics", "one cannot do astronomy without a thorough knowledge of physics" and "progress in astronomy (has) depended on newly acquired knowledge in physics" the report nevertheless makes untenable distinctions between graduates of astronomy programs in Physics Departments (notably at Queen's and York) and in Astronomy Departments.

The first distinction involves professional competence. It is stated that "alumni of such programs (astronomy at Queen's or York) emerge as physicists" and "any student who intends to specialise in astronomy should get one degree in a bona fide astronomy department". It is admitted that "all important branches in astronomy can be examined in a core curriculum at the fourth year or first year graduate level" (p. A-44) but although this and more is done at Queen's by faculty acknowledged (p. A-45) to be astronomers and commended (p. A-49 and 50) for their research, it is maintained that our graduates are in some important sense not equipped for careers as astronomers. There is no valid basis for this contention either in the report or on the

professional scene; Queen's alumni are presently employed as professional astronomers by leading Canadian universities and in full-time research institutes.

The second distinction involves employability. A well-trained modern astronomer should not be limited to "traditional" careers at observatories or universities but should be as able as a well-trained physicist to use his skills in a wide range of applications. The consultants' reasons for not imposing an enrolment ceiling for physics students apply equally to the product of a modern astronomy program.

Good-calibre students of astronomy whether trained in physics departments or titular astronomy departments have comparable credentials for careers as professional astronomers and equal flexibility in employment opportunities. Tables 2 and 3 of the report demonstrate that the astronomy departments attract Canadian students of high calibre; this is also our experience at Queen's, where our astronomy Ph.D. students since 1969 have been 88% Canadians and 75% NRC scholars. We submit that the distinctions drawn in the report are invalid and should be ignored, and further that the recommended ceiling for astronomy student numbers is unnecessary.

THE RECOMMENDATIONS

There follow our comments on each of the specific recommendations made by the consultants:

PHYSICS

1. *"no regulations be adopted which would place limits on the total number of graduate students. (page A-22)"*

This recommendat_ is sensible in view of the difficulty of predicting future demands for Ph.D. graduates.

2. *"the Ph.D. students of the province be distributed among the universities according to the numbers of faculty members who are found to be competent P.D. supervisors in the various physics departments. A recommended initial distribution is shown in Table 5.* (page A-39)"

More detail of the criteria used to evaluate faculty competence should have been provided. It is imperative that future evaluations be based on criteria which are clear, well-understood and seen to be just. The principle of encouraging a distribution of Ph.D. students according to the distribution of qualified supervisors is sound; however the recommended initial distribution is so similar to the status quo that regulation of graduate enrolment is unnecessary. Queen's has always protested strongly against attempts to make assignments of numbers of students in any university.

3. *"the projected enrolments and distribution of Ph.D. students be revised every two or three years.* (page A-40)"

Periodic reassessment is vital. The assessment of those departments which underwent rapid expansion in the late 1960's could change significantly as junior staff develop. As the mean lifetime of an individual Ph.D. student in a department is at least 3 years, reassessments at intervals less than this will lead to needless overlap in the statistical information used to assess each department and will serve only to exaggerate bureaucracy.

4. *"there be no assignment of responsibilities for specific fields of studies to particular departments but that the coordination of research activities of the departments be continued by the discipline groups.* (page A-54)"

We support this recommendation on the understanding that "research activities" is interpreted to mean research involving graduate student training.

5. *"no limitations be placed on the movement of departments into new areas of research but that, in the periodic reviews (see recommendation 4) of graduate programs, special attention be directed to new areas of research which have been started to ascertain that the students are under the guidance of well qualified supervisors.* (page A-54)"

We support this recommendation.

6. *"a university receive no provincial financial support for any Ph.D. student who has received a bachelor degree from the same university unless that student holds a masters degree from another institution or the university receives special permission from the Ontario Council of Universities.* (page A-51)"

The concerns which generate this recommendation are wholly understandable and laudable but the mechanism suggested is a blunt instrument. Queen's believes that it is a leading responsibility of its professors to advise the students to go to the Universities where they will receive the best training for their interests. Queen's would not readily accept action by a bureaucracy which restricts in any way the students freedom of choice.

7. *"the universities formulate policies governing applied research in graduate programs with particular attention being given to the safeguarding of the academic freedom, balance and coherence of the programs.* (page A-52)"

Queen's University has already formulated such policies.

8. *"all universities review their tenure and promotion practices to assure a standard up to that adopted by universities which have achieved a well-deserved reputation for high quality graduate work and research.* (page A-53)"

We endorse this recommendation.

9. *"serious consideration be given to developing graduate programs in optics and acoustics.* (page A-54)"

This recommendation is acceptable if it is understood that no new bureaucratic device is to be fashioned in order to implement it or similar proposals which may emerge in future assessments. A fuller discussion of the grounds for such proposals would however be desirable if they are to be accorded much weight.

10. *"the discipline group annually review and grade the applications of graduate students who have been accepted by the universities and that the results of this review be made available to the appropriate committees for evaluation and planning purposes.* (page A-55)"

This recommendation, while resulting from legitimate concerns, is liable to enhance bureaucracy to an extent which outweighs any possible advantages which might accrue. Its implementation should be left to the discretion of the discipline group.

11. *"at the four emergent universities the income from the province for graduate students should not be proportional to student numbers but a special fund be set up at these universities to support their research programs.* (page A-55)"

The problem to which this recommendation is addressed cannot properly be isolated from others associated with the BIU system of financing.

12. *"in order that the University of Ottawa be given an opportunity to develop a high quality bilingual graduate school in physics, the university be allowed to plan for a number of Ph.D. students higher than that assigned, but if future assessments find no substantial improvement in the quality of the faculty, consideration be given to having the Ph.D. program discontinued.* (page A-40)"

This recommendation is puzzling, as the issue of quality should be resolved under recommendations #2 and #3. The recommendation would be pertinent only if the figures given in Table 5 were interpreted as mandatory enrolment ceilings, which is clearly not the intention of the consultants. We refer to our earlier statement that Queen's would not readily accept assignments of student numbers to particular universities - for any reason.

13. *"an appraisal of the M.Sc. program at Laurentian University be carried out in the near future.* . (page A-35)"

The failure to specify the criteria and the academic considerations which generate this recommendation is unacceptable.

ASTRONOMY

1. *"no new graduate programs in astronomy be established in Ontario, but this is not to be construed that a thesis on an astronomical topic in an existing department of physics be interdicted.* (page A-48)"

2. *"for planning purposes the projected enrolment of Ph.D. graduate students in astronomy be reduced to 15 by the year 1978-79 and that these students be distributed between the University of Toronto and the University of Western Ontario in the ratio not less than 5:1 in favour of the University of Toronto.* (pages A-47 and A-50)"

3. *"recommendations 3, 4, 5, 6, 8 and 10 under "physics" also apply to astronomy departments."*

We have already emphasized our rejection of the report's distinction between astronomers trained in titular departments of astronomy and those trained in physics departments. In neither instance can a ceiling on astronomy Ph.D.'s be justified. We therefore see no need for the separate recommendations for astronomy.

SUMMARY

We support the consultants' approach to the promotion of excellence in the Ontario graduate programs in physics and astronomy. We endorse the consultants' concepts of "gentle but continuing pressures" to foster improvement in the quality of graduate education and of competition among several institutions as opposed to strong centralization. The importance of periodic reassessment of the recommended student distribution has been correctly recognized. The opportunities for such reassessment should not be pre-empted by precipitate action.

Although we have criticized some aspects of the report, particularly its treatment of astronomy and applied physics, we feel the consultants have displayed laudable concern and much wisdom in developing a rationale for academic planning in the Ontario graduate schools.

R. L. McIntosh,
Dean,
School of Graduate Studies and Research.

May 6, 1974.

UNIVERSITY OF TORONTO
School of Graduate Studies

OFFICE OF THE DEAN

Toronto 181, Canada

May 21, 1973

Dr. J.A. Preston,
Council of Ontario Universities,
#3033,
130 St. George Street,
Toronto.

Dear Dr. Preston,

The consultants' report to ACAP on the assessment of graduate studies in Physics and Astronomy is in some respects a fair summary of the state of those two disciplines in the province of Ontario. The consultants recognize that to function properly, university departments should not be constrained by rigid regulations and they clearly wish to preserve what is good in each of the departments. We are not sure, however, that they come to grips with the problems of maintaining the quality of science education in a situation of weakening enrolments and decreasing real financial support, nor do they indicate how Ontario universities can plan to develop physics departments of the international calibre that they would like to see. While they state at the outset (p.A-5) their belief in excellence, some of their recommendations seem ill-designed to meet such a goal or run counter to it. Some significant parts of the report seem to have been written with the protection of the status quo in mind, and the interest of the graduate student is too often a secondary consideration.

On p.A-8 of the report, the consultants reject the University of Toronto's position on the relationship between research, graduate instruction and undergraduate instruction. However, they do not pursue their own logic to its conclusion, namely that, given their analysis, there is no barrier to suggesting a greater degree of concentration of graduate instruction in a few centres of excellence, providing research support is available for those universities with fewer or

no graduate students. On the contrary, the consultants recommend a distribution of enrolments based on the number of 'competent' supervisors in each department. We find this proposal unacceptable for reasons which are outlined in greater detail below in our response to Recommendations on Physics, numbered 2,3 and 6, and on Astronomy numbered 2. Their scheme presents us with a quota system under a new guise, but a quota system nonetheless. Such a system would be difficult enough to justify when accompanied by some basic restructuring of graduate education, but has very little to recommend it in the absence of such change.

The section containing specific comments about the various universities is so brief and impressionistic that, if the example of this university is any indication, it could be misleading in some respects. For example, from the section of the report dealing with our Department of Physics, one might think that the nuclear physics groups consists entirely of experimental physicists. It is odd that the highly successful theoretical nuclear group (and its close collaboration with experimental work) is virtually ignored, whereas groups of comparable strength in other departments are described as outstanding and internationally recognized. With respect to the elementary particle physics group it is stated that "In this difficult area .... the work must be compared with that of some of the world's largest and best financed groups....", and this is followed by the statement "....the department can claim only moderate success." Is this meant relative to the world's largest and best financed, or is the remark meant in some absolute sense ? It is high praise indeed if it is the former, but if it is the latter the remark is merely disparaging without making any helpful point. In fact, it is recognized that the high energy group in the department is making a significant contribution to high energy research, as noted in the report of High Energy Physics Grant Selection Sub-Committee for 1974. It is further stated on the basis solely of comments by some students that ".... the department gains little by its large size." In fact, there are many advantages to both staff and students flowing from the present size of the department, as most successfully argued by Professor J.M.Daniels in the departments' five-year plan.

We are pleased to note the consultants' agreement with our decision to expand graduate studies in atmospheric physics, and their recognition of developments in graduate work on the Scarborough and Erindale campuses. We are particularly pleased that they have recognized the excellent work of the Department of Astronomy.

The Recommendations

Physics

1. We agree with this recommendation, in spite of our grave reservations about the manpower forecasting techniques used to arrive at it. It is unfortunate that consultants are still required to determine "desirable provincial enrolments year by year" and by degree and major subject divisions where appropriate. Their conclusion at the end of p.22 that "their projections are presented with little supporting data and no sound theoretical basis" could hardly be more frank about their view of the outcome. The arbitrary assumptions involved in such forecasts are well demonstrated in the demand for physicists (first paragraph, p.16) and the supply of students (last paragraph, p.17). In this case the compensating assumptions and errors in demand and supply happen to yield data which are approximately equal, thus sparing the consultants from proposing regulations on enrolment in which they do not believe. The basic question which remains is why such outstanding persons who can help us in so many other ways must continue to be asked to do estimates which they are not able to do, and in which most of them do not believe. I firmly believe ACAP needs before long to reconsider this particular part of the planning assessments on the basis of experience to date, among other things.

2. We strongly disagree with this recommendation, which appears to be a quota system under a new guise, with all the well-known defects of such a system. Firstly, the use of the term 'competent Ph.D. supervisor' is unfortunate since it implies that all other university physicists are not competent as Ph.D. supervisors. For Toronto this implication would apply to about 40% of our staff, and to about 70% of the physics faculty across the province.

The numbers given in Table 5 were calculated from a somewhat arbitrary formula which, for a given individual, took into account only the level of NRC support and the number of years elapsed since the Ph.D., with some modifications. The consultants themselves argue that other faculty members who are not meeting these standards are still suitable supervisors, and competent in the usual sense of the word. Secondly, such an attempt to distribute enrolments tends to work against the goal of developing truly excellent programs where both the excellence of faculty and the availability of fields and of facilities will attract excellent students. There is no way to ensure that the students enrolled at any institution will wish to work in the areas of competence of the "competent" supervisors and, if they do not, we see no purpose in obliging them to attend that institution. Finally, qualified students should be allowed to select freely the university at which they wish to study, based on their perceptions of competent faculty, of field concentrations, of the net financial costs to the student, and other factors.

3. Since we reject recommendation (2), this recommendation is also unacceptable. Such a short time scale would simply create greater instability in a process we find basically undesirable.

4. We agree that there should be no "assignment" of fields to particular departments, but we do not see why the consultants did not take the opportunity here to recommend to the various universities that they build on already proven strengths and thus develop concentrations of potential excellence.

   We understand that the Physics discipline group has not so far discussed the co-ordination of research activities of the departments. The Department of Astronomy notes that there already exists regular interdepartmental co-ordination.

5. We agree with the fundamental principle of academic freedom that we assume underlies this recommendation, but we cannot agree that this should be taken to mean that all departments should be permitted to give a Ph.D. in all areas of a discipline. Surely, such developments must be subject to al'

the normal constraints of appraisal and to the university's ability to provide funding. Again, the consultants have missed an opportunity to provide a planning basis for the development of our programs by indicating more fully the areas of proven and potential strength that could be a guide for departments in the system.

6. This recommendation is unacceptable, and in our opinion, unworkable. It appears to assume the Ontario graduate departments are approximately equal in quality, in the variety of fields, and in net financial costs to the student, when such is patently not the case. Once again, the proposal conflicts with the students' freedom to choose programs as his perception of faculty quality, fields, net financial costs and other considerations suggest. Moreover, the idea seems increasingly inappropriate for a field such as physics. Most physicists seeking university appointments today follow their Ph.D. with a period of post-doctoral studies. The most important time to change location is between these two phases of a student's education. And that change might well be to a different Department in the same university.

We do not wish to appear opposed to moves to encourage student mobility on a voluntary basis. A requirement to this effect, however, could create many problems which the consultants do not appear to have considered. Some good students might well leave the Ontario system and Canada for graduate work, or study in a field which is not their first choice, particularly if recommendation 2 is also taken into account. A student might be forced to give up a scholarship if he goes outside Canada. A student might not be accepted at another Ontario institution of his choice because of restrictions on numbers that can be admitted (see recommendation 2). A student might lose a year by not being able to start his Ph.D. until he has completed his M.Sc. To repeat, moreover, many personal circumstances influence a student's decision on graduate schools, and all of these are neglected in such a proposal.

7. We agree with the spirit of this recommendation, and believe it deserves attention by each university. There are already a number of protections of this kind, for faculty and students, in the regulations of this University.

8. The University of Toronto received a report on Policy and Procedures on Academic Appointments in the Fall of 1973, It has already implemented some of its recommendations and is still reviewing others.

9. We regret that the consultants did not indicate which universities seemed best suited to engage in such fields. We also regret that this recommendation was not listed with those for consideration by Astronomy.

10. We agree in principle with this recommendation, providing any review scheme is worked out carefully. We do not wish to see a centralized system for screening applicants before admission, but a post-admission evaluation could be quite valuable.

11. This recommendation touches on the basic question of the whole funding system and could not be implemented for one or two departments only or without a more general review. We presume the consultants knew that emerging universities already receive compensatory grants from the province and that federal research support to individual scholars is largely unrelated to numbers of graduate students.

Astronomy

1. It would appear from the text of the Report (pp.A-44,A-48) that this recommendation applies only to Ph.D. programs in Astronomy, and we believe this to be a sensible recommendation. However, we would hope that no embargo is put on new M.Sc. programs in Astronomy. Firstly, there is no such embargo for Physics, and in two such closely allied disciplines a one-sided embargo would hurt. Secondly, if undergraduate astronomy is to be developed at the several Ontario universities where it is not now offered, or is only peripherally available, it might be very desirable for the person appointed in such a capacity to have working with him one or more M.Sc. graduate students.

2. Our views on this recommendation are similar to those on recommendation 2 for physics. We do not favour setting a ratio for enrolment between the two universities, and we believe that the University of Toronto should be prepared to meet competition based on quality from other universities. The overall number of 15 Ph.D. enrolments in astronomy for the province in 1978-9 is unnecessarily rigid and we would prefer to see it removed. While the consultants have indicated there may be a problem of "oversupply" here (subject, however, to all the usual qualifications to such estimates) they note also that the figures are small and subject to large relative errors. Moreover, our departments appear to be controlling admissions strictly on the basis of student quality. Since enrolment restrictions are suggested for Physics, a shift of part of the Astronomy program to physics departments could well occur if Astronomy is restricted.

3. Recommendations 3,4,5,6,8 and 10 are dealt with under Physics, and our responses are intended to apply to Astronomy as well. We would again draw attention to recommendation 9, which, in our opinion, should have been added to the list of recommendations for Astronomy.

We are surprised that the consultants did not list among their recommendations for Astronomy the statement on p.A-45 that every university should have an astronomer to teach courses in Astronomy. We firmly believe that exciting, informative and up-to-date introductory courses in astronomy can only be taught by scientists whose life interest is in astronomy - persons who are thoroughly conversant with the current literature, attend astronomical meetings, belong to astronomical societies and either use astronomical instruments or do their major research in theoretical astronomy.

Because of the opportunities for co-operative research available to astronomers, having an astronomer does not mean making a commitment to large sums of laboratory equipment of a highly specialized nature. A single astronomer at a small or medium-sized university not only has academic contact with his physics colleagues but can participate in research in many ways

at the Algonquin Radio Observatory, at Las Campanas, at Mauna Kea in a few years, at the David Dunlap Observatory or at U.W.O's Observatory, at many American observatories, at the June Institute in Toronto, etc. This kind of co-operation is clearly what the consultants have in mind in several places of their report.

In conclusion, I would reiterate our strong reservations about recommendations 2,3, and 6 in particular, and the reasoning which underlies them. The consultants have used a single index ("competent" supervisors) measured on a limited basis to distribute students, while wholly neglecting other variables such as the distribution of field concentrations, student preferences of place or person, net student costs of attendance, and auxiliary facilities and equipment. Consciously or not, the consultants have in mind a university of Ontario model with control over placement of students in order to compensate for the obvious differences in size, fields, faculty, and locales of the departments and Universities. That may preserve the Ph.D. supervision of those defined as "competent" professors, and also preserves approximately the present distribution of such students, but it is fraught with dangers to students and to universities alike.

The misplaced emphasis of the consultants' plan also misses an opportunity for rationalization of a type which has been frequently recommended in other studies and accepted by ACAP and COU. The consultants are concerned to develop excellence, and they also indicate that two departments which have a high rating may be able to achieve the consultants' proposed quality standards while some others may do so on a more limited basis. Yet their basic proposals militate against such an outcome. We would draw ACAP's attention to a key statement from p.A-6 of the report :

"It is useful at this stage to consider very briefly the present state of graduate studies in physics in Ontario. By the standards outlined above, the graduate schools must be considered wanting. The two we have rated most highly approach the desired standard and, given the required condition, could achieve the proposed quality in a decade or two. All others fall below and some far below these standards. It is of course clear that the province

can not have three or four, much less nine or ten really outstanding graduate schools in physics and an equal division of the facilities, the funds and the talented physicist among all existing schools will assure the existence of none of outstanding quality."

The consultants refused to grasp the nettle posed by this statement and developed an alternative partly in conflict with it and which poses many other difficulties. I would urge ACAP to give serious consideration to the implications of this statement in considering their report.

Yours sincerely,

A.E. Safarian

A.E. Safarian
Dean

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TRENT UNIVERSITY

Response to ACAP Consultants' Report on the Physics and Astronomy Planning Assessment

General Comment on Report

It is apparent from reading the report that the consultants have done a thorough job of assessing the present numbers of graduate students and in making projections of student numbers for the future. The philosophy of university education, as given on pages A-8 and A-9, is excellent. There is little evidence, however, that the consultants considered some of the more elusive factors which should be characteristic of a good university such as the general academic atmosphere of the university, which includes the undergraduate programme, and the vitality and the optimism of the faculty. On the whole the report seems to dwell too much on the negative aspects of the situation in Ontario and little on the positive side. There has been a tremendous change in the quality of research and graduate instruction in Ontario during the past fifteen years. This fact should be mentioned in the report.

One of the omissions of the report is a serious discussion of the implications of the histogram on page A-19. With only a small number of additional physics faculty being hired over the next several years, the histogram will shift to the right. The average age of physics faculty will increase and there will be little infusion of eager young faculty members into the system. If this is coupled with declining numbers of Ph.D. graduate students it appears likely that a considerable number of the young faculty members presently on staff will not be Ph.D. supervisors and will have difficulty keeping a research programme going or of reaching the stature of research scientist necessary to maintain a good graduate school. These factors can have a serious effect on morale and on the vitality of a department.

Comment on Recommendations

A number of the recommendations can be accepted without comment. How-

ever, it is appropriate here to respond to some of them.

Recommendation #2 refers to the table on page A-39 which has as part of the title the words "competent Ph.D. supervisors". This title seems to be at variance with the intent of the consultants who attempted to assess the strength of a department by judging how many truly outstanding scientists were in the faculty. It must be acknowledged that some of these outstanding scientists may be very poor Ph.D. supervisors whereas a less renowned scientist may be an excellent one. It is unfortunate that this title implies that the remainder of the faculty are incompetent as Ph.D. supervisors.

It is recommended in #3 that projected enrolments and the distribution of Ph.D. students be revised every two or three years. It is unrealistic to expect universities to go through this exercise so often. It would be better to recommend that the Physics Discipline Group review the enrolment and the Ph.D. supervisor situations every two or three years and, if a revision is needed, recommend to ACAP that one be undertaken.

While it is a good policy to advise a student of the academic undesirability of acquiring all his degrees at the same university, recommendation #6 does not allow for the many exceptional cases which must be considered. The reasons for these may be family, financial or academic ones. Above all, the student should have a freedom of choice.

In recommendation #11 the four emergent universities are put in a separate category because the smaller scale of operations results in higher average teaching loads and, it could be added, higher average committee responsibilities. This recommendation is to be commended because its implementation would enable a faculty member's research to continue if, due to the natural fluctuation of small numbers of graduate students, he did not have, at a given time, a graduate student to augment his research effort.

It should be borne in mind, however, that if the consultants' projections of graduate student numbers turn out to be correct, there will be faculty members at other universities without graduate students who will claim an equivalent status.

It is obvious that this recommendation is a result of the irrationality of the present P.I.U. system of allocating money and that recommendation #11 cannot be divorced from this fact.

Statement on Trent

In considering the statement on page A-35 on the Department of Physics at Trent it is not clear what criteria the consultants used to decide that a department of 6 faculty members is marginal and one of, say 7, is not. The M.Sc. programme has been in operation for about five years with a total of 13 M.Sc. student-years (Table 1, page A-13, Report on Graduate Studies in Physics and Astronomy), which can be compared with totals of 8, 16, and 24 for other emerging universities for the same period. Thus Trent's programme is supporting the average number of M.Sc. students for the emergent universities and the comment which singles out Trent's programme as "marginal" seems unjust.

When a committee of external appraisers approved the physics M.Sc. programme at Trent in 1968, the complement of faculty in the department was, in fact, lower than at present. These consultants noted the division of research and graduate instruction into only two fields, namely, Radiation Physics and Chemical Physics. Research in these areas is carried out, on occasion, in cooperation with faculty members and graduate students from other departments of the university (i.e., chemistry), with scientists from national laboratories (N.R.C. Physics Division) and with faculty and graduate students from other Ontario universities (University of Toronto). Thus, graduate students in the department have an opportunity for interaction with faculty and students from

other departments and institutions, and are not isolated or disadvantaged because of Trent's small size.

The M.Sc. programme in Physics at Trent complements the graduate education system in the province by providing a sound master's degree without a "funnelling" effect into its own Ph.D. programme. Trent does not have, nor is it likely to have in the future, a Ph.D. programme. A survey of the graduates of this programme has shown that approximately equal numbers have found employment in the areas of teaching, industry and further graduate study.

In advocating the retention of an M.Sc. programme in physics at Trent it is necessary to realize that Trent, like most other universities, has a small fourth-year enrolment. In these circumstances, the presence of a few graduate students does a great deal to enhance the academic atmosphere encountered by the undergraduates. The graduate students belong to the student Physics Club and, on some occasions, have been the driving force behind it. They interact with the fourth-year students particularly when the fourth-year students are working on their projects. Above all, they help to provide a continuity to some research projects which could not be accomplished by technicians and they provide a stimulus to faculty research which is apparent but is difficult to quantify. In most cases, faculty time devoted to the instruction and the tutoring of graduate students is more than repaid by their assistance with the research programme. It needs to be pointed out here that, in a small department with hard-working faculty members who have many demands on their time, it is not easy to maintain all the factors which combine to provide a forward-looking, academically oriented department and one which creates a sound academic environment for the undergraduate students. Each of the components plays a part and a very important segment is the research and graduate programme. In a new and small university there is a delicate balance involving these factors and the removal of one of the underpinnings may result

in a slide into mediocrity. Since the number of graduate students involved is barely a perturbation on the Ontario scene it does not seem sensible to suggest that these graduate programmes be discontinued.

Conclusions

The report of the consultants includes statements which point the way to the development of departments capable of providing excellent instruction at the Ph.D. level. The discussions on pages A-5, A-6, A-7 and A-53 indicate clearly that the consultants believe that centres of excellence will occur only by competition and that these are unlikely to develop through government regulations. It may be assumed, then, that the assessment of the strengths of departments and the assignment of a percentage of Ph.D. graduate students based on this assessment is an attempt to allow this competition to operate. Under this scheme the competition will be based on the strengths of departments and not on how successful a department is in recruiting students. The consultants, however, made no judgement as to whether the present financing arrangements are adequate for this purpose. It is apparent that these proposals need to be considered carefully by those persons in decision-making positions.

Response of the University of Waterloo

to the Report of the Physics and Astronomy Consultants

to the Advisory Committee on Academic Planning

submitted to ACAP, May 21, 1974

Our reaction to the report on Physics and Astronomy is generally favorable in view of its excellent philosophy. There are a few general points on which we make some comment. We also have some comments on those parts of the report which refer to the programme at this university.

General Comments:

We believe that this report must be viewed in the light of the general philosophy which the consultants state as the basis of their judgments. This philosophy is brought out most clearly in the report in the section beginning at the bottom of Page A-5 and continuing at the top of Page A-6 where the consultants state that "Competitions between schools, driven by a pride in excellence which exists in a substantial portion of the academic community is likely to achieve the required result while designating particular universities as the homes of high quality graduate schools may lead to complacency and a decline in quality." The desired result referred to by the consultants is to achieve a number of graduate schools of the highest quality. They make it clear that only two of the departments in the province approach the desired standard at the present time. Nevertheless, while all of the others fall below the standard, they believe that even these departments should be left to compete with the first rate schools and that in this competition stands the best chance for the growth and emergence of more departments of the highest quality. We strongly endorse this philosophy and accept the challenge that is implied in it. We wish to emphasize however that this philosophy will lead to the desired result only if the universities accept the challenge to achieve excellence. It is therefore disappointing to find the report falling short of giving the kind of critical evaluation which would assist the universities in meeting this challenge.

The consultants identify the relative strength of the departments through the technique of giving the weighted number of 'competent Ph.D. supervisors' in each. In our view this is an unfortunate choice of phrase. Those faculty

who are not included are by implication incompetent to supervise Ph.D. students. It is evident however that this is not what the consultants mean as is made clear by the first paragraph which begins on Page A-38. We suggest that some phrase such as 'highly competent researchers' would have been more appropriate.

The use of the weighted number of 'highly competent researchers' to assess the strength of the graduate programmes must be approached with caution. While these numbers may provide a rough measure of overall quality, one must not use them too literally. To do so would ignore the strength of middle and junior rank faculty who have not yet acquired the status of 'highly competent researchers' but on whom the future development of the programmes will in large measure depend. Indeed the consultants themselves recognize this in calling for regular review of the programmes.

We applaud the decision of the consultants not to assign responsibility for specific fields of investigation to particular departments. The Ontario departments have themselves chosen the fields of physics in which they plan to develop their graduate programmes but the interests of physicists change and the more competent the investigator the more likely he is to shift his field of study. What is most important is to maintain a high level of competence among the faculty and students and this will best be achieved by retaining flexibility in the graduate programmes.

Specific Comments:

The section devoted to the University of Waterloo is generally fair. However, the statement that the quality of faculty in the department is somewhat disappointing is too vague to be helpful. We agree that the department lacks strength at the senior level but we believe that the group of associate professors is one of the stronger groups at that level in the province. The department has also maintained the level of scholarship students. We are pleased that the consultants have recognized the department's strong commitment to its undergraduate programme. We are also pleased with the recognition of the strength in the theoretical physics group in the Applied Mathematics Department. We also agree generally with the comments in the section on astronomy. Waterloo's effort in this field is modest but of good quality.

Comments on Recommendations on Physics:

Recommendation 1 - We agree with this recommendation.

Recommendation 2 - We cannot accept this recommendation since it implies a central distribution of students according to a system that in effect establishes enrolment quotes. In our view such a distribution of students would be contrary to the consultants' own general philosophy of open competition amongst the universities. The suggested enrolment figures can at best be taken as guides to the universities in planning.

Recommendation 3 - We agree with the desirability of a regular review of the quality of the programmes. We feel that this is most important because the strengths of departments change as younger members of faculty mature and develop. No assessment of a department's strengths and weaknesses however carefully carried out will remain valid for more than a few years.

Recommendation 4 - We agree that there should be no assignment of responsibilities for specific fields of physics to particular departments. We also agree that the discipline group should continue to coordinate the research and graduate activities of the departments.

Recommendation 5 - We agree with this recommendation. Indeed the discipline of physics is one which provides basic training for many fields. Physicists often go into work in fields that are not directly related to physics but where the education and general background they have acquired as physicists is valuable. In any field such as physics which is developing and changing, at times rapidly, it is necessary to have periodic reviews to ensure that new areas of research are developed adequately.

Recommendation 6 - We cannot accept this recommendation even though we support the principle that it is desirable for a student to go to different universities to receive a greater breadth in his education. We already encourage mobility but we would be opposed to any legislation which would attempt to enforce it.

Recommendation 7 - We agree with this recommendation. The University of Waterloo, which has a strong emphasis on applied research throughout its programmes, has established policies governing the use of proprietary information. and which protects the rights of the graduate students to freely publish their thesis research. We do not believe, however, that the balance between applied and nonapplied research can be legislated; what might be appropriate for one university may not be for another. The universities must be left to judge this for themselves.

Recommendation 8 - We support this recommendation. The University of Waterloo already has revised procedures in operation.

Recommendation 9 - We support this recommendation. Indeed we would suggest that the discipline group should constantly be alert to the desirability of developing programmes in important fields of physics which are not adequately covered in the Ontario system.

Recommendation 10 - We agree with the suggestion that the discipline group continue to play a role in reviewing the quality of graduate students accepted by the universities and that the results of these reviews be made available to the appropriate bodies.

We make no comment on Recommendations 11, 12 and 13.

Comments on Recommendations on Astronomy:

Recommendation 1 - We support this recommendation. In particular we strongly support the view that theses on astronomical topics in existing departments of physics be permitted.

Recommendation 2 - We oppose the concept of an enrolment quota in astronomy or any other discipline. Numbers can at best be guides to departments for planning.

Recommendation 3 - We have no further comment on these recommendations beyond what we have said above in connection with Physics.

Respectfully submitted,

L. A. K. Watt
Dean of Graduate Studies

C-61

Response from the University of Western Ontario to the ACAP Consultants' Report on Physics and Astronomy.

May 21, 1974

This reponse was prepared by two slightly different Senate committees created for the purpose of examining the Consultants' Report with respect to: I. Physics and II. Astronomy.

I. Physics

We agree with the philosophy that excellence in graduate programs is unlikely to be achieved by simply imposing external restrictions and regulations on the Universities. Experience has shown that regulations imposed by some central authority are often counter productive in a situation such as this and we agree that weaknesses of the graduate programs in Ontario must be corrected by firm pressures. Some of these pressures may be generated from outside the Universities but we feel that the health of the educational structure will suffer unless the universities themselves share in formulation and administration of any new policies.

With respect to the recommendations on pages A-2 and A-3, we would make the following comments:

Recommendation 1.

We agree that no additional regulations to limit graduate growth are needed. Existing dissuasions have been sufficient to seriously threaten the future of Physics in the province and in the country. Indeed, student prospects are such as to suggest that some resuscitation of the Physics image may be necessary in the near future to assure that even the minimum needs of the country are met.

Recommendation 2.

This University accepts the view that some members of its staff have largely withdrawn from research activities. We do not, however, agree with the Consultants' view of the capabilities of those still involved in research. We were disappointed at the time of the Consultants' visit that they chose to spend only one and one-half days with what they themselves acknowledged to be one of the larger groups in the Province. We also felt that their discussions with faculty were of a perfunctory and general nature, and not directed toward a critical evaluation of strengths and weaknesses, especially for junior faculty members. In any case, judgements based largely on size of NRC grants does not

fairly evaluate the competence or intellectual qualifications of many of the junior faculty members in this Physics Department. We are, therefore, unable to accept the figures in Table 5 (page A-39) as a fair assessment of our capabilities for Ph.D. supervision. A more appropriate figure for Physics and the theoretical physics sections of Applied Mathematics would be 18 rather than the figure of 8 suggested by the Consultants. We should also comment here on the question of university support for the department. In spite of a university policy to make no new appointments above the rank of Assistant Professor, an outstanding theoretical physicist was appointed as professor two years ago and a new Chairman from outside the University was appointed last year. During the past year, the University has provided tangible research support for promising junior faculty members and we expect that this support will continue in the future.

Recommendations 3,4 and 5.

We are in general agreement.

Recommendation 6.

This espouses an article of faith in graduate study but attempts to couple it with a sting. [redacted] our belief that few members in any class of qualified graduates should proceed directly into Masters and Ph.D. work at their undergraduate university. It should be recognized that many factors operate in determining the institution where an individual takes his graduate work and it is unreasonable to insist that all students take at least one degree away from the institution of primary training. We believe it is reasonable to request the discipline group or, more appropriately perhaps, a committee of Departmental Chairmen to examine the case for taking more than two degrees at a single institution. The introduction of funding sanctions, however, involves a totally different group of considerations and this Committee believes that control of this sort does not appropriately dwell in the Offices of the Ministry.

Recommendation 8.

We concur.

Recommendation 9.

We identify no prospects for programs in optics or acoustics in our Physics Department, although the Faculty of Engineering Science has a cooperative program in applied acoustics involving some members of the Physics Department.

Recommendation 10.

We concur.

Recommendation 11.

This recommendation introduces the principle of separate, extra-formula funding for individual graduate programs. The funding of emerging universities is already aided by special grants beyond the provincial formula grant. The adequacy of these special grants and the adequacy of the Physics share of these grants may be open to question, but it would be our view that supplementary funding of Physics programs should come through institutional grants and not by means of special program-oriented subventions.

Recommendations 12 and 13.

These recommendations do not concern this University and we have no comments.

II. Astronomy

The Committee is of the opinion that it is unfortunate that only one reviewer looked at Astronomy. Some subjective conclusions appear in the report that might have been tempered had another viewpoint been sought.

Astronomer members of the Committee were most laudatory in their descriptions of cooperative activities between the Toronto department and our own. Cooperation has included attempts over many years to obtain national observing facilities for all Canadian astronomers, particularly in the southern hemisphere.

With respect to the summary of recommendations on page A-3 of the Report, and the statements made with respect to this University, we offer the following comments:

Recommendation 1.

We concur that no new Ph.D. programs should be initiated in the Province.

Recommendation 2.

We find the expression of constraints on Ph.D. enrolment in this recommendation to be awkward and unworkable. In particular, we object to the proposal that the Ph D. students be distributed in a ratio of at least 5 to 1 in favour of the University of Toronto. The department at the University of Western Ontario does not have aspirations for 15 Ph.D. candidates within the foreseeable future; however, it finds unacceptable a constraint which defines its activities

in terms of another group over which it has no control. A sudden change in the department at the University of Toronto does not affect the competence of the staff at the University of Western Ontario. The establishment of regulation by remote control precludes any rational planning. Furthermore, the capabilities of the two departments are complementary and not grossly overlapping. Capable candidates interested in high-dispersion spectroscopy, polarimetry or theoretical work, should not be sent away simply because a program 120 miles away is at its full complement. We believe some better method, possibly a flexible quota (e.g. 4 ± 2) might be a workable solution. For the above reasons we believe that Physics Recommendation 3 should be supported and enrolment reviewed at least every two years in the case of Astronomy.

Physics Recommendations 4, 5 and 8.

These recommendations are acceptable as noted in Part I (above) insofar as they affect Astronomy.

Physics Recommendation 6.

It may be noted that the Astronomy Department at the University of Western Ontario has always adhered to this recommendation and has not accepted its own graduates as Ph.D. students unless they have completed a degree from another university.

Physics Recommendation 10.

It is the view of the Astronomy group that this recommendation is excessively complex for the comparatively small-scale operation in Astronomy carried on in Ontario. There is already extensive exchange of students between the two departments based upon student interest. It is not thought that improved quality would result from implementing this recommendation.

We believe that the comments made about the Astronomy Department on page A-49 may be misleading. The implication that antiquated equipment is painstakingly updated is inaccurate. Most observatories make the bulk of their observations on the photographic plate. Electrostatic image intensifiers are used here as elsewhere. The multichannel photon-counting scanner now nearing completion is among the most useful and advanced type of equipment; only a few observatories in North America have built comparable instruments. Image slicers, available at only a few observatories, are in operation here. Thus we seek to use our 48-inch reflector with maximum efficiency. We may also note that a Cassegrain echelle spectrograph, primarily for polarimetry, is under construction.

The statement that our Ph.D. program emphasizes the use of our 48-inch telescope and coude spectrograph may be misleading. Theoretical work is an important part of our program. Faculty and students have carried out extensive observing programs at such places as the Hale Observatories, Kitt Peak National Observatory, Dominion Astrophysical Observatory and Sacremento Peak Solar Observatory.

This Committee has observed that in dealing with numbers of faculty and students as small as those of Astronomy in Ontario, it is possible to obtain valuable information about the quality of a Ph.D. program from an examination of the quality of its graduates.

We regret that the reviewer has made unsubstantiated allegations about some members of our Astronomy staff which we feel is comparable with that of any good Astronomy Department, and we reiterate the virtue of seeking more than one opinion.

UNIVERSITY OF WINDSOR

UNIVERSITY'S COMMENTS ON THE ACAP CONSULTANTS' REPORT ON GRADUATE STUDY IN PHYSICS & ASTRONOMY

We have perused with interest the Consultants' Report on Graduate Studies in Physics and Astronomy. The Report as a whole represents a genuine and worthwhile effort on the part of the Consultants to assess the extent and quality of the graduate programs in physics in Ontario, and to conclude upon the competence of the various Physics Departments providing facilities for Ph.D. and M.Sc. studies.

Although we are generally in agreement with the sentiments expressed in the Report, we wish to take issue with some specific conclusions and opinions which it contains. The comments that follow are made under two headings: I Specific Comments on the Report as it touches upon our own Physics Department and Ph.D. program and, II General Comments concerning some of the basic assumptions and conclusions made by the Consultants.

I Comments on the assessment of the graduate program in physics at Windsor

a) Quality of Faculty Members

The Physics Consultants have chosen to assess the quality of the various graduate programs and physics departments by examining the quality of the individual faculty members. It is our opinion that, on this basis, the quality of a department and of the graduate program which it offers, depends not only on the actual number of "competent Ph.D. supervisors", but also on the fraction which these people constitute of the department as a whole. Within very broad limits, it is not just the presence of quality but, even more importantly, the concentration of quality in the department which determines its ultimate success. The Consultants make this very valid point on p. A-29 where they comment on McMaster University in which, they say, the fraction of outstanding faculty members in physics is higher than at any other university in Ontario.

We wish to point out that in the Physics Department at Windsor the percentage of "competent Ph.D. supervisors" (as defined in the Report) is third highest in the Province. It amounts to 47% as compared with 73% at McMaster, 70% at Toronto and 36% at Carleton, the next highest ranking Physics Department in this respect. (Some well-established and much larger physics departments have 20%-22% of "competent Ph.D. supervisors" on their faculties). * This fact should be considered when attempting to formulate any overall plan for the development of graduate studies in physics at Ontario Universities.

* According to statistical data provided by ACAP, the average operating grant (from NRC, DRB, and/or MRC) at Windsor was also third highest in the Province after McMaster and Toronto.

b) Quality of Graduate Students

The Consultants state in their Report (p.p. A-26 and A-33) that, on the basis of their criteria and of statistics in Table 3 (p. A-25), the quality of our Graduate Students has decreased markedly over the four year period 1969-1973. They also imply that the non-Canadian component of the student body somehow contributes to this unsatisfactory state of affairs. We believe that these statements are ill-founded and grossly misleading, and we wish to make the following points in rebuttal.

(i) The statistics in Table 3 are unreliable because of the very small numbers of graduate students that are involved. Each graduate student holding an N.R.C. award would change our percentage rating by about 5% and, consequently, the possible fluctuations are much too large to permit any conclusions as to the presence of a trend. Actually, in 1973-74 10% of our students were N.R.C. scholars and on the basis of the most recent N.R.C. competition, it appears that in 1974-75 20% of our graduate students will be holders of N.R.C. awards. We suggest that these facts supersede and render irrelevant comment No. 5 on p. A-26 of the Report.

(ii) The Consultants have remarked that a significant number of our graduate students has come to us from abroad. They have also implied that these foreign students are, by and large, not of high quality and that their presence tends to have an adverse effect on the level of excellence of our graduate program. We repudiate this implication in the strongest possible terms. Members of our Physics Department have many contacts with colleagues in European and American universities resulting from their research activities on the international scene. As the result of these contacts, we are receiving applications from various highly qualified and highly recommended students who have graduated with distinction in universities in Poland, Romania, Italy, Germany, the United Kingdom, Greece and the United States. Most of these students whom we have accepted into our graduate program (almost exclusively at the recommendation of scientists known to us), have shown themselves to be of scholarship quality and have received graduate fellowships from the University of Windsor in competition with students of all disciplines from Canada and abroad. These facts should be given proper consideration when formulating an opinion about the quality of our graduate students in physics.

Many

II General Comments on the Consultants' Report

a) Future enrolments in Graduate Studies (p.p. A-12 - A-22 of Report)

(i) The Report compares the density of graduate students in Physics in Ontario (79 per million population) with the density in

the United States (71 per million population). These are partial statistics and we question their applicability. It would, perhaps, be more appropriate to compare the density of graduate students in Ontario with that in New York State or the density in all of Canada with the density in the U.S., but the information as given in the Report is misleading.

(ii) In estimating the future demand for physicists, the Consultants did not consider the increased need for scientific manpower, arising from the 'energy crisis'. Recent reports indicate that in the energy area we shall soon be faced with grave problems. Even the most optimistic estimates indicate that we must urgently develop new sources of energy. This will undoubtedly mean a much increased demand for all scientists and, particularly, physicists.

The Consultants also appear to be treating Ontario as a closed system and imply that the Ontario Universities should expect to produce just enough physicists for Ontario's needs. We do know from experience that Ontario is not a closed system and that our market for scientists and engineers is particularly sensitive to even minor fluctuations in the United States. If the employment opportunities for physicists in the U.S. were to increase, this would immediately cause a serious drain on the supply of physicists in Ontario, such as has been experienced in the 1950s and 1960s.

There are good indications that the demand for physicists in the U.S. is increasing. We know, from reliable sources, that the U.S. Atomic Energy Commission alone will be looking for well over 1,000 scientists and engineers because of a large expansion in research and development related to problems of energy. This information has been recently confirmed by the huge increases in the A.E.C. budget estimates for F.Y. 1975 which, in some categories, have been more than doubled since 1974. With an increased demand for physicists in the U.S., many American physicists who are now in Canada will migrate back to the United States and many Canadian physicists will also emigrate according to the well-established pattern. If this were to occur, then we would again find ourselves faced with a shortage of qualified people to staff our universities and trying to reverse the various restrictive rules which have recently been implemented by the Government to discourage foreign graduate students and faculty members.

We contend, on the basis of the above considerations, that the whole section of the Consultants' Report in which it has attempted to estimate the future demand for physicists, is based on very shaky assumptions and should not be taken seriously unless we are willing to introduce legislation which would restrict the freedom of movement of physicists after their graduation, a move which would be politically unthinkable. If we were now to decrease deliberately the capacity of the Ontario Graduate Schools in Physics, we might well find in the future that, when we shall again need increased numbers of physicists,

we shall not be in a position to produce them.

(iii) We do not believe that a Ph.D. graduate in physics must necessarily engage in physics research in order to consider himself fully employed. There are many other worthwhile careers for Ph.D. graduates, in which they might not directly use their specialized knowledge but in which their advanced education and research experience are of definite advantage. This is certainly the case in many interdisciplinary and technical fields, into which physics (Ph.D.) graduates are now migrating and in which they seem to be establishing satisfactory careers. In many areas of the educational system, people in positions of responsibility are now expected to have a Ph.D. where in the past this was not deemed necessary. We believe that the recruitment of Ph.D. graduates to some of the key position in secondary education and in community colleges, will pay handsome dividends in the form of more enlightened educational policies, programs and curricula and, hopefully, better educated high school and community college graduates.

(iv) While we are fully aware that the value of a postdoctorate fellowship may be viewed differently by graduate students, postdoctorate fellows and faculty members, we believe, nevertheless, that postdoctorate experience is valuable and even essential for people who intend to pursue independent research work in universities, Government establishments or industry. It has been the widespread experience of Ontario Physics Departments that postdoctorate fellows of high quality are very scarce and also, that Ph.D. graduates, after spending about two years on a postdoctorate fellowship, ultimately do find a suitable position in university, government or industry. None of our Ph.D. graduates and Postdoctorate Fellows has failed thus far to find suitable full employment, usually after completing about two years in a Postdoctorate appointment. We maintain, therefore, that the Postdoctorate Fellowship constitutes legitimate employment for Ph.D. graduates in physics.

b) Quality of Graduate Students in Ontario Physics Departments

The Report appears to imply that the only students of good quality are those holding N.R.C. scholarships and that, almost by definition, all foreign graduate students are of unsatisfactory quality. The Report then proceeds to assess the quality of the graduate students in various Physics Departments on the basis of the percentage holding N.R.C. Graduate awards. There is no justification for this approach which produces spurious results and leads to erroneous impressions. It is not likely that the foreign students will disappear from the Ontario Graduate Schools because of changes in immigration regulations. Most universities recognize the benefits of having graduate students from many countries working together and are willing to provide graduate scholarships for highly qualified students from abroad. The following might be a more valid assessment of the quality of graduate students in any department.

(i) Determine the proportion of students holding N.R.C. awards as a percentage of those eligible rather than as the percentage of the total enrolment.

(ii) Assess the quality of the foreign students on some other basis such as results of the Graduate Record Examination.

c) The Role of Applied Physics

We support the recommendation on p. A-52 of the Report, that the universities should not engage in proprietary research activities or undertake any research the results of which may not be published in the open literature.

d) Tenure and Promotion

We support the statement on p. A-53 of the Report, that a proper policy with respect to appointments, promotion and tenure is the key to achievement of high quality in academic departments.

YORK UNIVERSITY
4700 KEELE STREET,
DOWNSVIEW, ONTARIO, CANADA

FACULTY OF GRADUATE STUDIES
OFFICE OF THE DEAN

17 May, 1974.

Dr. M.A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
c/o 130 St. George Street,
Suite 8039,
TORONTO, Ontario,
M5S 2T4.

Dear Dr. Preston,

This represents the York University response to the consultants' report on Physics and Astronomy. Our principal foci of concern will be summarized here, whilst the main body of our response which follows will cover the consultants' report in more detail.

A. QUALITY OF THE YORK PHYSICS PROGRAMME

(i) Faculty: We are pleased that the consultants have recognized that the Department could become one of the stronger Departments in Ontario in a few years. We would like to bring to the attention of ACAP that the improvement in the quality of the Department, recognized by the consultants, has been demonstrated clearly since the statistics on which the report was based were compiled (see paragraph III, 2 below).

(ii) Ph.D. Graduate Students: The consultants have recognized the proven capacity of the Department to provide quality graduate education. We would like to emphasize that all our graduates have found positions at appropriate levels in both pure and applied areas of physics, in Government, universities and industry, in Canada and elsewhere.

B. APPLIED PHYSICS

In our view the consultants' use of the term "applied" throughout the report is open to question. The core of physics was defined by the discipline group and accepted by the consultants. The profile of work in physics at York spans a substantial part of this core and has led to the coherent structure referred to by the consultants.

Our graduate students benefit from a broad education in the core areas of physics. Their exposure to some applied research of quality, which

forms part of the activity of the Department, has stimulated some of them to take advantage of worthwhile career opportunities.

C. PROJECTIONS

We note the consultants' opinions as to the availability of students in the future. It so happens that our opinion differs from theirs in this respect; but in any case our projections did not derive from consideration of some hypothetical system's number of possible candidates, but were based on the capacity of the Department to provide quality education.

D. ASTRONOMY AND ASTROPHYSICS

With regard to astronomy, we note with pleasure the consultants' comments on the high quality of our Astrophysical activities. Our graduates in this area have been very well received in other institutions. The recommended co-operation with the University of Toronto graduate programme already exists.

DETAILED RESPONSE BY YORK UNIVERSITY TO THE CONSULTANTS' REPORT ON PHYSICS AND ASTRONOMY SUBMITTED TO ACAP

I. We endorse the general philosophy of the consultants that the universities, provided they strive for excellence, should be free to exercise a high measure of independence and freedom within the present framework of regulations.

II. We appreciate the sympathetic view of the consultants to the immense amount of hard work that has gone into building the Astronomy and Physics Departments of Ontario. In any university created since the early 1960's, a substantial investment of academic effort has gone into building the Physics Department and not all that work has been concerned primarily with research. The shaping of undergraduate programmes and courses, the building of teaching facilities, the creation of regulations and procedures, and the exercise of democratic government, which is very much the feature of a modern university, all take considerable effort. It is indeed remarkable that so many departments, starting with elementary facilities, have built up substantial faculties and research facilities during this growth period and have in many instances gained an international reputation for the research work they have done in Physics.

It is not surprising that, in this period of sudden expansion, some weaknesses and difficulties have developed. We accept the intent of the

consultants to point to these problems and to leave us to rectify them as soon as possible without the need to apply bureaucratic regulations which could well destroy what has been so carefully created.

III. It now seems appropriate to deal with the summary of recommendations item by item and in the light of our knowledge of the operation of graduate teaching in Physics and Astronomy at this university.

Physics

1. We are in agreement with this. Sufficient regulation of the number of graduate students in a programme will be obtained through the existing fiscal regulations and operation of government policy on immigration to ensure that only those Departments that can maintain excellence in their graduate teaching and research will attract those students available.

2. We are not in disagreement with the principle that the distribution of students should correlate with the competence of the Departments. Table 5 is seen to attempt to do this in a predictive way. However we would emphasize most emphatically that this table as it stands should not be vested with infallibility. For example, using the criteria that the consultants employed to produce the weighted numbers of competent Ph.D. supervisors and hence the student distribution suggested, we have assessed this Department on the basis of the 1974 NRC grants and find that thirteen faculty members qualify on these criteria. Furthermore, if it is assumed that a weighting of two can be given to a faculty member whose NRC grant is greater than $40,000 then the weighted number for the Department becomes 15. This figure represents a startling departure from the 8 recorded in Table 5 for York University and a major perturbation to the suggested distribution. However this is understandable in the light of the comments made by the consultants concerning York University, that the quality of the Department has been improving. The improvement has been seen to have materialized on a much shorter time scale than the consultants might have anticipated when they conducted their survey.

We emphasize that the correlation between Departmental quality and student distribution should be arrived at through the free choices of graduate students aiming for excellence and timeliness in their research and not through some forcing procedure. It is apparent to us that statements of relative quality, such as are inherent in Table 5, will become public knowledge and will thereby influence choices. An unambiguous method of measurement of quality is difficult to achieve but not impossible. The consultants have used the yardstick of the scales of NRC operating grants and this can well be argued against, although in the final analysis it is the total

NRC funding to a Department which provides the bulk of research student stipends. We recommend therefore that the discipline group be charged immediately with devising a procedure and scale of values whereby the quality of a Department can be assessed on a quantitative basis and that the results of applying this scale of values, developed and modified in the light of experience, be published at regular intervals.

3. As far as the distribution of Ph.D. students is concerned, this has been dealt with under 2. The projection of enrolments should indeed be conducted on a continuing basis in the same way as is being done for undergraduate enrolments in most universities. The pressures of the times, the prevalent economic situation, the scientific stimulus gained by new applications of physics to the technological problems of our age, and the effect of immigration laws as they change to meet the needs of Canada and the U.S.A. are parameters which have considerable bearing and continuing influence on the demands placed on graduate departments.

4. We are in agreement with this. This has in effect developed in an informal way with the growth of Ontario universities, and this university in particular, as can be seen from the consultants' statement, has developed its own areas of research which have been very complementary to others in Ontario universities and in Government laboratories.

5. We are in agreement with this.

6. We are not in disagreement with the principle that students should normally be discouraged from staying in the same university for the whole period from entry as freshmen through graduation as Ph.D.'s. It is clear that the fiscal restrictions proposed by the consultants could make such a regulation workable. However we do not support a regulation that would deprive the student of his freedom to choose his own educational pathway. This choice might well be influenced by family considerations and personal financial restrictions in addition to academic aspirations.

7. This statement concerning applied research emphasizes the inadequacy of the consultants' definition in this area. It is apparent in reading the report as a whole that they equate applied physics with "routine measurement and data assembly for funded project purposes". We are sure that no responsible department would permit this form of application to form part of the graduate training of its students and it is most probable that universities' policies and the exercise of the external examining system already take care of this.

Dr. M.A. Preston 17 May, 1974.

8. It is unlikely that this recommendation can have any impact whatsoever. Over a number of years the senates and administrations of universities in Ontario have developed procedures for dealing with tenure and promotion. These are broadly similar throughout the province and identify candidates for tenure and promotion on the basis of a number of criteria, only one of which is research. The broad service that the universities owe to the community both at the undergraduate and graduate level has been taken into account in formulating these policies and they are continually under revision.

9. It is not at all clear why the consultants emphasize the need for graduate programmes in optics and acoustics. Work of this nature is done in a number of university departments as part of the continuing development in the techniques of the physicist. A number of engineering departments and departments of applied chemistry are also concerned with aspects of these fields.

10. We are in agreement that a general surveillance of the intake of graduate students to Ontario Physics Departments should be conducted to ensure that the quality of students is kept at a normally high level which at the present time is identified with a B-plus or better undergraduate honours degree.

11, 12, 13. We consider that statements concerning these three recommendations should come more appropriately from the universities concerned.

Astronomy

1. We are in agreement with this.

2. We consider that the projected enrolment of graduate students in astronomy and the suggested distribution should be argued by the University of Toronto and the University of Western Ontario. We would emphasize that this should not influence the distribution of students who are undertaking a thesis on an astronomical or astrophysical topic in an existing department of physics.

3. Our statements concerning Physics recommendations 3, 4, 5, 6, 8 and 10 also apply to this recommendation.

Yours sincerely,

Graham Reed

Graham Reed
Acting Dean of Graduate Studies

APPENDIX D

PROCEDURE OF PLANNING STUDY AND TERMS OF REFERENCE

Procedure for Physics and Astronomy Planning Assessment

February 15, 1973

The discipline groups involved are those in Physics and Astronomy.

A. Tasks Requested from Discipline Groups (with help available from ACAP at all stages)

A.1 The "major divisions" of study for purposes of collecting data will be recommended by the discipline groups: The method of dealing with borderline fields will be recommended by the discipline groups. See Appendix I.

A.2 Suggest suitable consultants. This also will be a matter for discussion with ACAP.

A.3 Develop and recommend procedures for the planning assessment, including comment on pro formae to be used for the gathering of information on current, past and future programmes as described in paragraph B.1.

A.4 Examine and comment on the adequacy of the data reported by the universities.

A.5 Both in consultation with ACAP and separately, consider the situation revealed by the statements concerning proposed future programmes and consider whether future plans should be modified or developed in more detail. As a result of this step, individual universities may wish to revise the material described in B.1.d. below.

A.6 Possibly develop a tentative plan for development of established or new graduate work in physics and astronomy in Ontario. Any such plans will be reported to ACAP which will transmit them to the consultants.

A.7 To hold discussions with the consultants, before they begin site visits and concerning their written draft report, and at other times as agreed. Shortly before the meeting to discuss the draft report, the draft will be made available to each member of the discipline groups on a privileged and restricted basis.

B. Information from Universities

The fields of study covered by this planning study are specified in Appendix I. A university is to report on its work in these fields in whatever departments it may be found: astronomy, physics, mathematics. Usually statistics are not expected for graduate work in chemistry departments or engineering departments.

B.1 Each university is asked to supply ACAP, in the form indicated by ACAP after comment by the discipline groups (paragraph A.3) information as follows:

a) for each major division

(i) as of December 1, 1972, current list of faculty members showing fraction of research and graduate instruction time devoted to the division; (Form 1)

(ii) as of December 1, 1972, a current list of part-time faculty members showing the amount of time devoted to university duties in this department; (Form 1)

(iii) numbers of full-time and part-time faculty members for each of the past five years; (Form 3)

(iv) for the current year and preceding five years, number of (1) master's and (2) Ph.D. candidates and (3) post-doctoral fellows and research associates, instructors, etc. doing research separately. (Students taking non-research degrees should be listed as a separate group, not under each major division). (Form 3)

Under the above four headings one individual may appear under more than one category.

b) (i) Curricula Vitarum of all faculty members in physics and astronomy (Assistant Professors and higher) showing whether or not they are now engaged in graduate work and showing inter alia complete publication lists, research funding in the past five years, and numbers of students and post-doctoral fellows supervised during their careers; (Form 2)

(ii) resources of space - a statement indicating the department's view of the adequacy of its space, and, in connection with the future plans in (d) below, discussing future space provision; (Written Statement)

(iii) undergraduate base; honours students or equivalent, number of qualifying or make-up year students, course enrolment, etc.; (Form 4)

(iv) other general items relevant to research and graduate study, e.g. computing facilities, major laboratory facilities and equipment, etc.: (Forms 5 and 6)

(v) library resources: analysis of holdings and budget; (Separate Questionnaire)

(vi) support from related departments including shared teaching and research, state cross-appointments; (Written Statement)

(vii) description of any inter-university arrangements for graduate work; arrangements with other research organizations: (Written Statement)

(viii) numbers of full-time and part-time faculty members for each of the past five years; (Form 3)

(ix) academic regulations for M.Sc. and Ph.D. degrees in the department, and a list of courses. (Written Statement)

c) table of characteristics of graduate students in the department in previous four years, separately for master's and Ph.D., breaking down numbers by:

(i) F.T. and P.T.; (Form 7)

(ii) immigration status, and countries of previous degrees; (Form 7)

(iii) sources of financial support; (Form 10)

(iv) time to reach degree; (Under Review)

(v) drop-out number; (Form 8)

(vi) degrees granted; (Form 9)

(vii) post-graduate employment of Ph.D.'s (a) immediate and (b) after two years. (Form 11)

d) proposed plans for the future, in as much detail as the departments can provide, including the proposed scheme for support of these plans, and accompanied by supporting arguments, including consideration of the sources of graduate students and an analysis of demand for graduates from the programmes. The various headings in a) and b) above should be dealt with quantitatively where possible; as a minimum, planned numbers of faculty and graduate students should be given for the next five years.

B.2 The material supplied under B.1 will be collated by ACAP and transmitted to the discipline groups for action indicated in paragraphs A.4, A.5, and A.6.

B.3 Apart from the material described in B.1.d and to some extent generated at the department level, each interested university will be requested to make an individual statement on its plans for the development of physics and astronomy, in particular the items of future commitment implied by item B.1.d.

Deadline dates for parts A and B will be established by ACAP.

C. Terms of Reference of Consultants

C.1 Consider the materials prepared by the discipline groups and the universities and obtain other data they may require to carry out the

tasks detailed below. They may obtain data and views from any relevant source; such as, employers of holders of graduate degrees, professional and learned societies, federal agencies. The campus of each interested university shall be visited by at least two consultants. After discussion with the discipline groups, consultants shall arrange their schedule of visits to the universities in consultation with ACAP to ensure uniformity. Reports of appraisal consultants are privileged documents and are not to be made available to ACAP consultants. Consultants shall consult with the discipline groups near the beginning of the work, during the work as they consider necessary, and immediately before preparing their final report.

In order to obtain a fuller impression of graduate work intimately related to physics and astronomy, the consultants may request information from universities concerning work in related departments, such as: chemistry, mathematics, electrical engineering, metallurgy, etc.

C.2 Report on the adequacy of the present state of graduate work in physics and astronomy in the province in general and in each university where applicable, discussing the following:

a. coverage of core elements and specialities, and extent of activity in each;

b. faculty quality and quantity;

c. nature of programmes offered;

d. enrolment size and distribution amongst universities;

e. quality of student body; admission requirements;

f. relationship to related disciplines;

g. physical facilities;

h. other matters considered by the consultants to be significant.

C.3 Make recommendations for the development of graduate work in physics and astronomy in Ontario between 1973 and 1983, but in more detail for 1973 through 1978, and, without limiting the generality of the foregoing, dealing with the following points:

a. Desirable programmes to be offered in the province, considering both possible limitations or reductions of existing programmes and creation of new programmes and new kinds of programmes including the appropriateness of part-time programmes. In particular, consider possible new fields in physics and astronomy and training of students for work in application-oriented and inter-disciplinary work in which physics and astronomy should be involved.

b. Desirable provincial enrolments, year by year, in the various levels of graduate study, and specialties where appropriate. One should consider the need for highly trained manpower and also the general cultural and societal factors which may lead students to pursue graduate work. In considering manpower needs, one should take account of the "market" available to graduates (at least all of Canada) and of other sources of supply for that market. Results of forecasts of high level manpower employment should be treated with due caution and only in a clearly balanced relationship with cultural and societal needs.

c. Distribution amongst the universities of responsibility for programmes and for specialties where appropriate, including consideration of the need for any increase or decrease in the number of departments offering doctoral work and including consideration of areas of collaboration and sharing of facilities at regional level and across the province.

d. Distribution of enrolment amongst the universities, showing desirable ranges of enrolment.

e. Desirable extent of involvement with related disciplines, identifying any suggested areas for greater collaboration.

In all cases, it is important that the rationale for the recommendations be clear; this is especially important for items c. and d. Consultants are asked to comment on advantages and disadvantages of various techniques for arranging that their recommendations become effective.

C.4 It is permissable for consultants to recommend appraisals of individual programmes. This would arise if consultants were to suspect that a programme would be found to be wholly or in part below minimum acceptable standards; an appraisal by the Appraisals Committee is the means of settling the question. It is recognized that this action would be infrequent. Perhaps more likely, in planning assessments in some disciplines, consultants may find an excess of programmes in the same area of study, all of which could pass an appraisal; they would then have to make their own judgments of relative quality (a task outside the terms of reference of the Appraisals Committee), and guided by this judgment and other factors, the ACAP consultants would have to recommend where enrolment should be curtailed or eliminated.

D. Appointment of Consultants

The consultants shall include one person of wide academic experience in Canada but in a different discipline.

E. Report of Consultants

The consultants submit a joint report to ACAP. Minority reports are, of course, possible. The reasoning leading to their recommendations should be given fully, in view of the subsequent treatment of the report. The report is submitted for comment to the discipline group and to each interested

university. There may be informal or interim exchanges of views amongst the discipline groups, the universities, and ACAP. Any university which wishes to make a formal statement on the consultants' report shall submit it to ACAP. Any such report shall be transmitted to the discipline groups. The discipline groups shall submit their formal comments and/or recommendations to ACAP. ACAP considers the discipline groups and university statements along with the consultants' report and transmits them to COU with its recommendations of the position COU should adopt. Copies of the material transmitted to COU will be supplied to OCGS, and to the Council of Deans of Arts and Science. If a publication is prepared, it will contain the comments of the discipline groups, and those portions of university responses which universities request.

APPENDIX I

The major divisions for the planning study are:

Astronomy and Astrophysics
Atomic and Molecular Physics
- Atomic and Molecular Collisions
- Atomic and Molecular Spectra
- Quantum Electronics

Elementary Particles
Nuclear Physics
Atmospheric and Earth Physics
Condensed Matter
- Crystal Physics
- Electronic Properties
- Amorphous Systems

Basic Theory
Other

Solid earth geophysics is specifically excluded as it has been studied already in the solid earth sciences planning assessment.

Biophysics will be more appropriately planned in connection with life sciences planning; it should be considered only marginally by the consultants in order to obtain a picture of the total effort of some physics departments. This planning assessment is not directed towards removal of the embargo on biophysics.

Although it may be important for consultants to obtain information about some of the graduate work in engineering departments, it is not part of their duties to make recommendations about the size of engineering doctoral programmes.

With the above exceptions, full recommendations are expected on work in the major divisions specified, no matter where it is located in a university's internal administrative structure.

A P P E N D I X E

DISCIPLINE GROUP MEMBERSHIP

PHYSICS DISCIPLINE GROUP

BROCK -	G. V. Kidson
CARLETON -	E. P. Hincks, until April 11, 1972 R. L. Clarke
GUELPH -	P. A. Egelstaff
LAKEHEAD -	V. Paranjape, until August 31, 1972 J. Warren
LAURENTIAN -	L. Reed
McMASTER -	*M. W. Johns
OTTAWA -	J. C. Wooley
QUEEN'S -	A. T. Stewart
TORONTO -	H. L. Welsh, until August 23, 1973 J. M. Daniels, until July 15, 1974 R. L. Armstrong
TRENT -	J. Lodge
WATERLOO -	J. W. Leech
WESTERN ONTARIO -	G. F. Lyon, until May 31, 1973 W. P. Alford
WINDSOR -	L. Krause
YORK -	R. W. Nicholls

* Chairman

ASTRONOMY DISCIPLINE GROUP

GUELPH -	P. A. Egelstaff
LAKEHEAD -	J. Griffith
QUEEN'S -	A. T. Stewart
TORONTO -	D. A. MacRae
WATERLOO -	G. A. Bakos
WESTERN ONTARIO -	W. H. Welhau
YORK -	R. W. Nicholls

A P P E N D I X F

ROLES OF ACAP AND OF DISCIPLINE GROUPS

Ontario Council on Graduate Studies

By-Law No. 3

A By-Law to establish a Committee on the Academic Planning of Graduate Studies.

1. The Ontario Council on Graduate Studies, recognizing the importance of providing for the continued and orderly development of graduate studies in the Ontario universities, establishes a Standing Committee to be known as the Advisory Committee on Academic Planning (abbreviation - ACAP).

Interpretation

2. In this By-Law,
   (a) "Committee" without further specification, means the Advisory Committee on Academic Planning;
   (b) "Council" or OCGS means the Ontario Council on Graduate Studies;
   (c) "Committee of Presidents" or CPUO means the Committee of Presidents of Universities of Ontario;
   (d) "university" means a provincially assisted university of Ontario;
   (e) "discipline" means any branch or combination of branches of learning so designated;
   (f) "discipline group" means a body designated as such by the Committee of Presidents of the Universities of Ontario, and normally consisting, for any one discipline, of one representative from each of the interested universities;
   (g) "planning assessment" means a formal review of current and projected graduate programmes within a discipline or a group of disciplines;
   (h) "programme" signifies all aspects of a particular graduate undertaking;
   (i) "rationalization" means the arranging of graduate programmes in order to avoid undesirable duplication, eliminate waste, and enhance and sustain quality.

Membership

3. (a) The Committee shall consist of at least seven members of the professoriate in Ontario universities, some of whom shall be members of the Council.

(b) The members of the Committee shall serve for such periods of time as the Council may determine, and they shall be selected in such a manner as may provide for reasonable balance both of academic disciplines and of universities.

(c) The members of the Committee shall be appointed as individuals.

Chairman

4. The Chairman of the Committee shall be named by the Council, and he shall have one vote.

Quorum

5. A majority of all members of the Committee shall constitute a quorum.

Functions

6. The functions of the committee shall be

(a) To advise OCGS on steps to be taken to implement effective provincial planning of graduate development;

(b) To promote the rationalization of graduate studies within the universities, in cooperation with the discipline groups;

(c) To recommend, through OCGS, to CPUO the carrying out of planning assessments of disciplines or groups of disciplines and to recommend suitable arrangements and procedures for each assessment;

(d) To supervise the conduct of each planning assessment approved by CPUO;

(e) To respond to requests by CPUO to have a discipline assessment conducted by proposing suitable arrangements;

(f) To submit to CPUO the reports of the assessments together with any recommendations which the committee wishes to make. A copy of the report shall be sent to Council.

Jurisdiction

7. In order that the Committee may discharge the functions described in Section 6 above, it shall be authorized

(a) to request a university to provide such information pertaining to graduate studies as may enable the Committee to discharge its functions;

(b) to request a discipline group to provide such information as may enable the Committee to discharge its functions;

(c) to receive reports from the universities and from the discipline groups, and to comment and communicate with the universities and the discipline groups concerning such reports;

(d) to convene a meeting of any discipline group for the purpose of discussing the development to date, and proposals for the future development of graduate studies in the discipline concerned;

(e) to send one or more representatives to a meeting of a discipline group at the invitation of the discipline group;

(f) to make such suggestions to a discipline group as may be deemed appropriate to the functions of the Committee;

(g) to supervise the conduct of planning assessments, and to report thereon to the Committee of Presidents of Universities of Ontario;

(h) generally to report and to make recommendations to the Council;

(i) to seek and receive advice from appropriate experts;

(j) to employ consultants in connection with planning assessments.

Procedures

8. The procedure to be followed by the Committee shall be as approved by the Committee of Presidents of the University of Ontario.

9. The Committee's function is solely advisory.

Effective Date

10. This By-Law shall take effect January 1971.

ACAP DISCIPLINE GROUPS AND THEIR ROLES

1. Establishment of a Group

a. When it is considered desirable to activate planning of graduate work in some discipline(s) or interdisciplinary area, COU, on the advice of OCGS, will authorize the establishment of an ACAP discipline group, if it was not already approved and included in the May, 1968 list. If it is already authorized, ACAP may decide to set it up as described in paragraph b.

b. The Executive Vice-Chairman of ACAP will then invite the executive head of each university (including Waterloo Lutheran University) either to nominate a member of the discipline group or to indicate that his university has no plans for graduate study in this discipline in the next five years or so. If a university can state no plans for future graduate work in the subject, but feels that a watching brief is desirable, it may appoint an observer to the group.

c. Changes of a university's representative are to be notified by the executive head.

d. The group shall select its own chairman.

2. Meetings

a. A discipline group may meet at the call of its chairman or in accord with its own arrangements.

b. A discipline group may be called to meet by the Executive Vice-Chairman acting for ACAP.

3. Responsibilities

a. The group is to keep under review the plans for graduate work in its discipline in Ontario, including new developments and trends in the discipline, and to make reports to ACAP on a regular basis.

b. The group may make recommendations to ACAP in connection with graduate work in its discipline when it considers it appropriate.

c. ACAP will assist the group in obtaining information and data, as mutually agreed.

d. When COU has instructed ACAP to conduct a planning assessment, the discipline group will assist and advise ACAP in determining procedures and terms of reference, will report as requested and will generally facilitate the assessment.

Approved by OCGS March 22, 1973
and by COU April 6, 1973.

A P P E N D I X G

CURRICULA VITARUM OF THE CONSULTANTS

LAWRENCE HUGH ALLER

Born Tacoma, Washington, September 24, 1913.

A.B. California, 1936.
A.M. Harvard, 1938.
Ph.D. Harvard, 1943.

Tufts College, lecturer, 1940.
University of California, physicist, 1943-45.
University of Indiana, assistant professor, 1945-48.
W.J. McDonald Observatory, research associate, 1945-48.
University of Michigan, associate professor, 1948-54
professor, 1954-62.
University of California, Los Angeles, professor, 1962-

Visiting Professor, Australian National University, 1960-61.
University of Toronto 1961-62.
University of Sydney) 1968-69
University of Tasmania)

National Science Foundation, senior fellow, Australia, 1960-61 and 1968-69.
Commonwealth Scientific and Industrial Research Organization, research associate, 1968, 1969, 1971.
Fellow, National Academy of Science.
Fellow, American Academy of Arts and Science.
Member, American Astronomical Society.

Spectroscopic and theoretical studies of the gaseous nebulae and stellar atmospheres; transition probabilities for spectral lines; cosmic abundances of elements.

Address: Department of Astronomy
University of California
Los Angeles
California 90024.

ALEXANDER EDGAR DOUGLAS

Born Melfort, Saskatchewan, April 12, 1916.

B.A. Saskatchewan, 1939.
M.A. Saskatchewan, 1940.
Ph.D. Pennsylvania State, 1948.

NRC, Acoustics Laboratory, research scientist, 1942-46.
NRC, Spectroscopy Laboratory, research scientist, 1948-67.
NRC, Division of Pure Physics, Associate Director, 1967-69,
Director, 1969-73.
NRC, Spectroscopy Laboratory, research scientist, 1973-

Canadian Association of Physicists Medal
Fellow, Royal Society of Canada.
Fellow, Royal Society (London).
Fellow, American Physical Society.

Spectroscopy and molecular structure.

Address: National Research Council
Ottawa, Ontario.

RUDOLPH ROLAND HAERING

Born Basle, Switzerland, February 27, 1934.

B.A. British Columbia, 1954
M.A. British Columbia, 1955
Ph.D. McGill, 1957.

McMaster University. assistant professor, 1958-60.
I.B.M. Research Centre, N.Y., research staff member, 1960-63.
University of Waterloo, professor, 1963-64.
Simon Fraser University, professor of physics 1964-72, head of department 1964-68, acting Vice-President (academic) 1968-69.
University of British Columbia. professor and head, 1973-

Fellow, Royal Society of Canada
Centennial Medal
C.A.P. Herzberg Medal

Member of Advisory Council, British Columbia Institute of Technology, Burnaby, B.C. 1965-72.
Chairman, Theoretical Physics Division, Canadian Association of Physicists, 1965-67.
Member, National Research Council Physics Grants Selection Committee, 1967-70.
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