

Report of the External Review Committee for the MIT/WHOI Joint Program in Oceanography and Applied Ocean Science and Engineering

November 2004

Preface

This report should be viewed in the light of the committee's view that the MIT-WHOI Joint Program is among the very best ocean science education programs in the world. The Environmental Sciences are applied sciences, albeit of a high order. There are two common routes into their study at graduate level, either from a few quality undergraduate programs (e.g. in geophysics) or from a solid basic training in a relevant scientific discipline (e.g., biology into Biological Oceanography). In general, university physics, chemistry, geology and biology departments do not contain staff in physical, chemical, geological and biological oceanography. The departments that do contain these specialities necessarily have a strongly graduate character, often associated with a relatively low number of undergraduate majors. Several MIT departments associated with the Joint Program are of this type. The implementation of policies that fail to recognise graduate-level specialisation, but instead assume a simple progression from undergraduate to graduate student within a department, risk doing severe damage to departments specialising in sciences of the environment. The MIT-WHOI Joint Program has been represented by senior administration members of both institutions as "a jewel in the Crown". It is a superb program that offers important advantages to both partners, a link to field-based environmental research for MIT and a link to fundamental science and engineering instructional courses and research for WHOI. The Joint Program is vitally involved with environmental sciences and engineering for which staffing policies based on undergraduate considerations are likely to lead to difficulties in meshing together the two partners of the Joint Program.

Introduction

The Joint Program in Oceanography and Applied Ocean Science and Engineering of the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution¹ was last subjected to external review in 1998. There have been many developments at both institutions since that time. Earlier this year the Provost of MIT, Prof Robert Brown, and Director of WHOI,

¹ Hereafter abbreviated as MIT, WHOI, JP, AOSE, etc.

Dr Robert Gagosian, appointed a committee² drawn from leading institutions in the U.S. and U.K. together with members of the MIT Corporation and WHOI Trustees to conduct a review of the program.

New features at the two institutions include development of Programs at MIT and Institutes at WHOI which have interdisciplinary foci and cut across some existing areas of the JP. There have been many staff gains and losses which impact on the viability of some program areas. Energetic program leadership has been evident at both institutions making it timely to take stock of what has been achieved and where problems might lie.

Terms of Reference

The Committee was asked to review the Joint Program in general, and in particular to address the following topics:

- Content and quality of the educational and research program, the opportunities for both disciplinary and interdisciplinary focus within the program, and optimal size for the program within the context of Masters and Doctorate degree offerings for the fields of oceanography and ocean engineering nationally and internationally.
- Quality of teaching and advising as they contribute to the learning environment for the graduate students of the Joint Program.
- Student support and student life, including climate for women and minorities, logistics support and housing.
- Balance between faculty support and student funding.
- Organization of the program including institutional commitment, committee structure, management by each institution and their interaction.

Procedures

The Committee met at MIT on Monday June 14th, transferring to Woods Hole on the 15th and continuing its work there until the 16th. In both locations we received presentations from administrators and JP staff, and meetings were held with staff and students. Committee members visited the departments relevant to their expertise while the Committee Chair met with department heads at both MIT and WHOI. In addition to thorough documentation, the Committee received several sets of written comments on aspects of the program from students.

² See Appendix for membership

Due to sea-going and other travel commitments of the Chair, this report was assembled some three to four months after the site visit. It has been reviewed and affirmed by all the Committee.

Content and Quality of Educational and Research Programs

The MIT/WHOI Joint Program remains a (if not *the*) top educational program covering all the marine sciences and engineering. The leading institutions of marine science around the world have significant representation of graduates of the JP on their staff. The vigour of the program is shown by the quality of students' research and the very warm feelings they express for the Institutions and people that foster their development. While this reflects very favourably on a great many individuals, it is clearly also due to the energy and leadership of Professor Rizzoli and Dean Farrington. The richness of the resources available to students in terms of access to ships, laboratories and the leading intellects in ocean science is unachievable by either institution separately.

Teaching and Advising

Teaching is always a moving target. At no university is it ever uniformly excellent. It has to keep pace with developments in the field and technical developments in presentation. The majority of the JP courses do just this. However, it was commented that there are one or two courses that are notorious for usually being bad. A few other courses have stagnant lecture notes that do not fulfil the ideal of keeping abreast of developments. While there have been improvements in the P-Tel system, lecturers skill at employing it is uneven and more training in its use should be given. Indeed, WHOI staff, who do rather less lecturing than their counterparts at MIT, in cases where student feedback indicates the need, could benefit from a training course on lecturing. Confidential consultation with students will easily reveal where the problems lie.

Disciplinary and Interdisciplinary Foci: Interdisciplinary Research

The principal problem we identify is the General Exam diversity discussed below. Otherwise we do not find any *general* problem with the structure of education and research within specific disciplines. The preparation in course work is broadly satisfactory (but note the difficulties in Biology outlined later) and fits the students well for a research career, but less so for a career in education.

In the area of interdisciplinary research, problems in the structure of requirements are evident. A document from the JP students encapsulates

many of the difficulties encountered in trying to forge an interdisciplinary path in the program:

“Students have succeeded in doing interdisciplinary research in this program, however it has not been easy ...Many ‘rules’ were broken along the way. ... interdisciplinary thesis research ...in some cases is not feasible. Biology, Physical Oceanography and Chemistry students would especially like to see significant changes in their class requirements for Generals, and the exploration of general exams tailored more to the research interests of the students taking the exam. *The major roadblocks identified were the general exam and its many associated class requirements.* ... students share the concern ... that *prospective students and current students do not perceive the Joint Program to be amenable to following an interdisciplinary course of study.* (Review Committee’s italics)

This points to problems both internal – lack of flexibility in course requirements – and most importantly, external negative perception of prospective JP students as to what they can actually do.

The presence now of four cross-disciplinary Research Institutes at WHOI has provided what might be seen as potential alternative structures within which to base educational requirements and research projects. The Ocean and Climate Change and Coastal Ocean Institutes offer clear potential. All such multidisciplinary combinations, capable of yielding highly employable graduates, require some lowering of barriers between Joint Committees, and harmonisation of course and examination requirements. We would expect the Joint Committees to remain the arbiters of the necessary core of their subjects, but to approach their task with a more positive eye to inter-committee collaboration.

The General Exam, Interdisciplinarity and Time to Completion

Having five different models for the General Exam requirement makes interdisciplinary pathways through the JP more difficult. The committees of the JP map onto the WHOI departmental structure. Three of the JP committees have their main MIT counterpart in one department (G & G, CO and PO in EAPS³), but this does not mean uniformity of the general exam requirement. For the other committees, Biology and more than one engineering department are involved. The main purposes of the General Exam are to ensure that the candidate has a satisfactory knowledge of the field(s) in which thesis work will lie, that a viable thesis topic has been identified, and that there is a good chance that the thesis work will be successfully completed. The diversity of requirements and differences of structure leading to the general exams poses a significant problem for cross-disciplinary innovation in education leading to

³ Geology and Geophysics, Chemical Oceanography, Physical Oceanography, Earth, Atmospheric and Planetary Sciences

research. We advocate simplification of requirements, allowance for greater flexibility, reduction of mandatory courses, and tailoring of the exam to the student rather than the student to the exam. Planning a route through the course program structure needs stability of course offerings on at least a two year cycle. This should be combined with harmonisation of the General Exam requirements, and some facility for students to tailor their course programs.

Attainment of a tenure-track position in a leading research organisation normally does not follow directly on the completion of the Ph.D.: one or more periods of post-doctoral fellowship work is the norm. Because the Ph.D. does not represent 'the end', piling on requirements in the Ph.D. tends to delay more than enhance the student's profile in relation to further career progress. To become employable at the highest level, students need to establish research lines for which they have intellectual ownership, independent of supervisors. Excessive time spent in the Ph.D. does not contribute to that goal.

The fact that in some areas mean time to completion of the Ph.D. is as high as 6.1 years indicates that several students are running into a 7th year. This is a year beyond the stage where "a special case" must be made for 6th year funding. This is not cost-effective use of student support funds. Simple arithmetic shows that 20% more students could be supported at no extra cost if the mean time to completion were reduced to 5.1 years. It is probably not just a coincidence that the longest mean time to completion occurs in the department/area (G & G) with the most extensive requirement for the General Exam (two papers/reviews, plus exams and thesis proposal).

We therefore **recommend** that (i) a representative committee be invested with the authority to develop more uniform requirements for the General Examination across all JP elements, and (ii) more stringent measures be put in place to encourage completion of the Ph.D. within 5 years and to discourage extension of thesis work into a 7th year. The exam should be uniform across disciplines in the JP, and as similar as possible to the general exam in relevant MIT programs (for example PAOC).

Program Size

The pool of those qualified to undertake work at this level is not large, but the program manages to admit a reasonable proportion of those accepted, constituting a very well qualified group of students. With more efficient encouragement of time to completion, the program could grow by up to 20%, and this would be beneficial in that class size is not particularly large; there is spare capacity. However, it is not entirely clear whether the limiting factor would be finances or availability of qualified students. If the former, fund raising is needed; if the latter the pool needs to be enlarged by concerted

vigorous outreach to basic science undergraduates around the country (and world) by the major oceanographic institutions acting together.

Balance between Faculty Support and Student Funding

A major issue is the diminishing salary support provided to WHOI faculty for teaching classes and advising graduate students. While budgetary constraints are understandable, and indeed fiscal belt-tightening at academic institutions is currently widespread, the lower compensation algorithms for teaching and advising are regrettable, because they reduce the incentive for staff members to be seriously engaged in the Joint Program. The researchers who teach in the program felt that they were inadequately reimbursed for their teaching, which could ultimately lead to less commitment by them and ultimately to a loss in the health of the teaching program. Furthermore, pay for advising students, though remunerated to a degree, does not reflect the time some advisors spend with their students. Additional funding for teaching or advising is a necessity, especially when financial times become more favourable for the JP parent institutions.

The committee recommends that WHOI work to raise the compensation rates to equitable levels, to ensure that faculty participation in JP activities continues at a vigorous level by sufficient interested and qualified staff. The Capital Campaign could have as one of its foci Educational Endowment funds – more named chairs, for example – to aid this area.

Student Support

Financial Support

Two issues are connected with funding of students. If the program is to grow a little, more funds will probably be required. At WHOI the Capital Campaign should also have as a focus for potential donors the support of students through a targeted component for increased endowment: e.g., a Hollister Fund for Students.

The second issue was mentioned in the last review, namely that there is a disproportionate take-up of student support funds in the area of biological oceanography. The program leaders should re-examine the justification for this, taking into consideration such matters as employability of graduates from different areas of the JP, faculty views on deployment of the funds, and historical quality of students judged not only at time of admission (a common argument for a biology bias), but also on graduating from the program.

Minorities and Women

The JP program student population has now evolved to the state where there is no great gender imbalance across the program as a whole, although there tend to be more women in biology and men in engineering. This reflects the position upstream in undergraduate departments that supply the Program's students.

However, a significant imbalance occurs in the staff of the institutions. This imbalance (paucity of women) is well known and is the subject of continuing efforts at both partners through affirmative action. It is important in provision of role models for women students and we encourage continued action in this area, particularly in the physical sciences. First was the awareness of the students that there were relatively few women on the research staff at WHOI. (Such a concern was not expressed to the review committee by MIT students, though it may well exist at that institution, as well.) The students, some JP staff, and the review committee noted that more than half the students in the JP program were women, and the JP program overall is increasingly subscribed by women students. The disparity between the visibility of women faculty and scientific staff in the JP and the increasing dominance of women in the graduate student ranks is a troubling nationwide problem. The disparity could lead to concerns by women in the JP program regarding their likelihood for success in the field. (The review committee recognized that this issue is not unique to the JP, but as a leader in the US community, it could do great service by addressing this imbalance.) Nevertheless, the strong leadership role of Prof. Paola Rizzoli is clearly a step in the right direction in encouraging women students to pursue a career in research.

The second, very serious concern is one expressed during interviews with several students and in a general meeting attended by the review committee and all JP students: unwanted sexual advances by ships' crew towards women during research cruises. It is not evident whether the comments reflect experience that is uncommon, but it is clear that the JP must investigate, with great care and complete confidentiality, the question whether women are the subject of harassment while at sea.

Minorities are under-represented both in the program and institution staff. This is a societal problem that is not confined to the USA. Minorities, particularly of Native American and Afro-Caribbean origin, are not equally represented in higher education and within higher education they are under-represented in the sciences. This does not mean the Program should do nothing, but it is recognised that the process, which will start with outreach to schools, will take a long time to bear fruit at the high level of a specialised graduate program. Given the long-term strategy, it is important to emphasise the outreach to high-school students.

Housing

Accommodation provision for transients at MIT was particularly praised, a clear improvement since the last Review. Accommodation for visiting MIT faculty at Woods Hole continues to be an important facility for “glueing” the Program together. Issues in this area have largely disappeared, at least for students. However there is nothing we can suggest to alleviate the escalating price of housing on the Cape and in Cambridge for research staff and faculty.

Student Life

Students commented favourably on many aspects of day to day life such as: commuting made as simple as possible, student group formation supported at MIT, importance of having guaranteed 5-years of funding, improved website and program visibility for applicants, and “no hassle reimbursement”. Areas that could be improved are similar; student group support at WHOI, and perhaps some lower level, less official, channels for dealing with student stress and conflicts with thesis advisors or other research workers, which might simply involve some student “ombudsmen” or mentors.

Additional concerns were apparent regarding the areas of career advising and the availability of activities that would assist students’ professional development outside their strict research experience. For instance, it was apparent in some of the discussions between the review committee and some staff in the JP that a research post, especially in academia, was viewed by some sponsors as the only desired professional appointment for their students. As mentioned in the materials provided to the review committee, however, the number of academic posts has dropped in many cases as compared with the numbers of PhD students completing oceanographic degrees in the US, and the need for educated experts in the field of oceanography extends well beyond academia and traditional sources of research positions. The students appear to desire greater knowledge about a range of career options, both from their advisors (who were apparently often unable to supply such advice) and other sources – including seminars and discussions with former JP alumni/ae. Furthermore, there appears to be a need for additional information about public speaking, grant writing and other skills required by successful professionals in the field, as well as formal discussions of scientific ethics.

Organisational Issues

MIT Program Coordinator vs. WHOI Dean

It has been noted in more than one previous review that the MIT Program Coordinator has too little influence and an inadequate budget. This is in stark contrast to the WHOI counterpart, the Dean of Graduate Studies, who is an

Associate Director and has a significant staff and budget. It is accepted that MIT is a much larger and more complex entity than WHOI; nevertheless some solution must be found to the problem of the lack of influence of the MIT Program Coordinator which, had it been greater, might have been able to affect the three-year dip in relevant staff numbers in EAPS and the continued run-down of OE. The previous review (1998) suggested that consideration be given to either making a relevant department head responsible for the JP or significantly increasing the Coordinator's discretionary resources. The Response (1999) and Update of Response (2004) do not suggest much concrete progress in this area. In particular, although it is said that the Advisory Board comprising department Heads from MIT and WHOI has met annually, evidently it has not prevented the difficulties identified in this report. A smaller, higher level board comprising the Provost, Deans of the two relevant MIT Schools, MIT Program Coordinator and WHOI Dean and Associate Dean would be more influential in relation to staffing and budget. Strengthening of the MIT Program Coordinator's position through an increased discretionary budget is also recommended.

Visiting Committee

For a number of reasons a Visiting Committee would be a valuable component of this program. First, Visiting Committees have high visibility within MIT. After their two day examination, they report in real time directly to the highest administrative officers of the Corporation, then an oral report is given to the Corporation members (trustees) at a meeting later on. It is very difficult to ignore problems revealed by this process. Secondly, Visiting Committees meet every two years. This schedule allows monitoring of progress on issues flagged two years previously. It is a focusing mechanism for Department Heads to look seriously at what has been accomplished over a fairly short but still meaningful time period. It also allows the Visiting Committee to bring pressure to bear on the Administration, if that is appropriate, with respect to any promises or commitments that were made two years ago. Finally, Visiting Committees are typically rich in experienced members who can and many times do help both the department and the administration to solve some of the issues that have been uncovered. The Visiting Committee should have members chosen from both the MIT and WHOI communities much like our present Review Committee. Such a committee should be invested with similar authority to Departmental visiting committees at MIT and report to the highest levels in both institutions.

Ocean Engineering

The Committee was baffled by the requirement that, at a major research university where the ratio of graduate to undergraduate students is 6:4, all subjects should have their viability and status determined by numbers of undergraduate majors, even for predominantly post-graduate specialisations such as Ocean Engineering. The progressive reduction of the Ocean

Engineering department from a staff level of 22 to its present 14 without notification of the Directorate and key partner department at WHOI has struck a serious blow at the viability of the JP-AOSE. A reduction of this magnitude represents a policy decision at MIT, is not accidental, and raises questions concerning the MIT view of the “jointness” of the program. Even though this program is so vital to the Joint Program, there were no formal conversations with either the MIT leadership or WHOI on the impact of such a fundamental organizational move. Would the program be kept intact? Would it be altered in some fundamental, and perhaps detrimental, way? Unfortunately, WHOI is generally not considered a relevant stakeholder when decisions affecting the JP and thus WHOI are made within MIT.

It is therefore imperative that MIT move to stabilise the situation with regard to OE. The preferred option would be to reinstate the department with increased staff strength. If, under present policy, this is felt to be impossible, any merger between OE and another department (such as M.E.) needs to guarantee protection of at least the present number of positions and identity associated with OE. A suitable level of autonomy also needs to be guaranteed for the group. In particular the term “Ocean” needs to be indexed in all material, print or electronic, and point directly to OE, whether as a department or as a section in a larger body (and other MIT locations).

The national strategic importance of the OE Department in the area of underwater acoustics and structure design in relation to the U.S. Navy is widely recognised. Graduates of the JP-AOSE and OE programs play important roles in industry, government and academic research. We suspect that the U.S. Navy will also wish to be assured of the continuation and re-invigoration of this key MIT base of the Joint Program.

There are wider policy issues involved in the actions of one partner unilaterally removing support from a key component of a collaborative venture that the Committee did not feel came under its terms of reference. Nevertheless they should be addressed at a higher level.

MIT's 'Home' for Biological Oceanography

The present “cost” for biological oceanography students to participate in the JP is to take 2 courses in the biology department that are usually not part of the requirements for graduate students in other biological oceanography programs around the country. Possibly the cost of participation in the JP for BO students would be more reasonable if other MIT units could become the sponsoring unit, or alternate focus, for JP students. This relationship would work particularly well if the MIT sponsoring unit had course requirements that were either fewer or more central to the training of a biological oceanographer. Additionally some of MIT’s departmental requirements could replace some of the required topical courses for BO students. This review committee is not

knowledgeable about the difficulty of developing ties with BE or CEE, but recommends that the JP explore these or other options for JP sponsorship of BO students at MIT.

Individual Program Components

Applied Ocean Science and Engineering

The Applied Ocean Science and Engineering (AOSE) program in the MIT/WHOI JP continues to be academically strong and very effective. The program involves the Applied Ocean Physics and Engineering (AOPE) department at WHOI, and ostensibly five departments at MIT (Departments of Ocean Engineering, Electrical Engineering, Mechanical Engineering, Civil and Environmental Engineering, and Earth, Atmospheric and Planetary Sciences, (OE, EE, ME, CEE, EAPS). The four specific issues and recommendations specific to the AOSE program, made by the previous visiting committee, have been addressed in a serious manner by the leadership of the JP and are either no longer issues, or are no longer issues specific only to the AOSE program and are dealt with elsewhere in this report.

The number of applicants to the program continues to be fairly healthy, and is the largest number after Biological Oceanography. There has been a steady improvement in the number of female applicants, the number of female admits, and the number of female students enrolling. Some caution needs to be exercised in interpreting the enrolment trends, however, because of the small numbers involved. Almost 80% of the students in the JP-AOSE are associated with the Ocean Engineering program at MIT. However, while the students seem to be equally distributed in terms of which campus they are performing their research, the WHOI faculty are still carrying a much larger fraction of the advising load as well as the financial support load.

Contact with AOSE faculty at MIT was limited to a presentation by Henrik Schmidt and a discussion with Arthur Baggeroer, both from the OE department. At WHOI we met with the leadership of the AOPE department as well as a broad spectrum of senior and junior scientists. Based on the presentations at MIT and WHOI we have the following comments regarding the plans presented by the programs and the issues raised by the program.

The Major Issue: The Ocean Engineering program at MIT and the vitality and excellence of the ocean acoustics program in the Joint Program

The view was expressed very clearly and emphatically by both the MIT and WHOI faculty that the vitality and excellence of the ocean acoustics program

must be maintained. There are only three significant acoustics programs in the country and it is important to our national interests to maintain the excellence of this program. Externally, the MIT/WHOI program in this area and structure design has impeccable credentials on an international scale.

At the heart of the issue is the run down of the Ocean Engineering department to the state where a proposed merger with the Mechanical Engineering department at MIT is deemed necessary. This is discussed in greater detail in the first part of this report. A second issue that was raised in this respect is the quality of the Navy M.S.-track students. The faculty at WHOI felt that the quality had been declining over the past few years. The WHOI viewpoint is that it is critically important to maintain the strength and identity of the MIT ocean acoustics group. Presently it is very difficult to get JP students into Electrical Engineering at MIT due to poor connectivity so although a potentially viable alternative this is currently not a good option for students interested in acoustics.

During the course of our visit the viewpoint was expressed from a number of quarters that the low number of undergraduate majors in Ocean Engineering (currently 19 undergraduate majors) was one of the primary reasons for the proposed merger with Mechanical Engineering. However this is a major research university with a graduate/undergraduate student ratio of 6:4. Ocean Engineering is a predominantly post-graduate specialisation. Moreover, it appears that while the number of majors is relatively small, the number of students taking classes from Ocean Engineering faculty is quite healthy. The ME/OE merger seems to be symptomatic of the asymmetry of the MIT/WHOI partnership. While the WHOI Directorate considers the JP in this area to be a thriving success based on an important partnership with MIT (with student numbers to back this view up), the MIT leadership do not seem to share this enthusiasm. At the faculty level things are different. For WHOI scientists, the OE department at MIT is a “home” away from Woods Hole and the opposite is true for the MIT faculty. The merger, viewed at WHOI (as we also do) as an unsubtle, eventual discontinuation of the OE program, will have a substantial effect on the productivity of the WHOI faculty, as well as the flexibility of their research.

It is therefore imperative that MIT move to stabilize the situation with regard to OE. The preferred option would be to reinstate the department with increased staff strength.

The Proposed Environmental Engineering Program at WHOI

The WHOI faculty would like to develop an environmental engineering program within the AOPE at WHOI. Some of the issues that are related to this proposal are the strength at WHOI in environmental fluid mechanics, the apparent intellectual opportunities in environmental engineering, and the fact that the

environmental engineering program at MIT is not represented in the Joint Program. The leadership of the AOPE, however, did not have any draft recommendations in this regard.

The fact that this recommendation has been floated by the AOPE is again a symptom of the lack of co-operation between a key MIT department (CEE) and the AOPE at WHOI. The sense of the committee is that the lack of collaboration in this regard stems from some degree of inflexibility of the part of CEE faculty in terms of course offerings for students. The WHOI faculty we spoke with were not uniformly supportive of this proposal for a number of reasons. First, some of the WHOI scientists do not feel that they are well treated by non-OE departments and faculty at MIT (“no presence or privileges”). Second, there is a notable lack of participation in the JP by key environmental engineering faculty at MIT, particularly in the environmental fluid mechanics area.

The feeling of the committee is that while a full-blown environmental engineering program per se may be not a wise path to pursue (the number of scientist slots needed to build a broad program is substantial, as is the resource investment needed), a program in Coastal Engineering would be an interesting avenue to consider. In the short term, the 2004 hurricane season has served to emphasise the economic and societal impact of coastal processes associated with extreme weather, and in the longer term, climate change will also have a significant coastal impact. Given that MIT’s excellence in Coastal Engineering is associated with very senior faculty members close to retirement (Mei and Madsen), and that some of the more notable programs in coastal engineering have declined over the years (UC Berkeley), there is an opportunity for WHOI to take the lead in developing a leading coastal engineering program. Such a program could be a substantial part of the JP if MIT invested in one or two faculty billets as well.

Connection Between EE at MIT and AOPE at WHOI

There is only a very loose connection between MIT Electrical Engineering (EE) and the AOPE scientists at WHOI. One faculty member who has a joint appointment with EE and OE at MIT does provide some minimum EE connectivity in signal processing and imaging to WHOI. In the past other faculty in EE at MIT were involved with the JP but that appears to have decreased over the years. In reality, at this time most of this work originates more from the OE program and faculty at MIT than the EE faculty. The Robotics group in OE has some connectivity with EE and some with WHOI. The underwater imaging program at WHOI is particularly strong but the scientists in this program are extremely frustrated with their relationship with EE at MIT. One scientist, in particular, was quite vocal about the fact that WHOI scientists did not have any “credentials” at MIT, and were not even given a simple workspace to meet with students while they were at MIT.

We sensed that there was a WHOI desire for more connection with MIT/EE that is not reciprocated. [In fact, this seems to be true of much of the MIT/WHOI engineering relations (with the clear exception of OE)]. All of this is very strange since the ocean provides an incredibly rich and challenging environment for signal processing, imaging and robotics. Furthermore, WHOI's well-earned reputation in exploring and imaging the ocean represents a tremendous opportunity for synergy between MIT/EE and WHOI (beyond the OE connection). Our conclusion is that there is a strong need with subsequent high payoff for an EE presence at MIT for collaborating with the Robotics and Underwater Imaging work at WHOI.

Student Funding

Student funding is a big issue for scientists at WHOI supporting students as research assistants. Substantial load in this regard appears to be carried by the WHOI scientists. Furthermore, meeting with students when they are at MIT is a problem for WHOI scientists. Again this relates to the fact that they have “no presence or privileges” in some of the departments at MIT.

Biological Oceanography

The biological oceanography component of the JP continues to be of very high quality, as assessed by the students presently in the program, its former graduates, internal JP researchers, and the academic and research community outside WHOI and MIT. The institutions continue to provide education on the cutting edge of oceanography and the research programs at both institutions represent the forefront and mature interests of much of the oceanographic research in the US and abroad. The academic program is fundamentally healthy, though there are areas where important issues still need resolution and where addressing student concerns could greatly enhance the experience of students in the program. The areas needing attention are the focus of the following discussion.

Course Load and Interdisciplinarity

A clear problem is the number of courses required for students in the BO section of the program. Seven required core courses (4 at WHOI, 2 at MIT, 1 [in statistics] at either WHOI-MIT-or-Harvard) and 6 more topical courses appear excessively high, as compared with the requirements of other equivalent Ph.D. programs in the U.S. The disciplinary BO program would do well to reduce the requirements. The problem with such a long list of course requirements is made even greater by scheduling conflicts that do not allow students to take multiple courses simultaneously or sequenced courses efficiently. In addition, a number of students and members of the review committee questioned the

applicability of MIT's requirement for all BO students to take the MIT biology department courses in biochemistry and genetics. (Discussions with the Biology department chair at MIT indicated that unless a graduate student took these 2 courses, the student could not be considered as having completed MIT's core requirements for biology graduate students.) Some, but not all students (and possibly their advisors) - appear unaware of their option to replace the required molecular-oriented genetics course at MIT with a possibly more relevant (for many students) course in population genetics at Harvard. Another solution may be to develop ties with other MIT units that would allow JP students in BO to enrol through their units, as discussed below, and have fewer, or more relevant courses that could substitute for some of the presently required courses.

The heavy course load for BO students in the JP is greatly exacerbated for students with interdisciplinary interests, students who must additionally take some of the requirements of a 2nd (or even a 3rd) field in which their research interests reside. As both the JP staff and the review committee realized, some of the most exciting new areas of biological oceanography cross into other disciplines. Indeed the committee was shown examples of exciting newly funded research initiatives at WHOI and MIT that will require students trained in such interdisciplinary areas. The JP needs to reduce the formal course requirements of BO students planning to conduct interdisciplinary research, tailoring coursework to the needs of individuals in order to allow students to proceed with reasonable speed through their course requirements, exam schedules, and research.

Relationship of BO students to MIT departments

A problem still exists in the experience of JP students who spend time both at MIT and WHOI, especially during the time JP students are taking courses at MIT. The problems appear to be less serious or non-existent for BO students whose principal advisor is at MIT, as contrasted with the bulk of the BO students, whose principal advisors are at WHOI. These concerns include the student's treatment by staff at MIT, their reception or even ability to work with advisors at MIT, and their ability to provide feedback that would be welcomed or acknowledged by MIT instructors or units.

A remaining serious problem is that for BO students in the JP whose field of research is not represented in any unit at MIT, or whose primary advisor does not reside in the biology department at MIT. Such a mismatch has led to the complaint, by many BO students in the joint program, about the MIT required courses (see above) and is evident from the historically very low level of sponsorship of JP students by Biology department faculty at MIT. In contrast, CEE and, most recently, the new BE programs at MIT, have faculty interested in and presently sponsoring, JP students. These units may represent additional, or more appropriate sponsoring units for JP students. The present

“cost” for biological oceanography students to participate in the MIT/WHOI JP is to take 2 courses in the biology department that are usually not part of the requirements for graduate students in other biological oceanography programs around the country. Possibly the cost of participation in the JP for BO students would be more reasonable if other MIT units could become the sponsoring unit for JP students. This relationship would work particularly well if the MIT sponsoring unit had course requirements that were either fewer or more central to the training of a biological oceanographer. Additionally some of MIT’s departmental requirements could replace some of the required topical courses for BO students. Exploring the development of ties with BE or CEE, or other options for JP sponsorship of BO students at MIT, might improve the health of its curriculum and the support for its students as well as reduce unwieldy course loads. Nevertheless the committee recognizes that for some students the Biology Department provides a supportive environment with space, computer access and great intellectual depth.

BO Student Life

There are a number of issues related to the ability of students in the program to provide feedback to the sponsoring institutions, thus rectifying problems they experience during their time in the JP. Additionally there is a range of other concerns that are expressed by either a significant minority of students or occasionally a majority of them. Examples of the former include some students’ distress about their lack of input on curriculum, course requirements, and exam formats. Examples of the latter include the lack of sufficient feedback from their advisor and the JP disciplinary community, and to a lesser extent, their access to a seagoing experience. Though it was clear that the WHOI office of education, WHOI Dean Farrington, and MIT JP Director Rizzoli are making considerable effort and progress in addressing these concerns, more work needs to be done.

Supervisory Problems

Finally, there were a few issues raised that reflect concerns of WHOI researchers involved in the JP. First, the BO classroom/teaching facility is badly out of date. The equipment in the room needs upgrading, an alternate room may be needed, and the Picture-Tel arrangement apparently is still not fully satisfactory. Additionally, the researchers who teach in the program felt that they were inadequately reimbursed for their teaching, which could ultimately lead to less commitment by them and ultimately to a loss in the health of the teaching program. Furthermore, pay for advising students, though remunerated to a degree, does not reflect the time some advisors spend with their students. Similarly, an important fraction of students felt they did not get enough time with their sponsors. The review committee realizes that students can be a great asset to an individual researcher’s program, and hence have benefits that ultimately increase the advisor’s output, but also that the

time spent with students, especially by young researchers starting their careers, detracts from time spent on their own research. This balance of gain and loss to academic sponsors and instructors could profitably be the subject of further discussion. Additional funding for teaching or advising is a necessity, especially when financial times become more favourable for the JP parent institutions.

Chemical Oceanography

Strong inter-institutional collaboration exists in chemical oceanography between WHOI and MIT. The diversity of faculty interests in marine chemistry, geochemistry, environmental chemistry, biogeochemistry and other subdivisions of the field, along with their ability to collaborate with other disciplines, is a major strength for the JP. The exceptional quality of graduate students in the JP is a testament to the strength of these collaborations and to the overall reputation of the program.

The chemical oceanography component of the JP is led by scientists in the Marine Chemistry and Geochemistry (MC&G) Department (24 scientific staff) at WHOI and the various faculty with chemical oceanography interests in EAPS and CEE departments at MIT. Additional strength is provided by scientists in other units at WHOI and MIT with interests in geochemistry and biogeosciences. Interactions between the WHOI and MIT scientists and faculty build solidly on long-term, close working associations between individuals in all of these units, as well as significant and sustained participation in the joint governance structure of the chemical oceanography program. These associations have included shared leadership and responsibilities for the support and development of a large number of highly successful chemical oceanography graduate students placed at top institutions around the world. The exposure of JP students to world class researchers and projects at WHOI and MIT is a major strength of the program.

After a period of major turnover in the senior scientific staff in MC&G beginning in the late 1990's, the department has now dramatically increased its strength at all scientific staff levels while diversifying research directions and the range of funded projects. This growth has happened in spite of the losses of major federal funding programs at DOE and ONR plus only sluggish growth in the NSF OCE Chemical Oceanography program. There are now five woman scientists in MC&G following the losses of Catherine Goyet and Kathleen Ruttenberg to other institutions. The new and enhanced research focus areas within MC&G range from marine microbiology and biogeochemistry to sophisticated modelling of the global ocean carbon cycle. Strengths include classical marine geochemistry, the cycling of dissolved organic matter, hydrothermal systems, sedimentary diagenesis, applications of stable isotopes

and radionuclides as tracers, palaeoceanography, and submarine groundwater discharge.

Chemical oceanography at MIT crosses more than a single department. The implication is that the JP must be seen as an important component in setting priorities at MIT if appropriate faculty searches are to be made. Losses of several key faculty members at MIT in the areas of geochemistry and aquatic chemistry (Edmond, Morel, Voelker) have left some serious gaps in focus areas that MIT previously helped lead in the JP. The same overall rejuvenating growth that has recently occurred in MC&G cannot yet be claimed at MIT where some serious needs, particularly in the area of aquatic chemistry, have not yet been met. However, a core group of outstanding environmental chemistry and geochemistry faculty remains at EAPS and CEE at MIT, providing excellent teaching and advising plus strong research collaborations that directly benefit JP students. This core group is bolstered by the recent additions of faculty with complementary interests including Julian Sachs (palaeoceanography) and Roger Summons (organic geochemistry and biogeochemistry). We again emphasize the value of the chemical oceanography component of the JP to MIT's departmental success, recommending that these needs be included in discussions of setting faculty recruitment priorities.

Interdisciplinary Research and Teaching Opportunities

Opportunities for students to pursue interdisciplinary coursework and research in areas related to chemical oceanography are expanding rapidly with the evolution of programs in the Biogeosciences and other fields. Traditional departmental curricula are widely under review around the country and traditional departmental boundaries in courses and research projects are beginning to give way to combined coursework and research opportunities that involve faculty from different disciplines with overlapping focus areas. The resulting cross-cutting programs emphasize breadth in addition to quality. It is no longer unusual to have Ph.D. advisory committees that consist of a mixture of chemical, biological, geological and physical oceanographers or even to have joint advisors from two different WHOI departments. However, such broad programs also require excellent students with the capabilities to understand and absorb more material than previously expected.

The breadth and strength of leadership across WHOI and MIT departments in disciplines central to these cross-cutting areas indicates the potential of the JP to be a global leader in providing outstanding interdisciplinary training for its students. Top student applicants with excellent undergraduate research experience, in addition to coursework preparation in traditional undergraduate majors, are now regularly seeking such opportunities. The JP appears to have the faculty and most of the resources needed to take advantage of new research and funding thrusts such as those in astrobiology or biogeochemistry. However, several important weaknesses appear obvious to the visiting

committee as discussed below.

Student funding Issues: Dependence on Grant Largesse

The size of the JP graduate student pool depends not just on fellowship funds but also on the availability of grant support for students, most challenging while they focus on coursework during their first two years. This dependence on “voluntary” funds may not properly serve the best interests of either the specific research projects or the students supported. It appears that there may be significantly more qualified applicants in chemical oceanography than available “flexible” grant funds can support. The support tied to specific projects may also serve to inhibit student exploration of other research avenues, although the record indicates a high degree of generosity and grant getting success on the part of individual grant PI’s.

Teaching and Curricular Issues

Teaching quality for formal course offerings at MIT is generally viewed as superior to that at WHOI, which may be partially the result of the different level of teaching experience for scientists at the two institutions. In addition, there are occasional concerns about course coverage. Most significantly, the continued offering of one particularly critical course, Aquatic Chemistry, may be at risk unless a new faculty member is hired to teach it, preferably at MIT because of the need by CEE students for this course.

Opportunities to gain Teaching Assistant experience are extremely limited at WHOI, and is also a problem in CEE at MIT, a department with few undergraduates. Teaching experience is particularly valuable when graduates are seeking to enter the academic market, an aspiration for many JP students. We can suggest no immediate solution to this problem other than faculty actively seeking to help interested students find opportunities wherever possible.

Team-taught courses that are part of the JP offerings are generally rated as inferior by students because of the lack of coherence in teaching styles, topics choice and depth of coverage probably inherent to such approaches. Good teaching requires well-organized coverage of the subject and effective two-way communications between students and faculty about course material and expectations for assessment (tests, papers, etc.). Both of these requirements are usually missing when more than two faculty, not in attendance throughout the course, merely rotate through a course to provide detailed lectures about their favourite topics. Regular course evaluations, including consideration of student comments on teaching quality, are an essential part of a successful education program.

Graduate Student Advising and Feedback

Students in chemical oceanography described the WHOI Education Office as “really great top to bottom” while they also complimented the MIT faculty for strong advising and excellent teaching. A regular scheme for monitoring student progress and the success of graduate student advising should help speed the progress of students and their research projects to the benefit of all, while helping them to best take advantage of the outstanding research environment at WHOI. We did note high student morale and strong support for advisors during our visits to both campuses. We also noted the strong student placement record.

There are few senior women scientists and faculty in chemical oceanography at MIT or at WHOI who can serve as role models for a JP graduate student population dominated by women. This is an issue across the JP and, increasingly, across oceanography in many U.S. institutions. MIT and WHOI would make a substantial contribution by taking a leadership role in addressing gender issues and scientific career progress.

Marine Geology and Geophysics

In the report of the 1998 External Review Committee, the top issue raised was the loss without replacement of key MIT faculty active in marine geology and geophysics (MG&G) and the consequent reductions in the level of research interaction between the partner institutions and in the quality and character of graduate student opportunities in this area. The reduction in MIT faculty participation in the MG&G component of the JP identified at that time was exacerbated after that review by the retirement of John Southard (sediment dynamics) and the departures of Thomas Jordan (geophysics) and Maureen Raymo (palaeoceanography).

The review committee this year was therefore pleased to see the strong interest in the MG&G component of the JP among five recent additions to the MIT faculty, including Julian Sachs (palaeoceanography, hired in 2000), Roger Summons (biogeochemistry and geobiology, 2001), David Mohrig (sedimentary geology and mechanics, 2001), Stéphane Rondenay (seismology, 2003), and Dan Shim (laboratory geophysics, 2003). Intellectual connections between the newest of these faculty members and WHOI staff members are in still-nascent stages, and the fraction of thesis advisors to JPMG&G students from among the MIT faculty remains small (12-15%). Nonetheless, there is a clear promise that the MIT side of the balance in MG&G is gaining in breadth of research opportunities and that a commensurate gain in JP student advising will follow.

The Geology and Geophysics Department at WHOI, too, has added considerable strength to their faculty ranks. In the last 5 years, 10 new faculty members have been hired in fields ranging from palaeoceanography (Olivier Marchal, Joan Bernhard, and Sarah Das), to the newly emphasized field of coastal marine geology (Jeff Donnelly, Liviu Giosan, and Ilya Buynevich), geophysics and tectonics (Jeff McGuire and Mark Behn), and petrology and geochemistry (Glenn Gaetani). These appointments, together with those at MIT, bring a real sense of new energy and promise to the educational and research endeavours of the Joint Program.

The second issue identified by the 1998 External Review Committee was the high curricular expectations of JP students in MG&G, including numbers of courses and scope of the General Examination, and the impact of those expectations on the time to completion of the Ph.D. degree. This issue was addressed at length by JCMG&G and MG&G faculty and students following the publication of the report of that committee, but it is the sense of this year's committee that the issue remains a valid source of concern. In statistics presented to the committee, the time to degree for Ph.D. students for the past 5 years (2000-present) has not changed from the average for the past 15 years; for both populations the average is 6.1 years (although the variance for the more recent period is somewhat smaller than for the longer time frame). This average figure is too high, because, it implies that a significant fraction of students are obtaining support into a seventh year of study. A shorter average time to Ph.D. would mean that more students could be supported at the same investment of resources. Given the recommendation elsewhere in this report for consideration of a more uniform set of requirements for Ph.D. qualification across the Joint Program, in large part to facilitate innovative interdisciplinary programs, the number of requirements and their effect on graduate student tenure should be factored into the discussions of how to respond to that recommendation.

Members of the committee met with MG&G students in residence at MIT during lunch on the first day. In general the students who participated were pleased with their educational opportunities and level of support for their research. Most were nearing completion of their Ph.D. thesis work and had clear plans for what they would be doing immediately following graduation. Articulate and motivated, the students constituted individual examples of the general conclusion that the JP is, on balance, achieving well its objectives of educating the next generation of leaders in marine science and engineering.

Members of the committee visited several individual laboratories of MG&G faculty at MIT (Tim Grove, David Mohrig, and Stéphane Rondenay) and heard from students and postdoctoral scientists who are working in those labs. The research groups were animated in their descriptions of ongoing research projects, all appeared to be addressing scientific problems of high importance,

and all of the labs were eager to recruit additional students from the Joint Program.

Committee members also visited a representative group of faculty from the WHOI Geology and Geophysics Department to hear their issues of concern. The biggest issue, discussed elsewhere in this report, is the diminishing salary support provided to WHOI faculty for teaching classes and advising graduate students.

Physical Oceanography

If not the best, then the MIT-WHOI Joint Program in Physical Oceanography is one of two best programs in the U.S. It has a rich set of basic courses, excellent name recognition, and very good students and advising record. Its graduates are to be found among the leaders in PO in the U.S. and internationally.

Discussions with faculty at both institutions indicated that this is a time of change for the JCPO, or more generally a time of change in the field of physical oceanography. With the development of extensive remote sensing capabilities and large arrays of moorings, surface drifters and profiling floats, along with sophisticated coupled ocean-atmosphere numerical models, physical oceanography has many of the attributes of a discipline like meteorology in which combinations of observations and model predictions are combined into near-real-time products for the broader scientific community and society in general. While the opportunities for individuals to specialize just in physical oceanography will remain, the pressures of operational science, the sources of funding, the challenges of understanding the ocean's role in past, present and future climate dynamics, and the excitement of opening up new fields of multidisciplinary research will push physical oceanographers to collaborate across disciplinary boundaries to address the complexity of biological-physical, physical-chemical and biogeophysical processes in the oceans. The importance of the physical processes of ocean circulation and mixing to the other disciplines, and the fact that the development of modern ocean instrumentation and platforms has largely been led by physical oceanographers, means that physical oceanographers will have an important role to play in developing the new interdisciplinary and multidisciplinary fields.

In order to address these issues and prepare the students, many JP faculty feel that physical oceanography needs to reinvent itself by widening the agenda of the field to include interdisciplinary or multidisciplinary work with chemistry, biology and climate sciences. Students are expressing more interest in interdisciplinary research, and there is a formal statement by the JCPO recognizing the need for adaptive procedures for such interdisciplinary

students. There seems to be a general agreement and discussions at both institutions regarding the need to change the written general exam (which has not changed in some 20 years), to accommodate the broader knowledge that is required of the modern well-educated physical oceanographer. Finally, there is the current intention to include marine meteorology as part of the curriculum.

The review committee encourages the JCPO to pursue these needed changes and use them as a lever for a further strengthening of the PO educational program. The committee offers the following specific suggestions on the physical oceanography program:

1. Interdisciplinary/multidisciplinary student research: It seems that although students are told they may take non PO courses, many avoid doing so because of their perception of the structure of the general exam and what's expected of them. The JCPO may want to consider changing the format of the exam to a two-part exam, one testing core-course knowledge in PO, and the other individually tailored to the (possibly non PO) courses and interdisciplinary research work of each student. Perhaps this might be a way of driving a change in the research direction of JCPO students. It also affords an opportunity to recognize the desirability of an individually-tailored program of study for each student in a numerically small program. The prospect of individual treatment and attention will always be a strong recruitment tool.

2. Tensions between the two institutions over the MIT Program in Atmosphere Ocean and Climate (PAOC) have been reduced, but not eliminated, as a result of various actions taken over the past 5 years. The fear on the part of WHOI staff that MIT might attempt to keep the best applicants for the exclusively MIT-based PAOC needs to be addressed, perhaps by encouraging applicants to visit both institutions. From the point of view of the students, it would be best to further lower the barriers between the JP and PAOC. The main obstacle seems to be the different general exam formats. Moving towards a similar format of exam in the two programs is strongly encouraged. Given that the distinction between the open/closed written exams has blurred over the years, and that the department in MIT is moving toward a uniform exam format, the above two recommendations regarding the general exam seem especially timely.

3. Young PO researchers appear to be getting a double message regarding their participation in the educational program. Some senior researchers/mentors/managers advise participation while others appear to consider it a distraction from the primary research mission at WHOI. We believe that young PO faculty in WH should be encouraged by senior faculty and especially by the management to participate in JP activities if it will add positively to the development of their careers. This will vary from case to case and individual advice in this area for young faculty would benefit greatly from a more formal mentoring program. Where appropriate, participation in teaching and advising will contribute positively to both the junior faculty and to the students.

4. Notwithstanding the extensive theoretical developments in geophysical fluid dynamics and theoretical PO, due in no small part to WHOI/MIT scientists, PO is still essentially an observational science that depends on observations for discovery and the testing of theories and models. The vitality of the field depends on having students who are familiar with the observational techniques and associated data analysis. Given the wealth of observational PO research programs at WHOI, the offering of observational PO courses seems somewhat limited. WHOI PO faculty need to be further encouraged to teach and advise via financial support for these activities. Team teaching, or short courses lasting 3-5 weeks, may be used to overcome the difficulties due to sea going activities.

5. The overall impression in the JP is that the attrition rate in PO is higher than in other disciplines. This issue is of importance to student morale, and the record of the JCPO seems to have improved in recent years. This may not be just a JP phenomenon, as other oceanographic graduate programs have experienced similar retention issues in PO over the last decade. This has been especially troubling with regard to the retention of female students. The committee encourages the PO faculty at both institutions to continue this improving trend, by reexamining admission criteria, and via enhanced support and advising for incoming students.

6. Teaching quality is generally high, but there were some comments from students about the need for some faculty to update their course material and notes. JCPO faculty should periodically review the content of individual courses and the synergy between them to make sure that there are no large gaps in the educational program. It would be useful for the JP to do this across all disciplines, especially if interdisciplinary/multidisciplinary education is to play a larger role. Of particular concern with teaching is the need for timely feedback to instructors of the less-well taught courses, and follow up by the JCPO to make sure that the issues are addressed. An improved and faster mechanism for dealing with less-well taught courses needs to be implemented by the JCPO. In addition, it seems that copies of student assessments in MIT are sent to lecturers sometimes months after the course. The committee recommends having these assessments sent to the MIT JP office to be processed more quickly, rather than waiting for the usual MIT procedures.

7. The proposed addition of “Marine Meteorology” to the program and to its name seems too narrow and could benefit from discussion with the atmospheric sciences and climate programs at MIT. Marine meteorology reflects the current research expertise in WHOI rather than the breadth of air-sea interaction processes that should be represented in an education program that addresses the physics of the oceans, and their role in the climate system.

Appendix: Committee Membership

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Woodwardian Professor of Geology
Department of Earth Sciences
University of Cambridge

Prof. Margaret Delaney
Professor of Ocean Sciences
University of California
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Prof. Robert A. Frosch
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