

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

September 2009

INTRODUCTION

The External Review Committee (the “Committee”) met in Cambridge on June 10, and in Woods Hole on June 11-12, 2009, to review the Joint Program in Oceanography and Applied Ocean Science and Engineering (the “Joint Program” or “JP”). The committee provided a preliminary oral report of its findings and recommendations during an exit meeting with Susan Avery, WHOI President and Director; Claude Canizares, MIT Vice President for Research and Associate Provost; Jim Yoder, WHOI Dean; Jim Price, WHOI JP Director, and Paola Rizzoli, MIT JP Director.

The Committee was chaired by Ken Melville, Distinguished Professor of Oceanography and Director of the Joint Institute for Marine Observations, Scripps Institution of Oceanography, UCSD, and included:

- Cindy Lee Van Dover, Professor of Marine Biology; Director, Duke University Marine Laboratory; Chair, Division of Marine Science and Conservation
- Katherine H. Freeman, Professor of Geosciences, The Pennsylvania State University
- Samantha B. Joye, Professor of Marine Sciences, University of Georgia
- Peter A. Jumars, Professor of Oceanography and Marine Science, Darling Marine Center, and Director, School of Marine Sciences, University of Maine, Orono, Maine
- M. Susan Lozier, Professor of Physical Oceanography; Chair, Earth and Ocean Sciences Division, Duke University
- Philip L. Marston, Professor of Physics, Washington State University
- J. Gregory McDaniel, Professor of Mechanical Engineering, Boston University
- Michael J. McPhaden, Senior Scientist, NOAA/Pacific Marine Environmental Laboratory; Affiliate Professor, University of Washington
- Warren L. Prell, Henry L. Doherty Professor of Oceanography, Brown University
- Sean C. Solomon, Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington

Members of the MIT Corporation

- Dr. Norman E. Gaut, Chairman and CEO, SuperWater Solutions, LLC
- Dr. Diane Greene, Technology Entrepreneur

WHOI Trustees

- Dr. James A. Austin, Jr., Senior Research Scientist, Institute for Geophysics, Jackson School of Geosciences, The University of Texas at Austin
- Dr. Alfred T. Dengler, President, Risk Strategies, LLC

The Committee received written input prior to its visit, and, during its time at MIT and WHOI, attended presentations on the JP and its disciplinary components. Members of the Committee met with individual faculty and scientists, and with students in both large and small groups. The chairman of the Committee met separately with department heads at MIT and with a group of department chairs at WHOI. Due to the efforts of Drs. Rizzoli, Price and Yoder and their staffs, the Committee had open access to all the information it requested and to the individuals and groups it wished to interview.

EXECUTIVE SUMMARY

The Joint Program is a leader in graduate education and research in oceanography and applied ocean science and engineering, combining the resources of two great institutions to provide students with an opportunity to learn and conduct research at the forefront of these fields. In its 41 years, the JP has produced graduates who have populated leading universities, laboratories, government agencies and commerce, generating new knowledge and disseminating expertise in ocean science and engineering around the globe. This enviable position is due to the original vision of the founders of the JP, the quality of the students, faculty and scientists, and the administrative skills and wise leadership of the JP that continues to this day. However, the Committee has serious concerns about whether this level of success can continue into the future, as competition from other graduate programs, including some at MIT, and advances in oceanography and the newer modes of conducting multidisciplinary research appear to be outpacing the ability of the JP to adjust. These issues are not unique to the JP, but they are complicated by the fact that this is a joint program between two independent institutions.

These issues must be addressed if the JP is to succeed to its full potential. It will require a reassessment of the relationship between MIT and WHOI in the context of the JP, and a coordinated approach to addressing the curriculum and student advancement through the JP. As demonstrated in this report, the relationship between the two institutions affects all aspects of the JP. In recent years, the original ideals of collaboration, consultation and cooperation between MIT and WHOI have been strained and need to be reestablished. Coordinating the curriculum across the traditional disciplinary boundaries will not be easy, but should be facilitated by the anticipated hiring of younger faculty and scientists who will be able to take a fresh look at the field and the programmatic needs of the students.

In the context of hiring, it is imperative that the JP be taken into account in the strategic planning at both institutions. This planning should also consider broadening the base of the JP at MIT beyond the Schools of Science and Engineering, to account for the role of the ocean in other areas of importance to society.

Securing resources for the JP continues to be a very important issue, especially funds for first-year fellowships. While progress is being made, the Committee expects that a coordinated effort between the development offices of MIT and WHOI would be more successful than independent approaches to potential donors.

The leadership of the JP continues to make progress in addressing quality-of-life issues for the students, especially those related to the physical separation of the two institutions. The Committee encourages more attention to these issues, not just for the benefit of the present students but also to address important aspects of student recruitment.

The Committee was impressed by the dedication, enthusiasm and administrative efforts of the current leadership of the JP to identify and address the issues that it confronts. However, those efforts are impeded by the speed with which changes can be made, and by the need for clarity on the shared responsibilities of MIT and WHOI in the JP.

The recommendations of the Committee are as follows:

1. Develop a joint strategic plan for the JP, with a primary emphasis on how the JP can continue as a leading, internationally recognized educational program focused on the use of science, engineering and technology to meet the ocean-related scientific and societal challenges of the 21st century.
2. Ensure institutional awareness of the Joint Program (JP) at the highest levels of both institutions by making JP issues a standing agenda item at regular meetings of the presidents of MIT and WHOI.
3. Establish JP representation in strategic planning at the departmental level and above at MIT, and across all levels of WHOI's strategic planning, including consultation between institutions on hiring affecting the JP.
4. In recognition of its cross-school reach at MIT, establish leadership of the JP at MIT in the Office of the Provost.
5. Revise the curriculum and exam structure to address the growing importance of multi-disciplinary graduate education and research.
6. Expand the use of modern communications to minimize the effects of the physical separation of the campuses.
7. Establish reciprocal privileges at both institutions for faculty and scientists involved in teaching and student supervision.
8. Provide access to a unified set of teaching resources and mentoring to those who teach classes and supervise students in the JP.
9. Coordinate fund-raising efforts at both institutions in support of the JP.
10. Address quality-of-life issues for students.
11. Conduct internal reviews of progress in responding to External Review Committee recommendations.

Supporting arguments for these recommendations are provided in the body of the report.

In view of the importance the Committee attaches to the diverging paths of MIT and WHOI, it is important to be reminded of the environment in which the JP was originally established, the letter and spirit of the original agreement, and some of the changes in oceanography in the intervening years. This is given in background material immediately below and in an appended copy of the original Memorandum of Agreement (MOA) between MIT and WHOI establishing the JP. The reader familiar with this history can skip directly to the supporting arguments for the recommendations.

Detailed observations and suggestions regarding the separate disciplinary components of the JP are included in appendices.

BACKGROUND

The Joint Graduate Program in Oceanography was established 41 years ago with a Memorandum of Agreement (MOA, attached here as an appendix) signed by the presidents of both institutions that recognized the growing importance of oceanography in the Earth sciences, the need for well-educated oceanographers trained at sea and, as with other sciences, the need to integrate fully graduate education with research. It also stressed that the marine facilities at WHOI, including research vessels, could be made more readily available to MIT faculty and students “through close cooperative planning”. The document implies that MIT would provide the educational resources of a top university, while WHOI would provide research opportunities supported by access to the sea, necessary to integrate education and research. The MOA also stated that each institution would operate as an equal partner, with decisions affecting the JP made through mutual consultation, and actions authorized by mutual consent.

Following its creation in 1968, the Joint Program quickly established itself internationally as one of the two or three leading graduate programs – some might say the leading program – in oceanography. Graduates of the JP have populated universities, research institutions and government laboratories around the world. As with any great graduate program, its graduates are its future competitors. As technology makes access to information and data easier, that competition will only increase. By any measure, because of the quality of students and the faculty and scientists involved, the JP has been a great success. Continuation of that success is threatened, however, by divergence in the scientific priorities of the partner institutions and by the evolving landscape of ocean sciences nationally and internationally. Continuing this tradition of excellence requires new approaches to address the changes occurring in ocean science and engineering.

Access to the ocean, ocean measurement techniques, and modeling have evolved significantly over the past four decades. With the establishment of the University-National Oceanographic Laboratory System (UNOLS) in 1972, making access to the national research fleet open to scientists across the nation, the need for bilateral agreements to access research vessels disappeared. Ocean satellite remote sensing, begun in the 1970s, finally gained acceptance by the oceanographic community in the early 1990s following the launch and success of radar altimeters (TOPEX/Poseidon) in measuring ocean circulation. Developments in computer and battery technology and satellite communications led to the development of autonomous ocean vehicles for measuring physical, chemical and biological variables *in situ*, reporting back to public data bases. Developments in computer technology and algorithms have led to ever more realistic numerical ocean models and coupled atmosphere-ocean models that include more interactive physics, chemistry and biology than the pedagogical classical theoretical process models. The Internet revolution has made access to ocean data and information widely and easily available. In effect, the observing platforms and sensors, numerical models, and communication tools provide a foundation for integrating the disciplines within oceanography to a degree never envisioned when the JP was founded.

In another trend, the recent proliferation of “ocean and coastal observing systems” along with advances in numerical models, are transforming oceanography into an operational science, akin to meteorology. That is, the delivery of data products and services to governments, industry and more generally society, have become part of the expected information stream that is regularly available and usually accessible on the WWW. These developments have put pressure on the oceanographic community to revise educational programs to reflect these developments at both the graduate and undergraduate levels.

The creation of the JP, which is inherently interdisciplinary, combining core sciences and engineering fields with oceanography, was in many ways prescient of current national trends in graduate education. Many significant science engineering and societal problems are large and complex, and they demand approaches, tools and insights from multiple disciplines. For example, research in climate and its impact on society; life’s interactions with its physical habitat; and biomedical fields and sensor technology, all cross boundaries between the physical sciences, life sciences, engineering, and the social sciences. As a result, universities are lowering disciplinary boundaries in graduate training in these and many other areas. The federal government has also recognized the need for a new generation of scientists that can work collaboratively and across disciplines, and thus the National Science Foundation has promoted innovative graduate training since 1998 through its prestigious IGERT (Integrative Graduate Education and Research Traineeship) program. Scientists and educators are also competing for ideas, resources and students in a global marketplace, with Europe and Asia providing strong challenges to U.S. research and educational leadership. Considering both this rising competition from abroad and from innovative graduate programs within the U.S., the JP would be well served to embrace programmatic transformations that enable continued leadership in oceanographic graduate education.

Has the JP evolved within the spirit of the original agreement and addressed the changes in the fields it covers to the benefit of the students and both institutions? In many ways yes, but it faces critical issues related to the relationship between the two institutions and the responsiveness of its educational program to the changes in oceanography since its inception. There is also much more to be done to benefit from the unrealized potential of the JP for both institutions. The Committee was very concerned by clear evidence of a divergence from the original collaborative and consultative processes of the JP. This may be due to the natural evolution of the institutions and their separate priorities; however, it is an issue that is central to the continuing success of the JP. This issue has been raised in previous reviews but never with sufficient force to command fully the attention of the highest levels of leadership at both institutions. Given the importance to society of the science and engineering addressed by the JP in the areas of climate, energy, biology, ecology and other fields, it is in the interests of both institutions to make sure that the opportunities afforded by the JP are fully realized.

RECOMMENDATIONS AND SUPPORTING ARGUMENTS

- 1. Develop a joint strategic plan for the JP, with a primary emphasis on how the JP can remain a leading, internationally recognized educational program focused on the use of science, engineering and technology to meet the ocean-related scientific and societal challenges of the 21st century.**

The Presidents of MIT and WHOI should jointly charge a broadly representative committee to develop a strategic plan for the JP. The committee should include strong representation by junior faculty and scientists, who will be responsible for the future of the JP. The plan, taking into account the changes in ocean sciences and engineering and in the institutions, and anticipated future developments, should have as its main component a clear vision for the JP as it moves into the coming decades. This vision should explicitly address how best to educate graduate students given the changing landscape of ocean science and technology and the interdisciplinary nature of many of the most pressing environmental problems.

The plan should also assess the ability to execute it within the context of the current MOA. It should define the governance of the JP, and directly address the logistical connections that remain an impediment to smooth running of the JP for students, faculty and scientists. The governance plan should describe how decisions are made for the JP at each institution, what decisions are joint, and the requirements for each institution to involve the other in decisions related to the JP.

The Committee recommends that the declining “jointness” of the JP be directly addressed in the analysis supporting the plan. This analysis should describe the purpose of the relationship from a viewpoint that includes the needs of the JP, the two institutions and society as a whole.

Following acceptance of the plan, the Presidents of MIT and WHOI should reaffirm the relationship, with a clear explanation of why to both communities.

- 2. Ensure institutional awareness of the Joint Program (JP) at both institutions by making JP issues a standing agenda item at regular meetings of the presidents of MIT and WHOI.**

In terms of student numbers, approximately 120-140, the JP is a small fraction of the graduate enrollment at MIT, and is a small fraction of the budgets of both institutions. However, in terms of the sciences and technologies impacted by ocean sciences and engineering, including climate, energy, biology, ecology and water resources, to name a few, the JP’s importance far exceeds these numbers. For an independent research institution such as WHOI, the presence of graduate students is essential for the vitality of the research and the institution over the long term. For these reasons, it is imperative that

the health and needs of the JP, and its potential impact on both institutions and society, be recognized and nurtured at the highest levels of both institutions.

- 3. Establish JP representation in strategic planning at the departmental level and above at MIT, and across all levels of WHOI's strategic planning, including consultation between institutions on hiring affecting the JP.**
- 4. In recognition of its cross-school reach at MIT, establish leadership of the JP at MIT in the Office of the Provost.**

One of the most striking aspects of the JP at present is the decline in MIT faculty involvement. Faculty involvement is best measured by student supervision. The Committee found that there is no faculty involvement in Oceanographic Engineering or coastal engineering/oceanography on the part of the MIT Department of Civil and Environmental Engineering (CEE) faculty; however, CEE faculty members are active in the Chemical Oceanography (CO) and Biological Oceanography (BO) programs. Of 23 students in Marine Geology and Geophysics (MG&G), including 4 who will arrive this fall, only one has an MIT supervisor. For CO the numbers are 23 and 6, in Physical Oceanography (PO) 15 and 6 and in BO 15 and 1. In discussing this issue with faculty and students, a number of factors appear to be contributing to this decline, including strategic planning that has not adequately considered the needs of the JP, institutional reorganization with negative impacts on the JP, and the development of programs that compete with the JP.

The Committee was told that the needs of the JP do not play a significant role in the strategic planning at either institution. For MIT faculty, who have been involved with the JP over decades and are still participating, there are competing cross-cutting programs in climate sciences, biology, the environment and energy for which getting institutional and first-year fellowship support for exclusively MIT students may be easier than for JP students. For example, this competition and concurrent loss of microbiologists at WHOI appears to be pulling microbiologists at MIT away from participation in the JP. Likewise, the loss of sedimentologists and paleoceanographers at MIT has decreased the opportunities for collaboration with WHOI scientists. These issues are not the responsibility of one institution alone, and can only be resolved by *joint* strategic planning for the JP.

With JP MIT faculty in several disciplines well into their sixties, the problem of MIT faculty involvement will be exacerbated if JP needs are not a factor in departmental hires. Does this mean that some places should be reserved for "JP hires"? No, but it does mean adhering to the original MOA and consulting with WHOI, if faculty departures from MIT are going to affect the JP. For example, canvassing WHOI for suggestions for MIT hires would also be in the spirit of the original JP MOA without violating the independence of each institution. The same should apply to WHOI consulting with and canvassing input from MIT.

Disbanding of the Department of Ocean Engineering (OE) at MIT four years ago was seen in some quarters as a violation of the JP MOA and featured prominently in the last review. The consolidation within Mechanical Engineering (ME) has had some positive influence on OE at MIT, and opened up new opportunities for ME, but there are ongoing concerns about the visibility of the ocean engineering group, which affects their ability to compete with the other demands for faculty hires within ME and overall for graduate students worldwide. MIT's Ocean Engineering group, jointly with WHOI, has consistently led the world in developing the all-important technological tools for exploring and understanding the oceans, such as autonomous vehicles and acoustic sampling and modeling. It is imperative that this leadership be maintained.

A similar situation of friction between the institutions and the JP arose when the Program in Atmospheres, Oceans and Climate (PAOC) was established at MIT. This, too, has settled down somewhat, but there are still residual concerns from faculty and scientists on both sides. The issue is discussed in more detail below, but the more general issue is that the JP may be losing prospective students who are attracted to the “climate” label of the MIT PAOC program but are not well versed enough to know that research in climate science can be conducted in the JP, with an emphasis on the role of the ocean.

The disciplinary structures of the JP and the departments onto which they are mapped at WHOI have not been sufficiently responsive to fields such as climate science that cross departmental boundaries. Several years ago, WHOI set up crosscutting institutes in the areas of deep ocean exploration, ocean life, coastal oceanography and climate change. These themes could provide a focus for crosscutting components of the JP. Adopting such themes would require significant changes to the current disciplinary structure of the curriculum and degree requirements, but it should at least be considered when setting out a new vision for the JP.

In the context of crosscutting themes, there is the related issue of the potential to broaden the JP to other schools at MIT beyond science and engineering. Because roughly 50% of the world's population lives in coastal regions and faces significant sea-level rise in this century, as well as issues such as coastal pollution, harmful algal blooms and related illness, the need for energy efficient buildings in coastal climates, fisheries economics, and coastal and offshore energy resources, there are multidisciplinary and interdisciplinary opportunities for students with a background in the ocean and related environmental sciences, along with economics, human health, medical research, architecture, urban planning, management, or political science. These are all areas in which MIT has programs, but as far as the Committee is aware none currently have any interaction with WHOI or the JP. Thus, while there may have been a drifting apart of some of the classical oceanographic disciplines between the two institutions, there would appear to be unrealized opportunities to rejuvenate the JP through developments in other disciplines. Consideration of such expansion should be integral to the formulation of a vision for the JP's future.

A broadening of the base of the JP between the two institutions would have a positive impact on student recruitment. The ocean plays a relatively small role in the basic disciplines of physics, chemistry, biology and engineering, and this has limited student recruitment in the past. Given the relatively small market for PhDs in oceanography, compared to those in the broader disciplines, a student considering employment opportunities may opt for a straight MIT PhD, and its marketability, over a JP degree. Any changes to the JP that open up new postdoctoral employment opportunities will also help address this issue.

Given the cross-school base of the JP at MIT and the potential to involve more than the schools of science and engineering, leadership of the JP at MIT should reside in the Provost's office.

5. Revise the curriculum and exam structure to address the growing importance of multidisciplinary graduate education and research.

While MIT and WHOI scientists and engineers have been leaders in planning and executing large multidisciplinary research programs in the ocean sciences, this experience has not translated very effectively into the educational program and exam structure of the JP.

How do you design and operate an educational program that provides the necessary foundation in one or two disciplines, while also giving the student the opportunity to work at the disciplinary boundaries, or in collaboration with those in other disciplines? This problem is not unique to the JP. It is being confronted by all graduate ocean science programs and, indeed, graduate programs in many disciplines. These issues have moved to the fore with the increasing influence of climate variability as a motivation for research in the ocean sciences and engineering. Studies of the carbon cycle, including ocean acidification, polar climate science, or the impact of climate variability on marine ecosystems, all require tools and insights from physics, chemistry and biology. Similar multidisciplinary issues will arise as physical oceanographers move to resolve dynamics that influence the ocean biogeochemistry at smaller and smaller scales.

In other areas, for example microbiology, the environment and energy, MIT has developed programs that cut across the strong departmental structure of the institution. In contrast, the JP seems solidly anchored in mapping the curricular programs to the WHOI departmental structure. When this is reflected in widely varying requirements of the different disciplinary programs, and the structure of the exams for progress through the JP, it constrains a student's freedom to work at the interface between the various sub-disciplines of oceanography and ocean engineering, let alone to work at the interface with other disciplines. While all students may not have the intellectual capacity to acquire the necessary skills in more than one discipline, the brightest will, and it is they who will become the intellectual leaders of the field. Educating the future leaders must continue to be one of the central missions of the JP. To do so, the JP must find a more flexible way of

educating students across the disciplines and of challenging them to develop broad perspectives on the major problem areas in ocean science.

The JP is relatively small (120-140 students with an entering class of 30 or so) and it should be nimble enough to design programs of study that allow greater flexibility. Certainly there is a knowledge base (and therefore courses) that should be common to students sharing the same disciplinary foundations for their subsequent research. But recognizing the value of including training from other fields may require greater efficiency and reduced course requirements in some of the JP disciplinary programs. These changes call for greater emphasis on flexibility and a balance between breadth and depth of training, rather than the very strong disciplinary structure of the present Program. To be effective, such curricular changes require more commonality in the structure of the exam and proposal process, to prevent artificial impediments to the timely advancement of students to the research component of the Program.

In some areas, for example PO, the curriculum is in need of modernization to accommodate changes in the field and the new research frontiers. This problem, too, is not unique to the JP nor PO: discovering how to span topics ranging from the fundamentals to the frontier in a limited time is a challenge in all the sciences. For example, while classical geophysical fluid dynamics provides the foundation for many of the physical processes underlying ocean circulation and wave propagation, the complexity of ocean dynamics and the role of turbulence and mixing must be addressed too, in ways that combine pedagogical simplicity with realistic models and predictions. We have to acknowledge that we cannot teach the students everything they need to know, but rather must provide them with a solid foundation for continuing self education.

The Committee also saw some indications of a negative feedback on the flexibility of the educational program resulting from low enrollments in some disciplines. If the enrollment in any year is low, the “non-core” classes in a discipline may not attract sufficient students (3) to be offered. This limits the choices for the students, essentially forcing them back into “core” classes or the popular classes in the discipline or in the JP overall. Low enrollment in the previous year is an impediment to future recruiting, and so the cycle continues. Again, this is not a problem unique to the JP, but other programs have attempted to address this issue by consolidating disciplines where possible, especially for the purposes of student recruitment and maintenance of class size.

- 6. Expand the use of modern communications to minimize the effects of the physical separation of the campuses.**
- 7. Establish reciprocal privileges at both institutions for faculty and scientists involved in teaching and student supervision.**
- 8. Provide access to a unified set of teaching resources and mentoring to those who teach classes and supervise students in the JP.**

The separation between MIT and WHOI is both physical and cultural.

Oceanographers now routinely collaborate nationally and internationally, but physical proximity (“corridor conversation”) is still very important in both education and research. Although the physical separation of the institutions cannot be changed, more effort can be made to encourage visits and reciprocity when faculty, scientists and students do spend time at the other institution. For example, MIT faculty members in the JP are typically given Guest Investigator status at WHOI, affording desk space, and library and IT privileges. There are no comparable reciprocal privileges for WHOI scientists at MIT. This disparity is incompatible with the statement of equality between institutions in the original JP MOA.

There is a continuing need for convenient transient housing at both locations for members of the JP community. This has been mentioned in previous reviews. While some progress has been made, housing continues to be an issue.

The JP has not kept up with modern technology in video recording classes and seminars of JP relevance at both institutions, and maintaining a web-based archive that can be readily accessed by all members of the JP community. It no longer takes a recording studio to produce an acceptable product, and seminars are just as important as classes in exposing students to the latest developments in their fields and in providing the basis for substantive interactions with colleagues in the JP.

Differences of opinion between the MIT faculty and WHOI researchers on the direction of the JP have led to some decline in collegiality between the two groups. Any sense of inequality, such as those described above, only exacerbates this issue.

Furthermore, there are continuing concerns about disparities between MIT and WHOI with regard to quality of teaching. While MIT has many resources for monitoring faculty teaching and providing learning and remedial resources, that does not seem to be the case at WHOI. This is not a criticism of WHOI, which is predominantly a research institution. Nor is this a new issue, having been a point of contention within the JP for at least the last 25 years. A simple contribution to a solution would be to provide those from WHOI who teach and supervise students in the JP access to teaching resources at MIT, and for participating WHOI junior scientists to be mentored in their teaching and student supervision by senior WHOI staff involved in the JP.

9. Coordinate fund-raising efforts at both institutions in support of the JP.

In order to recruit the best graduate students and to support faculty interest in the JP at both institutions, it is imperative that support for first-year fellowships be expanded. Such an expansion would permit the JP to compete more effectively for faculty interest and students with other crosscutting programs at MIT.

Resources are also needed to acquire and maintain itinerant housing at both institutions, to provide money for students to travel to conferences, and to seed funding for research that will lead to funded external proposals and doctoral research programs.

While the Academic Programs Office at WHOI has been very responsive to requests for resources, it was clear from the last review that the leadership of the institution then had other priorities for fund raising. Similarly, the Provost's office at MIT has been responsive to *ad hoc* requests for JP resources at MIT, but any strategic planning for the future of the JP should also develop plans for expanding resources and integrating fund-raising efforts into the strategic vision.

10. Address quality-of-life issues for students.

A continuing issue from previous reviews is student access to desk space and itinerant housing at both institutions. In many cases, it appears that *ad hoc* desk space is provided by individual faculty and scientists rather than being provided as a communal resource by the JP at both institutions. Some progress has been made in addressing this as a JP issue, but evidently more needs to be done.

Cleanliness of itinerant housing has also been mentioned as an issue, with professional cleaning not frequent enough to assure students that they won't have to clean up after the student before them. While periodic professional cleaning might be expected, it may also require a change in the rules for students: "you abuse it, you lose it".

Given the breadth and physical separation of major parts of the JP, students mentioned the need for an orientation program for new students introducing them to the research, faculty and facilities that are available through the JP.

Students were concerned about the lack of affordable day care, which we believe is a larger issue at WHOI than at MIT.

There were also concerns about the lack of health services at Woods Hole for the students. Students are covered under MIT's health insurance plan, which requires them to travel to see doctors at the MIT clinic. While this is inconvenient even for intermittent care, it is very difficult for those with chronic illnesses in need of frequent care. The Committee was assured by WHOI leadership that they are addressing this issue on a case-by-case basis, but this needs to be more transparent to the students.

Overall, the students expressed a desire for efforts to facilitate their participation in the life of both campuses, rather than being either an "MIT student" or a "WHOI student", students should consider themselves as "JP students". This is especially an issue after they have passed their departmental exams and chosen a "home" campus and thesis supervisor.

Students also expressed concerns about the difficulty in getting their doctoral committee members to make the trip between institutions for doctoral committee meetings. While face-to-face meetings are much preferred, this is also an area where better video-conferencing facilities would help.

11. Conduct internal reviews of progress in responding to External Review Committee recommendations.

Faculty and scientists at both institutions expressed their skepticism about whether this external review would lead to any significant changes that address long-standing issues that have been raised in this and earlier reports. Some Committee members have first-hand knowledge of the issues from their own time at MIT and WHOI, but we do not believe that an external review committee can spend a few days at institutions as large and complex as MIT and WHOI and understand all the subtleties of the issues faced by faculty, students and administrators in the JP almost every day. However, we can take the information they have provided us and make sure it is injected at the highest levels of the institutions. This we have tried to do.

The Committee believes that the major issues highlighted here, especially those that relate to the fundamental “jointness” of the Joint Program, and the responsiveness of the education program to the evolving states of science and engineering, cannot be left to simmer without doing lasting damage to what has been a remarkably successful program. They cannot be left for another five years between reviews, so it is important that they be addressed on a continuing basis, with perhaps an annual assessment of responses to the issues raised here.

APPENDICES

Review of the Joint Program in Applied Ocean Science and Engineering (JPAOSE)

General Observations: The affected MIT departments are Mechanical Engineering (ME), Electrical Engineering and Computer Science (EECS), and Civil and Environmental Engineering (CEE). Of these departments most recent students are affiliated with ME and EECS, and no current students are affiliated with CEE (in engineering). The lack of JP students in CEE suggests there are unrealized opportunities for research cooperation between MIT and WHOI pertaining to coastal engineering and related research. While it was only possible to meet with a few AOSE students, those students appeared generally enthusiastic about the program. An even greater number of AOSE WHOI research staff met with the committee to express their support for the program. Some very positive remarks were made about the quality of the Ph.D. candidates, though there was general concern about the inadequate preparation in recent years of Naval Officers seeking a Masters Degree. Particularly active areas of research for Ph.D. students concern undersea robotics, AUVs, acoustic signal processing, and acoustic and optical methods for monitoring biological populations important in the food chain. While there are on the average research opportunities available in these sub-fields, in any given year it may be difficult to connect funding to interested applicants. A strong case can be made for increasing the number of available Recruitment Fellowships for bringing in more students in these fields.

Curriculum, Teaching, and Advising: Some change to the JPAOSE procedures pertaining to students is evident following the merger of OE and ME Departments at MIT. Some issues that may still require attention concern the timing and preparation for the ME doctoral qualifying examination (ME-QE) for students in the JPAOSE. There was a perception by some WHOI faculty that those students are expected to complete the ME-QE after only 1.5 years of graduate study, while ME students not in the JPAOSE might forgo taking the ME-QE until 2.5 years of study, placing them at an advantage when scores are directly compared. On the positive side, however, it was reported that participating WHOI faculty have been given voting rights in those exams (though it is not clear yet if this modification is being used). Also on the positive side, it has been reported that some WHOI faculty are consulted concerning the content of selected ME-QE questions. On the negative side, however, it is unclear if all courses needed for preparation for the ME-QE by JPAOSE students are taught at MIT with sufficient regularity and frequency. The ideal is for JPAOSE students to be able to complete their required coursework at MIT within two years of entering the program. A related concern is whether or not the detailed rules pertaining to the selection of area exams in the ME-QE may put some JPAOSE students at a disadvantage. (The details are not comprehensible to the Committee in the time available. It seems a consensus should be possible between affiliated WHOI and MIT ME faculty as to what is fair for JPAOSE Ph.D. students.) From the limited data available, the Electrical Engineering and Computer Science qualifying examination (EECS-QE) and course offerings appear adequate. The concern over the frequency of course offerings in ME arises because it is

unclear if following the merger of OE with ME, the frequency of offerings has been affected by other teaching demands on OE (Area 5 of ME) MIT faculty.

Space: In spite of the good will of ME-Area-5 and EECS MIT faculty, there remains concern that inadequate space is available at MIT for JPAOSE students and visiting WHOI research faculty. A related issue may be if adequate space is available for the ME-Area-5 program at MIT.

Review of the Joint Program in Biological Oceanography (JPBO)

The JPBO maintains its reputation as a world-class graduate program in biological oceanography. Faculty members in the program are productive and creative scientists at the forefront of research in a number of subdisciplines and often transcend disciplinary boundaries in their work. The program is highly selective, with the result that students entering the program have exceptional ability. JPBO faculty are supportive of matriculated students, as reflected in their 85% retention to degree completion over the five-year review period, the highest in the Joint Program by > 10%. On receiving their doctoral degrees, JPBO graduates enter academic and other professional careers commensurate with the exceptional quality of the program and their own appreciable talents.

Unlike previous reviews, however, this one found a convergence of alarming trends that either began or greatly intensified since the last review. Each signals the need for broad change, but together they demand it. One is a dropping level of acceptances of offers to prospective students, now near 50%. A second is a rising dissatisfaction among both Biology faculty and JPBO students with the constraints of the JPBO curriculum. A clear majority of faculty and students who chose to speak with us expressed this dissatisfaction. Entering class size has dropped from a range of six to eight to a range of four to five. Enrollment stayed steady at 35 or more through 2005, dropped slowly to 28 in 2008, and is now apparently (based on the table of current JPBO students provided at the review) only 15. But perhaps the most disturbing is a sudden erosion of the “jointness” of the Joint Program, *i.e.*, a sudden drop from historic highs in the early 2000s from 20% of JCBO students to only one supervised by MIT faculty.

Strategic Planning. As discussed in the body of this report, responsibility for the strategic vision of the JPBO and other components of the Joint Program has drifted to the point where there appears to have been insufficient attention to strategic planning for an appreciable duration. The JCBO currently appears to function to maintain the administrative needs of the JPBO, but apparently is not charged with evolution of the program. The lack of joint strategic planning by both MIT and WHOI faculty for the JCBO has resulted in a graduate program that has changed little since the start of the Joint Program. The quality of the faculty and the students has ensured that the graduates of the program successfully compete for jobs of the highest caliber. Whereas the JPBO program has not changed substantively in 40 years, the interests of students have changed toward research that addresses the grand challenges of today’s world. At the same time, the number of competing graduate programs of a caliber equal to that of the Joint Program is increasing; these programs are often young, agile, interdisciplinary and well able to attract top students away from programs that seem ossified, however misjudged this appearance may be. There is some such competition between innovative graduate programs at MIT and the Joint Program. It is arguably not the time for the JPBO to point to its past success as an indicator of its future potential.

Curriculum. A perennial issue in JPBO seems to be the JPBO required curriculum and

the course-focused general exam, with wide-ranging views and concerns that suggest they are dysfunctional in their current design and timing. The uncontroversial strength of the required curriculum in the broad disciplines of oceanography is that it trains students to view the ocean system from multiple disciplinary (and interdisciplinary) points of view. There are significant costs, however, to this in-depth, cross-disciplinary accountability. The extensive course requirements limit course exploration at other interdisciplinary boundaries, *i.e.*, between biological oceanography and non-oceanographic fields (*e.g.*, terrestrial-marine linkages). Because the interdisciplinarity in the current curriculum is so tightly prescribed, alternative and novel interdisciplinary approaches are effectively proscribed.

A number of the Biology faculty (both junior and senior) at WHOI expressed strong dissatisfaction with the current curricular requirements and with the timing and coursework focus of the general exam, noting the especially worrisome trend that, when the curricular and general exam demands are combined with the push for students to complete a PhD in 5 years, students do not have sufficient time to conduct research of the depth and quality deemed appropriate for a JPBO degree. A majority of junior faculty felt that this expansive coursework at the beginning and the aggressive JP-wide attempt to reduce total time in the program to 5 years had truncated JPBO research projects and was endangering quality of the research. They argued the need to move students sooner from evaluation on course performance to evaluation on research performance. They also argued that the truncation reduces opportunities to mentor students through all phases of the publication process and prevents students from having multiple papers (and in some cases even one) published before departure. It would be useful to collect data on post-admission timing of first publications based on JP research and timing of subsequent publications based on that research to test this criticism. The long up-front period before whole-hearted research begins also has led some senior faculty to question the net benefit of taking on students. Although students have time to conduct research during their first two years in the Program, some faculty indicated that preparation for the general exam during these periods often was allowed to trump research. A faculty-perceived deterioration in the quality of Ph.D. research alone should be sufficient reason for JPBO to reconsider the JPBO curriculum and its consequences.

Curricular dysfunction can cause contention among students and faculty and so has potential cost in distracting the JPBO from moving on to other business. Incremental responses to past criticism of the curricular requirements from External Review Committees have not been effective in alleviating the issue. Students noted in both interviews and course evaluations that, although faculty in other disciplines accommodate the learning needs of JPBO students in their courses, there is a perceived cost to students in other departments who expect and need deep knowledge in their respective disciplines. They felt that they were held back by JPBO students just at the time when they were most hungry for acquiring knowledge and skills in a classroom setting. JPBO students also expressed frustration in having to fulfill so many course requirements when there are world-class scientists at MIT offering courses that would build intellectual foundations, allow JPBO students to explore a larger set of knowledge than they could in their

preparation for graduate school, and allow JPBO students to recognize the leading edge in a new field and see ways to move beyond it.

Enforcement of a regimented set of curricular requirements in the face of a panoply of intellectual opportunities seems stifling, archaic and in conflict with contemporary graduate pedagogy. With regard to curricular requirements in genetics and or biochemistry, we observed sentiments ranging from ambivalence to appreciation of the core knowledge these requirements provide to students and value of the flexibility on the part of students to select the ‘flavor’ of these courses. As other External Reviews before us have noted, it is time for the JPBO to develop more sweeping curricular and general exam reforms that allow it to move forward and train the best research scientists for careers in modern ocean science. Alternative solutions for achieving the worthy goal of broadly trained oceanographers may be accomplished through a set of learning expectations achievable through topics courses, a survey course, or other innovative curricular activities that demand less of the students’ time and give them freedom to explore other intellectually rich fields of study. It is paradoxical that the Biology Department passionately retains its name (in favor of the “Biological Oceanography Department”) and prides itself in hiring faculty with backgrounds outside traditional biological oceanography but effectively seals off such backgrounds for its own students.

WHOI-MIT Partnership. There is uniformly mutual respect between WHOI and MIT faculty involved in the JPBO, but an issue of serious concern is the continuing decline in the “jointness” of the JPBO program. This issue is also taken up in the body of this report, but derives in part from observations within the disciplinary programs. Admittedly, we interviewed very few MIT faculty associated with JPBO, but those with whom we did speak expressed the view that there was little incentive to serve as Joint Program advisors, given the myriad opportunities to entrain MIT students into their programs. CEE has been a key player in JPBO advising. The current dip in such advising is in part stochastic, reflecting graduation of several students, but WHOI Biology’s loss of microbial and genomic talent has also been cited by MIT faculty as a reason for less interaction with the JPBO.

For MIT faculty, there are significant impediments to taking on a JPBO student, namely the curricular requirements of JPBO students and the lack of first- and second-year fellowships. There appears to be little or no involvement of the Biology Department at MIT with the JPBO. Some WHOI faculty expressed a general sense of apathy and disinterestedness toward the MIT contribution to the JPBO. The strong impression is that the WHOI-MIT partnership receives little or no thought from one day to the next in JPBO, and that this disinterest has been of long duration.

BO students as a whole have no natural physical or intellectual home at MIT. EAPS recently and generously has stepped forward to remedy the problem of a stable space to occupy when BO students are on the MIT campus for coursework. EAPS’ recent addition of faculty in geobiology increases the future likelihood of EAPS JPBO advisors and connections, but they are again impeded by the extensive course requirements in JPBO. After a long, gradual and steady increase in the fraction of JPBO students advised

by MIT faculty, it has fallen abruptly to one. Much of this advising was by three of the MIT CEE faculty, Chisholm, DeLong and Polz. Part of the drop may simply be stochastic (coincidence of completed degrees), but another factor cited by MIT faculty is a decrease in WHOI faculty oriented toward microbial and genomic research. Nurturing the CEE connection would seem a high priority. In addition to retaining involvement of faculty who are already engaged, some effort could be made to entrain others with marine interests (*e.g.*, Roman Stocker). Potential for student supervision by MIT Biology and Biological Engineering faculty appears limited by the extensive, WHOI-based coursework required of BO students.

MIT encourages cross-cutting, cross-departmental and cross-college research through exciting, institution-wide initiatives such as: the Microbiology Program; the Program in Atmospheres, Oceans and Climate; the Joint Program on the Science and Policy of Global Change; the MIT Energy Initiative; and, the nascent Faculty Environmental Network. Rich opportunities for research also exist at the boundaries between biological oceanography and marine policy, but it is not clear how BO students could take advantage of the Marine Policy Center at WHOI or of the Sloan School at MIT. JPBO students appear to be blocked from ready participation in these many examples of cross-cutting research at least in part by their extensive required course load.

JP students now are admitted in large measure based on fit to proposal dollars in hand for specific projects. This approach is rational as a means to conserve financial resources under the guarantee of five years of support, but it further limits the ability of students to catalyze new research connections at WHOI and especially between WHOI and MIT.

Student Satisfaction. Notwithstanding the Committee's observations and suggestions for improvements, students in the JPBO almost universally express satisfaction with the program, the quality of student life, and the opportunities the Joint Program opens for them. Most students experienced porous boundaries between disciplines and found they enjoyed easy access to scientists and resources in other Departments. JPBO students value their mentors and especially noted their appreciation of the support they receive from the Academic Programs Offices at MIT and WHOI. They were largely satisfied with the quality of teaching in the Program. Some students expressed a desire for more opportunities to understand and prepare for positions outside the academic research environment. The size of the Program is modest, with sometimes very small entering cohorts. This situation has not changed or has worsened slightly over decades and leads to challenges in developing an *esprit de corps* and in providing a critical mass for coursework in Woods Hole. The students generally find ways to work around this impediment by engaging with the larger group of JP students, often with the benefit of increased peer learning across disciplines

Fellowships. There was universal expression by students, WHOI faculty, and MIT faculty of the need for first- and second-year fellowships to enable students to explore options and to eliminate the need for faculty to support student coursework on grants and contracts.

Review of the Joint Program in Chemical Oceanography

Health of the MIT and WHOI partnership and Management of the program

Chemical Oceanography continues to be a healthy and vital component of the Joint Program. It is a world-renowned program in marine chemistry, geochemistry, environmental chemistry, and marine biogeochemistry. MIT and WHOI scientists enjoy good collaboration, engagement and communication. The strong inter-institutional collaboration noted in the 2004 review continues and it is clear that mutual appreciation and interaction between faculty members and scientific staff is fostered and valued by the Joint Committee on Chemical Oceanography (JCCO).

Chemical Oceanography in the Joint Program is largely supported by faculty in Marine Chemistry and Geochemistry (WHOI) and within Earth, Atmospheric and Planetary Sciences (EAPS) at MIT, with some additional participation by MIT faculty in Civil and Environmental Engineering (CEE). MIT and WHOI faculty expertise in other areas is also tapped as student research projects have expanded past traditional disciplinary boundaries. Faculty participation on the MIT side has narrowed over the years and is now limited to a small group of participants. Recent retirements and departures of MIT faculty formally engaged in the JP has unfortunately concentrated JP efforts onto the shoulders of a few individuals who remain dedicated to the program, but who also are close to being, if not already, overtaxed. The future strength of JCCO that derives from a strong and collaborative MIT-WHOI relationship is therefore at serious risk unless increased MIT faculty interest is fostered via recent and future hires within EAPS and other departments. Chemical Oceanography is an obvious area of strength for EAPS especially, and supporting the JP and JCCO interests should be a departmental priority.

WHOI staff departures have challenged the program's strength in marine microbial biogeochemistry. Attracting top researchers in this area is essential for maintaining research prowess and fortifying connections with EAPS, which in recent years has hired three new faculty in the areas of geochemistry and geobiology. Encouraging and facilitating involvement of new, and future, MIT faculty in the JP is critical.

Quality of the Student Research and Products

The JCCO program attracts excellent students. The strong caliber of the students is a major motivation driving collaborations and attracting MIT faculty and WHOI staff participation in JP activities. The strength of the students is also manifest in their publications and other research products, which can be found in leading scientific journals.

Opportunity for Interdisciplinary Research

The curricular and exam requirements of JCCO accommodate breadth in research training for graduate students. The course requirements are limited to one core offering (Introduction to Marine Chemistry) and a Seminar in Chemical Oceanography, which they take during each of their first two years. Seminar topics vary each year, and the course places an emphasis on oral presentations and classroom discussion of the

literature. In addition, students take elective courses at WHOI and at MIT offered by EAPS, CEE and in the departments of Chemistry, Biology, and Mathematics as well as at Harvard and Boston University. Students work with their research advisors and academic advisory committee to design a unique course of study.

Students conduct a research project during their first two years, and to help build breadth in their training, students are encouraged to pursue research in an area distinct from their expected thesis area. General exams are taken during the spring and summer of the second year, and the process includes a written exam that evaluates material in the core curriculum as well as areas specific to the student's research interests. Thus all CO students answer one or two common questions, and then can select questions from a list of choices to evaluate knowledge in their chosen subfield. The exam also includes an evaluation of the student's independent research project. Students do not present their work orally; the research assessment is based on a written document. Following the exams (3-6 months), students present and defend a thesis proposal.

The curriculum and general exam structure is flexible, and is designed to ensure both depth and breadth in graduate training. The structure appears to be working well, as both students and faculty expressed satisfaction with it. However, the faculty noted that a small number of students who seek broad training, for example with equal depth in two oceanographic fields (such as biology and chemistry), have voiced concern about the depth required in Chemical Oceanography, and of the JP disciplinary structure in general.

In synthesis, the CO curriculum and exam format is meeting the needs of the majority of students in the program and is not in need of substantial assessment and revision. The flexibility and nature of the JCCO program offers a model for other JP disciplines to follow in light of discussions regarding the need to promote interdisciplinary education and break down traditional 'discipline-derived' barriers to cross-cutting research and educational activities.

Advising and preparation of JP students for post-graduation opportunities and quality of mentoring

The satisfaction among student regarding faculty mentoring varies with the advisor (as it does at most institutions), but in general students are proactive and successful in getting the advice they seek. As is common in strong, research-oriented graduate programs, the perception of mentoring is fairly narrow, with the focus on faculty input to research and research-related activities (i.e., papers, presentations). A broader concept of professional mentoring and a growing emphasis on professional development is emerging among graduate training programs nationally, in part because of the emphasis on such activities by NSF training programs. The JP and CO faculty would be well served to strengthen preparation of their students for a work environment that may be very different from the research and academic institutions of their own experience. For example, a focus on science communication to a broad constituency (non experts) is lacking, even though emerging professional opportunities in energy, climate and marine policy demand scientists who can work with a wide range of stakeholders.

Quality of Teaching

Interviews with students yielded echoes of the concerns about teaching quality noted in the 2004 report. Such negative perceptions were not universally held by the students, and several first and second year students expressed general satisfaction with the teaching in the curriculum. However, students did note that teaching quality is generally higher by MIT faculty than with WHOI staff. As teaching is a job advancement requirement for a salaried faculty at MIT, the perceived differences might be expected given institutional emphasis on research at WHOI. However, teaching is remunerated at WHOI, reflecting its vital role to the success of the JP; thus, a continued effort to conduct regular course evaluations and mentoring of staff teaching is essential.

Adequacy of Financial Support

The CO program has a strong expectation that students focus on academic courses and conduct research outside their thesis area during the first two years. This expectation is directly at odds with a funding model that places first and second year students on research assistantships paid for by research grants. This conflict demands greater efforts to develop resources that enable placing new students on fellowships or other funds not tied to specific grants.

Quality of Student Life (incl. housing, logistical support and climate)

The quality of life for traditional demographics of graduate students (young adults, with no dependents) is fairly good. However, it appears that peer interactions, social networking and informal community building takes place after work hours. For non-traditional students (older adults, especially those with families), it is difficult to join informal social activities after work hours. The program is encouraged to consider building student interaction times during the regular day, perhaps through a coffee hours or other activities that foster informal interactions among staff and students.

Review of the Joint Program in Marine Geology and Geophysics

The External Review Committee found an active and vibrant Joint Program in Marine Geology and Geophysics (MG&G) and an impressive cadre of outstanding Ph.D. students. The MG&G component of the Joint Program continues to receive applications from highly qualified applicants in steadily growing numbers. Although the MG&G program has experienced a decreased yield in acceptances over the last few years, this decrease is likely an artifact of natural fluctuations; yield statistics should nonetheless be monitored.

As part of our review, the Committee met with Joint Program students in residence both at MIT and at WHOI. However, none of the JP students who met with us at MIT were from the MG&G program. In general, the students who participated in our WHOI meetings were pleased with their educational opportunities and level of support for their research. Articulate and motivated, the students constituted individual examples of the general conclusion that the Joint Program is, on balance, successfully achieving its objective of educating the next generation of leaders in marine science and engineering.

Several of the MG&G students at WHOI reported that they'd had little contact with the Joint Committee for Marine Geology and Geophysics (JCMGG) during the prior year and that formal tracking of progress seems to have slowed. We **recommend**, on the basis of these anecdotal reports, that the JCMGG and student advisors in the Joint Program devote greater attention to regular communication with each student regarding progress toward major program milestones. Such communication is key to the issue, discussed below, of maintaining a low but realistic time for completion of a Ph.D. in the JP.

Committee representatives also visited with several faculty members from the MIT Department of Earth, Atmospheric and Planetary Sciences (EAPS) who participate in the Joint Program (Brad Hager, Thomas Herring, and Stéphane Rondenay) and with a larger group of faculty from the WHOI Geology and Geophysics (G&G) Department. Faculty members at MIT were open in their assessment of areas of the Joint Program that warrant strengthening – including a greater pool of fellowship support for first-year students, greater involvement of MIT faculty in student advising, and greater collaboration between faculty at MIT and WHOI on research problems of mutual interest. We found telling, however, that the MIT faculty group with whom Committee representatives met was comparatively small, and that the EAPS Department had apparently given little collective thought prior to our visit about enlisting a larger fraction of the EAPS faculty to engage the Committee or discuss specific issues from the MIT perspective. The primary concern of the G&G faculty at WHOI was again the need for greater fellowship support for first-year graduate students. They felt that such support would improve graduate student recruitment, give first-year students greater flexibility in their choice of research projects for the General Examination, and make it more likely that students and research advisors would be better matched by the time the student embarks on a major research effort. WHOI faculty also raised the issue that their opportunities to offer new courses are limited, particularly for the junior staff. We address this topic further below.

On the basis of the documents provided by the Joint Program and our meetings with students and faculty, the committee identified four areas of concern. These include:

1. An increasing lack of “jointness” in the Joint Program, in MG&G as well as across the full program.
2. An imbalance in the MG&G curriculum between course offerings and student and faculty research interests.
3. A time to completion of the Ph.D. degree that is high but decreasing.
4. The high cost of supporting a Joint Program graduate student on a federal grant.

The “Jointness” of the Joint Program

In the reports of the 1998 and 2004 External Review Committees, the top issue raised in the area of MG&G was the loss without replacement of key MIT faculty active in fields relevant to the Joint Program, and the consequent reductions in the level of research interaction between the partner institutions as well as the quality and character of graduate student opportunities in this area. The reduction in MIT faculty participation in the MG&G component of the Joint Program identified in the last two review committee reports has been exacerbated by the subsequent departures from MIT of John Grotzinger and David Mohrig in sedimentary geology and Julian Sachs in paleoceanography.

The Review Committee was told that of 25 faculty members at MIT in the areas of geology, geochemistry, geobiology, and geophysics, 12 participate in the Joint Program through student advising and research. However, the level of that participation is difficult to ascertain for most of those faculty. Only one of the 12 (Tim Grove) is currently serving as the principal advisor for the Ph.D. thesis research of a Joint Program student. The Review Committee was informed that of 17 Ph.D.s in MG&G since 2005, none had a primary advisor at MIT; two were co-advised by an MIT faculty member, but their primary advisor was at WHOI. Moreover, of the 23 current Joint Program students in MG&G, including four students who are scheduled to arrive in the fall, only one has an MIT faculty member as his principal advisor. The fraction of Joint Program major advisors among MIT faculty over the past several years is smaller than at any time in the last few decades of the Joint Program, if not the entire 41-year history of the enterprise.

One encouraging aspect of the current involvement of MIT faculty in MG&G areas of the Joint Program is that three of the 12 participants are junior faculty members (Tanja Bosak, Taylor Perron, and Stéphane Rondenay). As those faculty members build their research groups, it can be hoped that their level of involvement in accepting and mentoring students within the Joint Program will grow.

The G&G Department at WHOI has suffered key losses recently in the teaching program, but has also added considerable strength and diversity to their faculty ranks, particularly at junior levels. In the last five years, 11 new faculty members have been hired, in fields ranging from coastal marine geology (Andrew Ashton, Ilya Buynevich), to biogeochemistry (Joan Bernhard), paleoceanography (Sarah Das, Bill Thompson),

geophysics and tectonics (Mark Behn, Pablo Canales, Dan Lizarralde, Adam Soule), and petrology and geochemistry (Chris German, Alison Shaw). These appointments, together with those at MIT, bring new promise to the educational and research endeavors of the MG&G component of the Joint Program.

To accelerate the realization of this promise, we **recommend** that both MIT and WHOI administrations take steps to enhance communication between the interested groups of faculty at the two institutions. We endorse suggestions made during our visit to establish lecture series at both institutions for staff at the partnering organization, as well as to institute one or more Joint Program “retreats,” either by major discipline or for the entire program. WHOI faculty in the G&G Department would be well served to become more knowledgeable about major crosscutting initiatives at MIT, such as the Joint Program on the Science and Policy of Global Change; the Program in Atmospheres, Oceans, and Climate (POAC); the Faculty Environmental Network for Sustainability (FENS); and initiatives in the area of energy. Such programs may provide mechanisms and opportunities to develop and strengthen collaboration with MIT colleagues. An important motivation to enhance collaboration between investigators at the two institutions would be provided by an opportunity to seek seed funds to initiate novel directions in cooperative research. We **recommend** that the administrations at MIT and WHOI provide a joint source of such seed funds, to be awarded on the basis of competitive proposals by collaborative groups of investigators from both institutions.

MG&G Curricular Balance

Course offerings in MG&G at the two institutions appeared to be adequate in total numbers, but the number, diversity, and balance of courses offered varies greatly among disciplines, ranging from 12 (5 at MIT and 7 at WHOI) in geophysics and tectonics to only one (at WHOI) in marine geology and sedimentology. No courses are explicitly offered in coastal marine geology, despite the fact that this field is central to one of the recently formed interdisciplinary institutes at WHOI and is the research focus of two of the recent staff additions to the WHOI G&G Department. Likewise, offerings in paleoceanography do not reflect the range of faculty and student effort in this area. A parallel issue noted above, and identified by several of the younger staff members in G&G at WHOI, is a perceived lack of encouragement by the JP Academic Programs Office to the offering of new courses, even in areas for which there is strong student interest.

We **recommend** that renewed attention be given to course offerings in MG&G at both institutions. The JCMGG, energized with the addition of members now highly active in Joint Program research and advising, should carry out a comprehensive review of course offerings across the MG&G portion of the JP. On the basis of current research foci within the two institutions, as well as feedback from current and prospective Joint Program students, the JCMGG should identify areas where new courses are needed and propose areas where existing courses might be combined or eliminated to make more effective use of faculty and student time. As part of that process, the G&G faculty at WHOI might develop an internal curriculum committee to address balance in course

offerings at WHOI, with appropriate attention given to student numbers and needs, equitable allocation of teaching opportunities across the faculty, and coordination with courses and crosscutting initiatives at MIT.

Time to Completion of the Ph.D.

An issue identified by both the 1998 and 2004 External Review Committees was a time to completion of the Ph.D. degree that was higher than comfortable (~ 6 years) and the coupled issue of whether high curricular expectations for Joint Program students in MG&G, including numbers of courses and scope of the General Examination, were a contributing factor. The question of time to Ph.D. appears to have been addressed effectively over the past several years, with average times of 5.8, 5.6, and 5.3 years for Ph.D. graduates in 2006-07, 2007-08, and 2008-09, respectively. In part, this decrease has been attributed within the JP to a “recalibration” of expectations for the research projects presented by the students as part of their General Examination.

Beyond that “recalibration” of expectations, which was put into place in 2002, little change has occurred in the General Exam structure since the last two review committee reports. This structure differs from those in other tracks within the Joint Program, which may constitute a barrier to some students seeking to undertake interdisciplinary work. Nonetheless, current Joint Program faculty argue persuasively that the exam structure does foster breadth of research expertise through the requirement that the student complete two research projects in different fields under the guidance of two different advisors. Moreover, the structure is consistent with the General Examination structure within the fields of geology, geochemistry, geobiology, and geophysics in the MIT EAPS Department, a fact that may enable EAPS students to transfer into the Joint Program if warranted by their selection of thesis research area.

Cost of Supporting a Graduate Student on a Federal Grant

A final concern, raised by the faculty at both institutions, is the high cost of supporting a Joint Program graduate student on a research grant. The current-year cost quoted to us was \$64K, after tuition adjustments. This cost is high relative to the cost to a grant of supporting a graduate student at a number of competing institutions, with the result that proposals with budgets that include graduate student support from MIT and WHOI can be less competitive than from peer organizations. This topic is not one on which an External Review Committee can expect to have any impact. It does, however, underscore one of the principal recommendations of the overall report of this Committee, that an increased number of fellowships for graduate student support, particularly for first-year students, should be a top priority of both partner institutions in the Joint Program.

In summary, the Joint Program remains one of the premier educational programs in the world in the marine sciences. That said, there are several areas for which attention by the partner institutions will strengthen both MG&G and the entire Joint Program.

Review of the Joint Program in Physical Oceanography

As mentioned in the main report, the MIT/WHOI Joint Program has had a long and distinguished history, graduating many outstanding students who have gone on to productive careers in academia, government and industry. The Joint Program in Physical Oceanography (JPPO) is certainly no exception. However, the scientific landscape has evolved significantly since the inception of this program over forty years ago, rendering changes necessary if the JPPO is to remain a premier graduate program. Concerns that emanated from the external review conducted in June of 2009 are listed below, followed by the committee's recommendations for how to address those concerns.

Divergence of Interests

The JPPO has been sustained through the years by faculty in EAPS at MIT and by scientists in the Physical Oceanography Department at WHOI. Because the Joint Programs are mapped onto the WHOI departmental structure, and because research foci within university departments naturally evolve over time, the once solid and shared commitment to JPPO is more fragile than it was forty years ago. Given that hires within the WHOI PO department are naturally focused exclusively on physical oceanography, while hires within EAPS cover the breadth of earth, atmospheric and planetary sciences, a divergence of research foci was inevitable. With these diverging interests, and a Joint Program locked to WHOI's disciplinary structure, the Joint Program has, understandably, lost some of its appeal to MIT faculty. Hence, some faculty in EAPS have looked to other venues for training graduate students with interests that extend beyond the disciplinary bounds of physical oceanography. In particular, the MIT Program on Atmospheres, Oceans and Climate (PAOC) has served as an attractive alternative to JPPO for several EAPS faculty in the ten years since its inception. The attractiveness of PAOC is seemingly manifest in the decline of MIT advisors for JPPO students relative to WHOI advisors: prior to 2000, MIT faculty advised the majority of students, yet since 2000 the majority of students have been advised by WHOI scientists. Currently, 15 JPPO students have WHOI advisors; 6 have MIT advisors. Meanwhile, 6 current PAOC students have advisors who are physical oceanographers within EAPS.

Despite this trend, most of the PO faculty in EAPS have been or still are actively engaged in JPPO, but several are approaching retirement. There is a concern that, given the diverging research interests of the two institutions, new EAPS hires may not be in areas that benefit or strengthen JPPO. That concern is heightened by tension that exists between some MIT and WHOI faculty over questions of curriculum, teaching standards and research directions. This tension has contributed to a lack of strategic planning on how to evolve the JP in general and JPPO in particular. Essentially, JPPO appears to be headed in the direction of its sister programs wherein there is little "jointness" in the Joint Program.

Disciplinary Structure

From many fronts, at WHOI and at MIT, from students and faculty, there was a common lament about JPPO, namely that the disciplinary structure is too rigid. In principle, it is possible to do interdisciplinary research in the JP and intriguing examples of JPPO

students pursuing interdisciplinary research were highlighted during the review. Jim Price and Jim Yoder are to be commended for their efforts in this direction and encouraged to continue. In practice however, the lack of consistent degree requirements in the different JP disciplines has frustrated students and some faculty who view the “stovepiping” of the curriculum as an impediment to pursuing interdisciplinary research. In contrast, EAPS has been more nimble in developing MIT-only programs that cut across disciplinary lines. As mentioned above, PAOC is an example of one such venture. Though not intentional, PAOC effectively competes with JPPO for oceanography students who wish to pursue climate-oriented research. This competition has created tension between the faculties at the two institutions.

In addition to frustration with the lack of interdisciplinary cross-over, some students and faculty expressed concern that the physical oceanography curriculum itself was too narrowly defined. While appreciating the value of having a core set of courses that define a course of study in physical oceanography, several students and faculty believe that the current curriculum is out of step with current trends in physical oceanography, with too much emphasis on geophysical fluid dynamics and not enough on other topics such as observational methods, statistics, and numerical modeling. In particular, it was noted that students leave JPPO with little understanding of global ocean models, coupled ocean-atmosphere and physical-biological models, and global data assimilation systems.

Recruitment

An apparent trend towards declining enrollments in JPPO, most recently with only 2 acceptances in each of the past two years, can be taken as a signal that the faculties of the two institutions need to rethink the curriculum and their terms of engagement with one another if JPPO is to thrive in the future. Alternatively, one may be understandably cautious in drawing interpretations from relatively small numbers. However, the review committee believes there is more risk in this cautious interpretation than in the interpretation that would prompt change.

Declining JPPO student recruitment is also a concern because with fewer students, required and elective courses will potentially be offered less frequently, making it more difficult to satisfy degree requirements and/or tailor one’s course load to particular research interests.

Retention

Since 1995, those receiving Ph.D.s from the Joint Program represent 85%, 72%, 64% and 59% of the students entering the Ph.D. program in B.O., MG&G, C.O. and P.O. programs, respectively. Though JPPO is not terribly out of line with the other programs, the perception of current JPPO students, and the message they deliver to potential recruits, is that JPPO has higher attrition rates because of the difficulty of the general exam.

Other statistics compiled by Steve Lentz indicate that for the period 1980 to 2002 (the last year class with no currently enrolled students) only 6% of 127 JPPO students enrolled in the program did not earn any degree (MS or PhD). This number increased to

11% of 34 JPPO students for the period 1995-2002. For the same period, the number of PhDs granted dropped from 71% to 59%, though some of this drop was compensated by an increase in the number MS degrees granted. For the period 1995-present, 69% of 62 incoming students earned PhDs while 8% failed to earn a degree of any kind, numbers that are closer to the long term average.

These statistics provide a mixed picture of JPPO attrition rates. In particular, it is not clear that there has been a significant trend towards higher attrition rates in JPPO or that JPPO's retention is less ideal than that of its sister programs. Even so, it will be important to continue to closely monitor retention rates as one performance metric of the program's success.

Teaching

In general, JPPO students expressed satisfaction with the quality of teaching in the program. Students remarked on the large variability in the quality of teaching from one instructor to another, but none of the students interviewed found a difference in the quality of teaching between MIT faculty and WHOI instructors. JPPO student concerns focused more on curriculum and retention issues, discussed above, and quality of life issues, discussed in the main report. Somewhat ironically, issues related to teaching were brought up more frequently by the WHOI and MIT faculties, as discussed below.

JCPO

As the administrative unit for JPPO, JCPO has responsibilities to the students and to the faculty at both MIT and WHOI. A fair amount of frustration with JCPO was voiced by students and, to a much larger degree, by junior faculty at WHOI. First, the student concerns: students commented that they were no longer getting adequate or timely feedback from JCPO and that the general exams are often "soft pedaled", when in reality the exams are a serious challenge for many, if not most of the students. On the plus side, there was a great deal of student satisfaction with the new position of the JCPO Education Coordinator and many expressed the view that because of this new position, the program was becoming more attentive to student needs.

Some junior faculty at WHOI have been disenfranchised from JPPO because of their interactions with JCPO. It is difficult to ascertain the roots of this disenfranchisement, much less prescribe a cure, but issues surrounding teaching and advising assignments have caused ruptures not only between MIT and WHOI faculty, but also within the WHOI faculty. Junior faculty at WHOI repeatedly remarked that they had "no voice" in JCPO matters despite persistent efforts to contribute to the program. Clearly, communication has been strained on many fronts within JCPO; equally clear is the potential damage to the program in the long run from these strains. It is critical that JCPO rethink its practices and priorities to harness the enthusiasm and talent of junior faculty members who wish to engage in JPPO.

Recommendations

1. First and foremost, it is recommended that physical oceanographers at WHOI, and interested faculty members at MIT, take an active and perhaps leading role in discussions

on the future of the overall MIT/WHOI Joint Program. The overall recommendation of the external review committee is for MIT and WHOI faculty to develop a shared vision and strategic plan for the Joint Program in order to adapt to the changing landscape for ocean sciences in the 21st century. Since physical oceanography plays such a strong role in the other oceanographic subdisciplines, it is recommended that physical oceanographers be proactive in making their discipline integral to the future vision for the Joint Program. Instead of protecting disciplinary boundaries, physical oceanographers are encouraged to intertwine their educational efforts with the other disciplines to strengthen the overall Joint Program and that of JPPO.

2. In order to reengage the MIT faculty with the Joint Program, JPPO needs to be more proactive. With an open marketplace, students and faculty will flock to the most attractive graduate programs. Rather than lamenting the success of PAOC, it is recommended that JPPO evolve into a successful partner, which likely will involve curricular and other significant changes. In order to achieve this transformation, however, MIT faculty need to be involved from the outset. Given the current limitation due to the small number of EAPS faculty presently engaged in JPPO, EAPS and WHOI faculty might want to consider also engaging MIT faculty members outside of EAPS in a redesign of this program.

3. To address the frustration with the JCPO expressed by junior faculty at WHOI, it is recommended that a task force, whose membership should be named by the Chair of the WHOI PO department and the Director of the Joint Program, identify the major issues of concern and recommend structural and/or procedural changes necessary to meet those concerns.

Finally, the committee wishes to thank JCPO for their input prior to, during and after the external review. In particular, the efforts of Steve Lentz were much appreciated. His quick replies to queries and acquisition of requested data were key to our work. Finally, the frank comments from students, MIT faculty and WHOI scientific staff were quite helpful to this review. Though points of disagreement were apparent on several issues, everyone is clearly committed to JPPO and shares a common goal of its continued success.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
WOODS HOLE OCEANOGRAPHIC INSTITUTION

JOINT GRADUATE PROGRAM IN OCEANOGRAPHY

Memorandum of Agreement

The Corporation of the Massachusetts Institute of Technology and the Board of Trustees of the Woods Hole Oceanographic Institution, recognizing that

- there is a growing need for well-educated oceanographers trained at sea, and that
- oceanography is becoming an increasingly important component of the earth sciences, and that
- research in the oceans, as in other scientific endeavors, must be wholly integrated with the education of graduate students, and that
- the education of students at the Woods Hole Oceanographic Institution can be improved by formalizing the program including a responsibility for awarding graduate degrees, and that
- the education of students in oceanography at the Massachusetts Institute of Technology can be improved by a more formal program of cooperation with the Woods Hole Oceanographic Institution, and that
- the marine facilities at Woods Hole, including research ships, can be made more readily available for use by the Massachusetts Institute of Technology faculty and students through close cooperative planning,

have each approved the creation of a Joint Graduate Program in Oceanography for which there will be established appropriate graduate degrees to be conferred jointly by the Massachusetts Institute of Technology and the Woods Hole Oceanographic Institution.

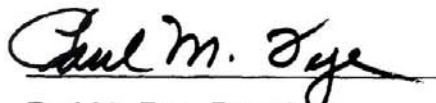
The Joint Graduate Program in Oceanography will be operated through a cooperative arrangement in which each institution, for these purposes, will participate as an equal partner. Decisions affecting the program will be made through mutual consultation, and actions authorized by this agreement will be taken only with the common consent of both institutions.

Moreover, it is recognized that each institution retains full autonomy in appointment of faculty and staff, awarding of degrees, and in all other matters involving that institution alone.

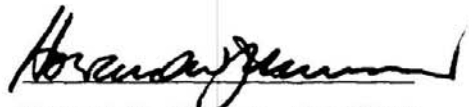
To provide for the effective operation of the Joint Graduate Program in Oceanography, there will be established a joint education committee with equal representation from each institution. This committee will have over-all responsibility for the academic standards of the joint program and for full coordination between the two campuses.

Matters of general policy and guiding principles which require a decision at a higher level than that of the joint education committee will be referred to the President and/or Provost of the Massachusetts Institute of Technology and the President and/or Director of the Woods Hole Oceanographic Institution.

Each institution having obtained the necessary Charter modifications from the Commonwealth of Massachusetts, and the governing boards of each having given their approvals, the undersigned do hereby establish a Joint Graduate Program in Oceanography.



Paul M. Fye, President
Woods Hole Oceanographic Institution



Howard W. Johnson, President
Massachusetts Institute of Technology

May 8, 1968