

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

February 20, 2015

Introduction

The External Review Committee (hereafter, the Committee) met at MIT on December 2, and at WHOI on December 3-4, 2014, to review the Joint Program in Oceanography and Applied Ocean Science and Engineering (hereafter JP). The Committee provided a preliminary oral report of its findings and recommendations during an exit meeting with Susan Avery, WHOI President and Director; Maria Zuber, MIT Vice President for Research; Jim Yoder, WHOI Dean; Rob van der Hilst, EAPS Chair; Meg Tivey, WHOI JP Director; Ed Boyle, MIT JP Director.

Members of the Committee:

Daniel Rudnick, Scripps Institution of Oceanography, Chair

Sonya Legg, GFDL/Princeton, Principal Reviewer for Joint Committee Physical Oceanography (JCPO)

Jess Adkins, CalTech, Principal Reviewer for Joint Committee Chemical Oceanography (JCCO)

Kathy Gillis, University of Victoria, Principal Reviewer for Joint Committee Geology and Geophysics (JCMGG)

Ruth Preller, Naval Research Lab, Principal Reviewer for Joint Committee Applied Ocean Science and Engineering (JCAOSE)

Bess Ward, Princeton University, Principal Reviewer for Joint Committee Biological Oceanography (JCBO)

Emmanuel Boss, University of Maine, Principal Reviewer for Interdisciplinary/Joint Committee Crosscuts

Mike Roman, University of Maryland Horn Point Laboratory, Principal Reviewer for Interdisciplinary/Joint Committee Crosscuts

Ted Dengler, Risk Strategies, L.L.C. WHOI Trustee representative

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 faculty, scientists, students, and administrators. The Committee Chair met separately with department chairs at MIT and at WHOI. The Committee was fully engaged and questioning during presentations and meetings. MIT and WHOI personnel were open to answering all questions. The Committee requested and received additional information in a spirit of complete disclosure.

Findings and Recommendations

The overview document of the JP provided to the Committee does an excellent job of summarizing appropriate background, as does the review of 2009. For this reason, we do not repeat this background here. Rather, we launch directly into our findings (in bold black font) and recommendations (in bold blue font), leading with areas of excellence and followed by areas of concern. Many of the areas of excellence were created or strengthened based on advice from the previous review. All involved with the JP are to be commended for their earnest efforts in responding to that review.

Areas of excellence

The JP continues to be recognized as one of the strongest programs in the country and the world. The JP is a national asset, without which the ocean sciences in the world would be diminished. The JP is a gem in MIT's portfolio that, while small in student numbers when compared to the totality of the MIT graduate program, is unique in its importance to ocean science. JP students do excellent, often world-class work. The theses of JP students are among the finest produced in the country, and JP students get more than their share of national and international awards. The importance of the JP is reflected in the quality of its graduates and in their stature in ocean science around the world. JP graduates continue to get good jobs and to retain them; the pipeline from the JP is not leaky. The committee has no specific recommendations related to this finding except to urge all players in the JP to treasure what they have and to make every effort to keep the JP and improve it.

Efforts to encourage interdisciplinary research by JP students have been successful. A growing number of student theses are focused on interdisciplinary topics, some spanning to social sciences. The structure of the departments at MIT and WHOI still emphasizes traditional disciplines; however, we did not find it to hinder the ability of students in the JP to do cutting-edge interdisciplinary work nor does it inhibit an advisor from one department to advise a student at another department. On the contrary, thesis committees are increasingly interdisciplinary and diverse in their membership. We believe that a contributing factor to this success was a reduction in the number of required courses associated with a departmental PhD (students are still required to have a home department) and the effort to make the general exam more similar across departments. Interestingly, several recent graduates have decided to become Knauss fellows, combining the interaction between science and society and the opportunity to advise policy makers. **We recommend that the JP enhance its website to provide more examples of interdisciplinary opportunities and encourage the JP to**

emphasize its offerings in marine policy and marine resource management to its students and applicants.

The JP has taken several steps toward improving student life. These steps include improving access to health care and subsidizing membership at a fitness club on Cape Cod. Students commented on these improvements, and are appreciative of the effort of JP administration. The students were especially appreciative of a \$10,000 grant they received towards Woods Hole-based social activities, and they forwarded extensive information about how they were spending the funds. Some students at WHOI expressed frustration finding health care providers, but this difficulty is inherent to the location and is not a reflection of the JP. The committee has no specific recommendation related to this finding other than to continue efforts to minimize the stresses caused by the separation between the two campuses.

The JP has paid close attention to the professional development of its students, including tracking them as they proceed in their careers. Former students continue to get good jobs in which they use the skills learned in the JP. The Committee was impressed at the number of JP students involved in research careers (roughly 2/3 of students). The statistics shown to the committee suggests this ratio of 2/3 continues into the latter stages of JP graduates' careers. This is clearly a record to be commended. In addition, JP graduates take careers in industry, non-profits, the government, and the military. The JP has been mindful of the trend for students to take career paths that do not involve research or academia, and has provided mentoring to help graduating students. This help includes the impressive resources at MIT and special events held at WHOI. The Committee urges the JP to continue to provide this help, as it is a model for other academic institutions in this respect. **In order to improve preparation for careers in education, a recommendation is to provide more opportunities for students to teach, perhaps through TAing undergraduate classes. As part of the efforts to keep the JP at the forefront of the field, we recommend that the JP poll its alumni regarding the adequacy of their training and potential ways to improve it.**

The JP has made changes to the general exams to create a more uniform format across the disciplines. On the whole these changes have been for the good. The primary change has been for all disciplines (except AOSE, whose exam is tied to those in Engineering departments at MIT) to have a research component. Two research reports has been the standard in MGG for some time, with students widely happy with the effectiveness and fairness of the exam. For some disciplines this research report is a new component. Whether this additional component has been accompanied by a reduction in requirements in other parts of the exam is unclear for some disciplines. The Committee understands that there is some experimentation going on to improve the general exam. At the same time, the Committee urges the JP to appreciate that the students bear the brunt of this experimentation. It is incumbent upon the JP to make new requirements clear to students well in advance of the exam. **Our recommendation is to proceed carefully with the new general exams, with due consideration for the effects of new requirements on students.**

The academic training of the JP remains excellent. The best measure of the JP's success is the quality of the graduates, which is outstanding. The Committee heard some negative comments about teaching and advising from both students and faculty. In the final analysis the Committee believed that there were no more negative comments than one would expect from a program of the size of the JP. By far, the good outweighed the bad. For example, some comments about mediocre teaching were accompanied by praise for the availability of WHOI scientists outside the classroom. The advisor/student relationship is certainly a central aspect of the graduate experience, and, as with all relationships, requires efforts from both sides to be successful. **In an effort to maintain academic excellence, we recommend that faculty be encouraged to participate in mentoring programs, and that the JP provide support for faculty to improve their teaching skills.**

WHOI scientific staff greatly values the JP, and are committed to its success. This feeling of ownership, and the intrinsic worth of the JP was expressed nearly universally by WHOI scientists with whom the Committee spoke. The JP is essential to recruitment and retention of WHOI scientists, with many scientists citing the JP as one of the main reasons why they came to WHOI, and why they stay at the institution. The JP clearly has a bright future to the extent that the talents of WHOI scientists are directed towards its success.

EAPS leadership cares about the JP, and is committed to its continued success. Included in the Committee's definition of EAPS leadership is the chair and several committed faculty members. The description of the JP as a "gem" quotes from an MIT faculty member in another department. The committee notes that the EAPS chair is now the *de facto* head of the JP at MIT, in a role that was formerly held by the MIT VP for Research. While the EAPS chair now has the responsibility for the JP, the Committee did not see that the concomitant authority was also transferred. This authority is essential to coordinate a program involving more than one department. **We recommend that the EAPS chair be given some measure of authority commensurate with the responsibility of running a JP that spans several departments at MIT.**

Areas of concern

Jointness.

The decreasing "jointness" of the JP threatens the very existence of the program. This is an issue that was raised in the previous review, and was mentioned by four of the five disciplines in their contributions to the report given to the Committee. The decreasing jointness is caused by a natural dispersion of scientific interest at MIT and WHOI since the original MOU was signed in 1968. This dispersion of interest is natural, and neither institution is at fault. **Nevertheless, the Committee believes that both institutions must take steps immediately to ensure the continued existence of the JP.**

Issues of jointness exist in all disciplines, although these issues vary in type and severity. The aging and retirement of MIT faculty devoted to the JP is the most common cause of decreasing jointness across the disciplines. Many MIT JP faculty are senior, raising the obvious question concerning the next generation of JP leadership at MIT. The laudable approach to faculty hiring at MIT is to target the best people available regardless of their specific field. While this will lead to a strong faculty overall, it does select against the small field of ocean sciences, which will not have as many strong candidates in any given year as would larger fields of research, such as Mechanical Engineering. A metric of jointness is the fraction of JP students advised by each institution. The fraction of students supported by MIT faculty is distressingly small in BO and MGG, a concern in CO, and robust in AOSE. The situation in PO needs attention, as the fraction of MIT supported students has declined markedly in the last four years. Jointness is further discussed in the reports on each discipline below.

The Committee has a number of recommendations that the JP might consider to improve jointness. These recommendations may call for changes to standard operating procedure at MIT and WHOI, and thus may prove challenging to implement. However, the Committee believes that some short-term discomfort is worth enduring to preserve the JP.

It is incumbent upon WHOI to improve relations with MIT with regards to the JP. As the future of the JP at MIT depends on a rejuvenation of personnel, WHOI should work to develop productive relationships with young MIT faculty. Specific actions that might be taken include the provision of seed funding to encourage young faculty at the two institutions to embark on joint projects. Another wise use of funds might be to create student fellowships that require joint advising by young scientists at MIT and WHOI. Any steps that forge intellectual ties between young MIT faculty and WHOI will benefit the JP. While both institutions should care that these ties be made, the Committee believes that WHOI should be proactive in fostering these relationships. MIT, for its part, should make clear that working with the JP is desirable for young faculty.

The JP should make special efforts to be involved in MIT initiatives. For example, the nascent MIT environmental initiative offers a valuable opportunity. The Oceans at MIT website is another venue for JP involvement as is MIT's Joint Program on the science and policy of global change. To the extent that these initiatives succeed, they will bring in new resources. If the JP can make itself central to the success of the initiatives, then it would be only natural that the JP's standing at MIT would improve. The Committee is not privy to the detailed history, but it appears that the JP has not always been appropriately involved with some new developments at MIT. It is not worth trying to figure out why this happened, or who was responsible. The essential point is for the JP to make the effort to be involved going forward, by making itself important to the success of MIT initiatives that are relevant to the JP.

MIT and WHOI should develop reciprocal efforts in hiring. The dispersion in faculty interest in the JP is best addressed through a modification to hiring practices. Creating some preference towards participation in the JP in MIT hiring will be the most

effective way to deal with the demographic problem. Having some participation from MIT in WHOI hiring would help to improve intellectual compatibilities between the two institutions. Reciprocal arrangements could include consultation in writing ads, advice on choosing candidates, or membership on search committees. Hiring cooperation could take many forms, limited only by the imagination of MIT and WHOI. The Committee understands that participation in each other's hiring may constitute fundamental change for both institutions. The Committee notes that the inclusion of search committee members from outside the home institution is done in many places. The trust and connection fostered by joint efforts in hiring could be essential to the JP's future.

The JP should focus on improving communications and interactions between MIT and WHOI faculty and students. Activities such as annual JP Colloquia for each of the JP focus areas could include student presentations and faculty discussions on program strategies and education activities. Increased team teaching by MIT and WHOI JP faculty as well as greater course enrollment would be facilitated by more remote teaching participation. The JP should examine their current video classrooms with respect to state-of-the-art technology; classroom layout to enhance interactive teaching; and devise incentives for faculty to teach remotely.

Enrollment

In recent years, there has been a troublesome downward trend in enrollment. This particular concern was highlighted in the material the JP provided to the Committee. If this downward trend continues, the threat to the JP's existence is substantial. The underlying cause of this trend seems to be the general decline in external funding to support students. Exacerbating this trend, in the Committee's view, was an overly cautious approach to admissions in the JP. The Committee has a number of recommendations that might improve enrollment.

The JP should consider yield more carefully in deciding how many students to be offered admission. With increasing competition for the best students, the JP must expect that fewer students will take up their offers than may have done so in the past. The promise of 5 years of funding to incoming graduate students is made by many institutions, so such a funding commitment seems required if the JP is to remain competitive with other graduate programs. At the same time, this promise creates a risk as it depends on the JP to underwrite its scientists who raise the bulk of student support through external grants. There is a delicate balance between admitting students "further down the list" who are less likely to have many competing offers, and having enough funding in case recruitment efforts are wildly successful. The Committee urges the JP to lean a bit more towards accepting risk. Towards this end, the recent requirement that 18 months of funding be in hand before admitting students might be reconsidered.

The budget of the WHOI Academic Program Office should be structured so that higher enrollment is incentivized. Although the Committee did not have the time to understand the budget completely, the appearance was that the WHOI APO budget

took a hit for each additional student. For an administrator trying to be financially responsible, this negative incentive is real. The budgets for many academic departments are structured so that there is a modest positive effect of adding students. In a large, complicated organization, this sort of financial incentive helps to make clear institutional priorities.

Fellowship funding at MIT should be structured, as much as possible, not to disadvantage the JP. There seemed to be some confusion, especially among WHOI scientists, whether there was substantial funding available to MIT graduate students that excluded participation from JP students. The situation is not completely clear to the Committee, given our short visit. But the fact remains that a perception exists that there are advantages to MIT faculty to steer students toward MIT-only programs, possibly given that they may be more likely to obtain assistance in funding the students. To the extent that there is this advantage, young MIT faculty would be especially sensitive to the disadvantages of the JP. Some effort toward addressing this issue would, at the least, improve collegiality between MIT and WHOI.

First-year fellowships for graduate students should be made a priority for development efforts. Both students and faculty benefit from having early fellowship support. Students benefit from having the freedom to shop around and choose a compatible advisor. Faculty benefit by preserving their grant money for students whose interests most closely align with their own. Many development offices find that raising money for student support is an easy sell, as donors often make personal connections with the young people being supported. The Committee understands that student support may conflict with other development priorities. However, the long-term health of the JP is vital to WHOI so its needs should be justly considered in fund-raising.

We close the discussion of enrollment with a few statements on the value of the JP to WHOI and MIT. **Graduate students benefit the research endeavor.** The vitality of graduate students helps scientists to form new and exciting ideas, and to work together across boundaries. WHOI scientists then feel more connected to their institution, and are more likely to want to stay rather than pursue positions at universities. Ocean sciences expertise at WHOI enhances opportunities for MIT faculty to supervise graduate student projects in areas not well represented at their institution. **Having a robust student enrollment improves jointness.** The purest expression of the JP's value is through the productivity of its students. A large, vibrant student body mentored by MIT and WHOI faculty will make the JP more valuable to both institutions.

Conclusion

We close by reiterating the Committee's great respect for the JP. If both institutions take the care now to ensure its future, there is every reason to believe that the JP will continue to excel at graduate ocean sciences education. Any institutional leader should be pleased to be able to add an item to their resume that the JP was rejuvenated during their time in office. At the same time, no reasonable person would want the loss of

the JP to happen on his or her watch. The Committee hopes this report is helpful in some small way towards ensuring the JP's continued success.

Disciplinary reports

Applied Ocean Science and Engineering

The Applied Ocean Science and Engineering portion of the Joint Program (JPAOSE) includes, at MIT, the Civil and Environmental Engineering (CEE), Mechanical Engineering (ME), and Electrical and Engineering and Computer Science (EECS) Departments. Strong interactions exist between the CEE and ME Departments at MIT and the WHOI Coastal Ocean Fluid Dynamics Laboratory, the PO Department (and EAPS at MIT) as well as the BO, MGG and CO Departments at WHOI. The ME and EECS Departments interact with the WHOI Ocean Acoustics and Signals Laboratory and the WHOI Deep Submergence Laboratory.

The JPAOSE offers Interdisciplinary degrees in Fundamental and Applied Ocean Physics and Engineering. Degrees include a PhD in Ocean Engineering, an Engineer of Ocean Engineering and a Masters in Ocean Engineering focused on US Navy students. The program currently offers a broad variety of disciplines of study including (in Ocean Engineering) ocean sensing systems, ocean instrumentation, acoustic remote sensing, acoustic communication and navigation, autonomy and signal processing, ocean physics, and modeling. Disciplines in ME include geophysical hydrodynamics, navigation, communication, autonomy, environmental acoustics, and signal processing. Disciplines under CEE include coastal processes, estuarine processes, and marine biology, while disciplines under EECS include signal processing, robotics, and computer vision. Staff at both MIT and WHOI felt that the program offered at MIT was strong. A few of the WHOI scientists stated that they would like to be able to offer more "hands-on" type courses, and had, in fact, offered these to a small group and gotten excellent feedback from the students. However, the WHOI scientists also understood that, due to the full course load the students had in these engineering disciplines, the students would spend most of their first two years in the program at MIT taking courses. Additional courses at WHOI would then be relegated to the third year of study or later, when often the students were ready to attack their research problems rather than continue to take courses. There is concern about how to get the WHOI expertise into the course work if it is not part of the first two years of courses. This should be further evaluated.

Overall, the JPAOSE program still seems to be very attractive to candidates as reflected by the number of applicants. The program has maintained an average of about 60 applicants in the last 6 years, an increasing number from the earliest date shown at the review (1999 had 27 applicants). Since 1999, anywhere from 5-13 students were admitted each year with anywhere from 3-12 students accepting (9 in 2013) until 2014 when a record low number of students were admitted (3 out of 58) and a record low number, 2, accepted. It is difficult to identify a one-year low as a trend, particularly since there was another low year in 2011 (53 applicants, 5 admitted and 3 acceptances). However, this

certainly bears watching in the next couple of years. If this truly represents a trend, it will require immediate review and action to maintain the health of the program. Some scientists suggested that the program needs to reevaluate the level of risk they are willing to take on with respect to the admission of new students. The WHOI scientists felt they needed to be very conservative and only offer admissions to students they were reasonably sure they could fund for the full 5 years associated with their degree. Being willing to take more risk and the recommendation of first-year fellowships for students should be considered to address this problem if it continues. Young WHOI researchers who are very enthusiastic and interested in having students in the JP find it difficult because of the expense (cost per year of the student) and the level of funding that they are able to obtain as young researchers. First-year fellowships might help, in part, to alleviate this problem.

JPAOSE currently (2014) has 23 students. Five of these students have two primary advisors, an MIT and a WHOI advisor. Of the remaining 18 students, 12 have primary MIT advisors and 6 have primary WHOI advisors. This ratio has changed over the past 5 years with a decline in the number of WHOI advisors (currently ~60%/40% MIT/WHOI). It was suggested that this may be a natural fluctuation in the program that should be carefully watched over the next couple of years. Students graduating from the JPAOSE program move on to positions in both academia and industry almost equally, and as expected more of them go to industry than students graduating from the JP program overall. There were several discussions of the decline of the US Navy students seeking a Masters Degree from the JP. The number of Navy students in the program had dropped to anywhere from 0-2 students over the past 8 years (from a high of 3-4 in previous years). In the past, these students came to the program with Navy funding to support them. Recently, the Navy support has been for one student at most and there is still concern about the inadequate preparation of the Navy students seeking admission. In the past, this Navy support had been viewed as part of the backbone of the acoustics program. The overall long-term decline in U.S. Navy student support implies that the program will remain small in the near term.

There still appear to be some lingering issues associated with the Ocean Engineering (OE)/Mechanical Engineering (ME) merger that took place in 2005, including the fact that OE had always played a bigger role in the JP than ME. There now appear to be a reduced number of admissions to Ocean Engineering. There was also concern about the current admission process. Students of the JPAOSE must be admissible by both the Joint Program and the MIT School of Engineering (SoE) department. JCAOSE admissions are controlled by the SoE department and there are inconsistencies with the way the admissions are viewed: JCAOSE focuses on advisor interest and available funding while ME's focus is on intellectual potential and less on career choice. This process results in a limited pool of OE applicants (based on the ME emphasis) and should be reevaluated. The qualifying exam structure is viewed as somewhat incompatible with interdisciplinary study (judged by a discipline focused exam committee) putting interdisciplinary students at a disadvantage. There was also concern voiced by the WHOI AOSE scientists who felt that they often had to interject themselves into interdisciplinary student projects as they were not invited. There has also been a recent reduction of JP faculty at MIT in ME, CEE and EECS and these positions have not

been replaced. This obviously results in a reduction of subjects offered in AOSE. This faculty attrition issue must be addressed to maintain the health of the program. A common theme in several of the JCs is the lack of faculty involvement and the overall lack of jointness of the program. This is a problem for the JPAOSE as well. Finally, another problem appears to be that the JPAOSE is viewed at MIT as a very small part of the SoE and there is concern that JP issues do not receive a high enough priority to be addressed.

Biological Oceanography

The Biological Oceanography portion of the Joint Program (JPBO) has an outstanding faculty and excellent students. Many of the faculty and students are involved in wide ranging interdisciplinary research. The morale among students and faculty at both institutions appears to be strong and cooperative. Among the WHOI component, the major concern is stipend support for students, which is related to secondary concerns about the size of the program and its sustainability through years when the number of matriculating students is small.

The number of applicants appears to have leveled off since 2009 and the number of admits has generally declined since 2004. The number of applications remains very high, however, so the admit pool is very selective, ensuring that the caliber of admitted students remains high. Of those admitted, the acceptance rate varies around 50% with no significant trend – yet. Retention among students who start the program was 61 % in the last 5 years, the lowest level in the JP. Most of those who left did so after a Master’s degree, mostly because they discovered the JP was not the best fit for their ambitions. This relatively low retention could be a problem because in a sense it represents lost or wasted faculty resources – if students are supported on research grants and they leave before producing publishable research, this is a strain on faculty funding. This may be partly responsible for the decline in admissions recently – a general (and understandable) conservatism on the part of the faculty in the face of an increasingly uncertain funding climate and the need to use research funding productively.

The last review found the JPBO curriculum somewhat ossified, with little apparent change since its inception. Major revisions to the curriculum and course requirements were undertaken in response to that critique. The effect of those changes is difficult to evaluate after this short time so we are not going to micromanage. The number of required courses has been minimized, and several topics courses are offered, such that there is the necessary flexibility to devise rigorous programs of study in traditional BO and in any interdisciplinary flavor. A new interdisciplinary course was introduced in 2014, to provide background particularly in physical and biological oceanography for students entering the program without a marine background. Both faculty and students are enthusiastic about the potential for this course to facilitate interdisciplinary background training across the JP.

In response to the overall advice from the last review to all the JP faculties to increase consistency among the general exams, JPBO has modified its exam to include a written research report, rather than a written exam, as well as an oral proposal defense, with the goal of initiating research sooner and increasing the likelihood of completing the degree within five years. It is too soon to evaluate the effect of these changes on retention or graduation rate, so again, we will not micromanage, but we trust the JCBO faculty to implement and evolve their curriculum and exam format for the benefit of their students. These curricular and exam changes are positive in that they only enhance the opportunities for students to devise their optimal coursework and research experiences.

We understand that the focus of the JCBO in the past few years was the curricular and exam reforms discussed above, and that the next big challenge to be faced is the issue of jointness. This was the main topic of discussion between the JCBO faculty and the visiting committee. While JCBO students are admitted through the Biology department at MIT, the everyday experience of interaction between the two departments is one of benign neglect. JCBO faculty are pleased that the MIT Biology Department is cooperative in accepting their students and in allowing them the autonomy to pursue coursework and advising at WHOI. However, very few MIT Biology Department faculty serve as advisors or even members of advisory committees for JCBO students. Interaction and connection with MIT faculty and JPBO students is more often found with faculty from EAPS and CEE. JCBO is generally satisfied with this level of interaction and did not perceive much change in the degree of jointness over recent time. Increases in jointness were seen as most likely in connection with EAPS and CEE but departures of active faculty members could be a challenge to the program.

The JCBO recognizes the increasing pressure that national funding trends place on the enrollment in the JP. Several factors collectively are exerting pressure on enrollment towards fewer students: declining funding levels at some federal agencies, decreasing numbers of MIT faculty who are actively engaged in advising JP students, and competition for students with related programs at MIT. It is recognized that the JP needs MIT more than vice versa. Therefore it behooves the JCBO to increase not only its visibility but also its desirability to MIT. This need is common across the JP, but the solution involves both marketing and education that are specific to individual JCs. JCBO should identify attractions such as the special expertise of their faculty, the diversity of their research programs, the excellence of their students, unique technical expertise and facilities, exciting research opportunities, etc. in order to increase engagement among MIT faculty in various departments. They might look beyond the usual departments as well as find ways to collaborate with the current partners, and to avoid competition or fragmentation with programs at MIT.

Chemical Oceanography

The Chemical Oceanography portion of the Joint Program (JPCO) is one of the premier training grounds for future marine chemists and geochemists in the country. Even with increased competition from schools beyond the traditional oceanography

institutions, the quality of students and the quality of their research remains very high. Over three quarters of the PhD graduates go on to academic positions in their first job and these statistics do not change dramatically beyond the post-doc years.

Faculty leadership of the program has actively maintained this enviable strength. Students graduate during their 6th year of the PhD program, taking 5.5 years on average over the last 10 years of data. This is in light of a historically low attrition rate of ~20%. In response to the last visiting committee's report, the general exam structure was altered in some important ways. The chief goal was to increase the ease of interdisciplinary research, including JPCO based students that pursue projects that might also have a home in other parts of the JP. At the same time, the JPCO has managed to maintain a culture of the exam process being truly general and serving as an educational experience where students take the time to synthesize their knowledge of oceanography. This is a remarkable achievement and is a useful model for other parts of the JP. Students are asked a year ahead of time (and one year into the program) to choose 5 topics on which they will be examined. Professors then write an exam question in their area of instruction and the students' written answers are followed by an oral examination. In an attempt to include a research portion in the exam, students have to write a report on something they have pursued during the first two years. Generally both the students and the faculty seem happy with the revised exam structure, even after only a few years of implementation.

While the main point of this section is to convey the current health of the JPCO, there are some areas of concern. There is a deep trust between the faculty at both institutions that forms the basis for all decision making and problem solving in CO. This trust is key to the operation of the program and the overcoming of inevitable hurdles. It is always difficult to pinpoint a reason for why this trust exists, but once established it is vital to nurture a culture of mutual benefit and sacrifice for the good of the program. Face-to-face meetings of JCCO and student advisory committees certainly help keep this culture. However, it is the hard work put in by the ~90% of the WHOI CO faculty that participate in the JP and the few "heroes" at MIT which really make the program go. Most of these MIT faculty are in the later parts of their careers and retirements threaten to erode the JPCO jointness if new blood is not identified and nurtured. It is important for the WHOI end of the program to identify potential MIT faculty and then to make sure they understand the benefits, perks, and special relationships available by participating in the JP. Access to top-notch students is just the beginning of the ways that a young MIT faculty member's career can be affected by building strong bonds with WHOI. As mentioned in the general sections above, this process could be greatly aided by having joint membership on each institutions faculty search committees.

WHOI, as an institution, is charting its path forward in an uncertain funding climate. These financial pressures are also evident in the JP. Recent rules that attempt to ensure the availability of GRA funds to support students may not be serving the program well. There is a long statistical record of a 50-60% acceptance rate of JP offers in CO. This robust statistic could be better used to guide admission policies and would lead to smaller fluctuations in class size, and will probably help alleviate the slight trend in declining enrollment. While it is a complex mixture of factors that cause a WHOI faculty member to leave for another institution, the current federal funding prospects are

certainly part of the answer here too. Departures of young faculty who were active in the JP also threaten the health, trust, and collaboration in CO. Many WHOI scientists in CO cite the JP as a key attraction for being at the Institution. The JP is a recruitment and retention tool for WHOI and every effort should be made to keep faculty members on the staff that help it thrive.

In sum, the JPCO is producing strong students with cutting edge thesis work. Application numbers show that students are still very interested in the JP and generally students are happy and well advised during their PhD work. When problems do arise there seem to be good mechanisms in place to deal with them and the mutual trust between the MIT and WHOI faculties is used to find the best outcome. Challenges from trends in federal funding and looming MIT retirements need to be thought about deeply and creatively as they threaten the current health of the program.

Marine Geology and Geophysics

Overall, the Marine Geology and Geophysics component of the Joint Program (JPMGG) left a very positive impression on the Committee. JPMGG continues to recruit outstanding students who are being trained in highly relevant earth system topics. Their students are publishing in top journals, winning awards and going on to faculty and industry positions around the world. Leadership of the JPMGG is strong, due to the committed and active members from both institutions. Thus, JPMGG is in a good position to maintain its position as one of the premier national programs for training the next generation of marine geologists, geophysicists, and interdisciplinary scientists.

The WHOI/EAPS JPMGG faculty we met with see great value in the JP, as it offers opportunities to supervise very high quality students and helps facilitate interactions with a broader pool of researchers, adding depth to their respective pool of colleagues. All felt that the jointness of the JPMGG has improved, but have concerns that the jointness is fragile. The Committee agrees that jointness has improved and considers the participation of more junior faculty in JCMGG and student supervision a very positive development. We have concerns about the JCMGG leadership at MIT in the future, as senior faculty retire. A challenge faced by junior WHOI faculty is how to weigh the pros and cons of participating in the JP, as teaching and mentoring graduate students are not required for promotion and are not given much weight in the review process. We recommend that all parties involved in mentoring provide consistent guidance and that junior WHOI faculty who choose to participate in the JP be well supported. This is not only essential for recruitment and retention of junior faculty, but also for the long-term health of the JP.

We were impressed with the enthusiastic praise by the JPMGG students about the educational opportunities afforded by the JP. JPMGG students feel fortunate to have access to the talent of both MIT and WHOI faculty, and greatly value the flexibility of their program. Some students have been challenged to find an MIT advisor for their thesis committee, due to the small number of MIT faculty actively involved in the JP.

The students acknowledged with appreciation how the APO has worked to improve student life since the last review.

The structure of the JPMGG appears to be working well for its students. Students value the flexibility of the program in choosing their thesis projects and, as stated above, they are tackling important and highly relevant earth system questions. In particular, the general exam requiring two projects is highly valued by both students and faculty, as it provides a mechanism for students to explore two disciplinary areas before settling into their thesis project. The students expressed satisfaction with the general exam and some indicated that its structure was a key recruitment consideration for them. An additional benefit of the general exam structure is that solid earth EAPS students also complete two projects. This parallel requirement reduces the disincentives MIT faculty may feel in selecting JP versus EAPS enrollment for their graduate students (see main text for a more thorough analysis of the incentives/disincentives for MIT faculty).

Enrollment trends of the JP overall are broadly addressed in the main text of this report, and the issues raised there concerning yield and taking risk are relevant to JPMGG. That said, JPMGG has been fortunate to keep its enrollment reasonably steady (~ 5 per year), although admitted student numbers are more variable. Funding is clearly a grave concern and the conservative financial approach used recently has the potential to drive down enrollment. We are encouraged by the APO's comments during our visit that a less conservative approach will be taken going forward.

The diversity of JPMGG students' interests has placed strains on their course offerings. JCMGG faculty and students expressed concern about the required enrollment of 3 JP students for a course to be offered, even if MIT students bring enrollment to ≥ 3 . While the Committee understands the financial practicality of this limit, cross-fertilization of MIT and JP students, and by association their supervisors, is greatly enhanced by the joint participation of these student bodies. The JP/APO is encouraged to continue to explore ways to offer courses with mixed MIT/WHOI enrollments.

The diversity and predictability of course offerings are a concern for JPMGG going forward. A shift in the demographics of JP students from more traditional fields (e.g., geochemistry, geophysics) towards more climate-related or interdisciplinary topics poses some challenges for course offerings (due to enrollment issues discussed above). We strongly support the ongoing efforts of JCMGG and the Education Coordinator to consolidate courses in disciplines that have lower enrollment. While not ideal, finding a way to offer the "marine" perspective on a discipline that augments courses offered at MIT is a practical solution. Better to make some compromise on content than not be able to offer any course in a discipline. We also support the plans of JCMGG to introduce Topics courses as a means to teach, for example, hot topics and smaller disciplinary groups. Broad consultation with staff and students at both institutions, as well as advance planning, should aid in getting the numbers required. The JCMGG will need to consider if a 6-unit Topics course will be adequate to fulfill the course breadth requirements. A related issue is how the course offerings are determined. Based on some anecdotes, we have a sense that some courses are offered because of their popularity (and perhaps the persuasion of the instructor) rather than because they were the best courses to fulfill the

collective needs of the students. It is critical that annual course offerings are determined at the JC level and we encourage the APO to ensure that the JC has the authority to determine the priority of course offerings. Another issue that is not unique to JPMGG is how to entrain junior faculty into the teaching schedule and to rotate teaching assignments in an equitable way. Some junior faculty aspire to teach and feel that having these opportunities is important for their professional development and job satisfaction. This is a challenging issue for the JC and Education Coordinator to resolve. We suggest that the APO and JP Committee work with each disciplinary committee to support them in putting together sensible, fair teaching rotations.

One particularly successful program led by JPMGG is the Geodynamics program, an annual seminar series with a field component, supported by the APO and the Oceans Exploration Institute. The topic changes annually, with an impressive range spanning the breadth of the earth system through time. The program is a unique forum that has successfully brought together EAPS and JPMGG staff and students, in addition to staff and students from other WHOI units (e.g., PO, CO). This excellent program has a long history of success, and the JP/WHOI should do everything it can to keep it going. The JP could consider this as a model for other potential programs that could serve to strengthen the “jointness” of MIT-WHOI.

By all accounts the learning environment in JPMGG is very positive. The JCMGG faculty have an open door policy and informal teaching opportunities are many and of very high quality. WHOI has research groups with a strong sense of community, both at the research and social level. Students commented that cohesion and vibrancy across these disciplinary groups is not nearly as strong. We found it surprising that JPMGG does not have a lecture series that brings all groups together. An event held in Fall 2014 that brought all JPMGG students and staff together to learn about student projects is a great step towards developing more cohesion. We encourage JPMGG to consider hosting department-wide events such as the one described above on a regular, on-going basis.

In closing, JPMGG is producing highly trained marine scientists who have a strong record of success upon their graduation. This success is due to the ability of JPMGG to recruit top students in a competitive market and to the dedicated faculty involved in the JP. This success can also be attributed to the JCMGG and APO who have developed a flexible program structure that allows students to explore a wide range of cutting edge earth system problems. Some of the concerns identified in this disciplinary report can be addressed at the unit level, whereas others will require the attention and commitment of both institutions to keep the JP viable on the longer term.

Physical Oceanography

The Physical Oceanography portion of the Joint Program (JPPO) remains one of the premier programs in the country combining a rigorous curriculum with sea-going opportunities and access to a wide variety of expertise. It continues to attract high quality

students, with no significant trend in enrollment detectable beyond year-to-year fluctuations, and those students go on to successful research employment in the USA and abroad. Significant progress has been made since the last review in addressing several concerns raised at that time. In particular, efforts have been made to facilitate interdisciplinary research by reorganizing the curriculum and aligning the general exam more closely with that of other disciplines. Several junior faculty from WHOI have been entrained into teaching at the request of JCPO. However, several areas of concern remain, as described below.

The jointness of the JPPO is at an all-time low. Like many of the JP disciplines, research interests at WHOI and MIT have diverged over the years, and the motivations for MIT faculty to be involved in the JP (i.e. access to sea-going facilities) have declined in importance. In JPPO, this divergence in research interests has also been accompanied by the development of the Program in Atmospheres Oceans and Climate (PAOC), which has provided an MIT-only focus for graduate education for over a decade. However, the diminishing involvement of MIT faculty in the JP has accelerated since the last review; JPPO now includes active involvement of only two mid-career faculty and one senior faculty from MIT. Some MIT faculty indicated that they perceive disincentives to advising JP students compared to PAOC students, namely less availability of first year fellowships and greater bureaucracy. Not surprisingly therefore, only 5 out of 21 current JPPO students are advised or co-advised by MIT faculty. Those MIT faculty who remain actively involved in JPPO are being called upon to do more and more, particularly given requirements for 50% of JCPO and at least one member of every thesis committee to come from MIT, leading to an obvious overburden of a few individuals. Hiring of new MIT faculty in PO is therefore imperative, in order to replace recent and upcoming retirements, and maintain a viable PO presence at MIT. Ideally, new faculty should be willing and able to participate in the joint program; including consultation with WHOI faculty in the search process could enhance the likelihood of this. WHOI JPPO faculty, for their part, need to encourage new hires to participate in the JP by highlighting opportunities at WHOI (e.g. the GFD laboratory and observation facilities), providing inducements for the new hire to spend time at WHOI, and initiating collaborations with the new hire. As in other disciplines, making more first-year JP fellowships available would help to make JP students as attractive as PAOC students to MIT advisers.

More problematic than the diminished presence of MIT faculty in the advising of JPPO students is the breakdown of collegial relations between the two institutions in JPPO. The ability of JPPO faculty to work together to produce a modernized forward-looking program focused on the best interests of the students is being negatively affected by this poor relationship. A substantial effort therefore needs to be made to rebuild the cooperation between the faculty at the two institutions, focusing on greater openness and better communication. Decisions that will impact the joint program should not be made unilaterally by one institution, but rather discussed in advance between them. For example, appointments to JCPO should be discussed in advance with JCPO, rather than be made unilaterally by one institution. Courses that are fundamental to both PAOC and JPPO students should be coordinated between JCPO and PAOC. Course evaluations for all core JPPO courses should be shared with JCPO, no matter if an MIT or WHOI faculty teaches that course. PAOC and JPPO should recognize that they have common goals (i.e.

the provision of a world class graduate education in physical climate sciences) and work together to achieve those goals. JCPO can help to increase openness and communication by holding more regular meetings open to all faculty.

Reorganization of the general exam, currently in progress, following the recommendations of the previous JP review, appears to be largely positive, but students are worried by uncertainty and lack of clear guidelines. The changes in JPPO take the form of a reduction in the written exam from two days to one day of open book questions only, and the addition of a written research paper. This coming spring will be the first implementation of this form of the general exam, although some changes have taken place each of the past few years. Particular concerns include the lack of guidance for the written paper requirements, and for the level of advisor involvement allowed in the writing of the paper. These concerns could be alleviated by communication of clear guidelines for the goals and scope of the written paper component, along with the level of advisor involvement permitted, and criteria for evaluation, distributed in writing to all pre-generals students and advisors well in advance of the exam.

A further concern is that with the addition of the written paper, extra components have been added to the general exam, and to the workload of the 4th semester, yet the student handbook still advises students to take 12 courses as before. This may lead to an unrealistic workload. JPPO should reconsider whether the recommendation of 12 pre-generals courses is still reasonable, and ensure handbook advice is updated accordingly. If fewer courses are to be taken pre-generals, then some consolidation of courses may be necessary to condense the essentials into a manageable number of courses.

Students are also concerned that the new, more flexible course recommendations may not translate to more choice in topics for the written general exam. This concern comes despite assurances to the contrary from the faculty, because there is a lack of trust between the students and faculty concerning the general exams. Students have a perception that the written general exam has been poorly organized in the past, resulting in students occasionally being assigned questions unrelated to any courses they have taken.

We realize that the general exam is still in the process of modification. However, JPPO faculty should realize that while they can make adjustments next year if this year's implementation reveals problems, for students a poorly implemented exam may be a life-changing event.

Some students reported feeling isolated during the pre-general stage, when they do not have a thesis committee to provide perspective in addition to their advisor. This could be alleviated by providing additional mentoring support to pre-generals students, perhaps in the form of an academic advising committee, as in other disciplines.

Both students and faculty reported that several aspects of JPPO have not been well organized in the past few years. In addition to the disorganization in the implementation of the written general exam, other events of concern include the failure to communicate feedback from the annual reviews to the students for several months, until

after the general exams had already taken place; failure to respond to students' requests for meetings with JCPO in a timely manner; failure to hold regular JCPO meetings including the other faculty; and delay in the revision of the student handbook. Individually, these may seem trivial, but together they make the students' time in the joint program unnecessarily stressful, and contribute to the breakdown in trust between students and faculty, and among the faculty. JPPO faculty should therefore take administrative and implementation responsibilities as seriously as they do teaching and advising, and avoid distributing these responsibilities in such a way that a few individuals are overburdened.

Interdisciplinary Studies

While the coordination, curriculum and exam formats of the JP are divided into five focal areas (biological, chemical and physical oceanography, marine geology and geophysics and applied ocean physics and engineering), an increasing number of JP students choose to conduct interdisciplinary research. The JP webpage contains a "Joint Program Interdisciplinary Statement" which adequately describes how students can effectively engage in interdisciplinary research in the JP. Interdisciplinary students still have a "home" in one of the focal areas, but often have co-advisors that are from different focal areas. Examples from past interdisciplinary students are given for research topics and courses taken. The overall description of interdisciplinary research, paths taken by former students and the general encouragement of students to conduct interdisciplinary research were all clear and compelling. A contributing factor to facilitate increased JP interdisciplinary research is a reduction in the required courses associated with the traditional focus areas and the effort to make the general exam more similar across focus areas. More uniformity or even a common JP general exam format and timing should still be considered.

In order to encourage applications from students interested in interdisciplinary research as well as to facilitate review of the applications, the application form should be modified such that applicants could link the ocean science fields they are interested in pursuing.

Increased funding opportunities and strategic planning in ocean sciences as well as student interests have a greater degree of synthesis between environmental and social sciences. While the WHOI Ocean Policy program is not part of the MIT/WHOI JP at this time, inclusion should be considered as well as more interactions with policy/social science programs at MIT (e.g. MIT's Joint Program on the Science and Policy of Global Change) and partner institutions (e.g. Harvard). Students we met with have pursued some of these opportunities, but they could be featured on the JP website and formally engaged in the JP. Increasingly, this trans-disciplinary research approach will be the norm and will be of interest to current and future JP students.

Interdisciplinary studies in "Climate Variability and Impacts" are highlighted on the JP website which includes an overall statement of their importance, strengths of the

JP in addressing important research area, related courses, and recent student research dissertations. This interdisciplinary topic area is well done and will likely stimulate student applications and acceptance, and can serve as a vehicle to enhance fund raising and awareness for the JP. There are other important challenges to our society such as sustainability, energy, water security, etc., that could be similarly highlighted in the JP website as interdisciplinary research themes. Such clarification of opportunities afforded by the JP may assist with recruitment, as interdisciplinary programs are now the norm at many institutions.