

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

April 10, 2020

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1 Introduction

The External Academic Review Committee (hereafter, the committee) met at MIT on October 28, and at WHOI on October 29 & 30, 2019, 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 Mark Abbott, WHOI President and Director; Rick Murray, WHOI Deputy Director; Rob van der Hilst, EAPS Chair; Margaret Tivey, WHOI Vice President of Academic Programs and Dean; Ed Boyle, MIT JP Director; and Phil Gschwend, MIT Associate Director for the JP.

Review Committee Members

Robert Anderson, Lamont-Doherty Earth Observatory; Principal Reviewer for Joint Committee for Chemical Oceanography (JCCO), Chair

Tuba Ozkan-Haller, Oregon State University; Principal Reviewer for Joint Committee for Applied Ocean Science & Engineering (AOSE) – Coastal

Louis Whitcomb, Johns Hopkins University; Principal Reviewer for Joint Committee for Applied Ocean Science & Engineering (AOSE) –Engineering

Peter Franks, Scripps Institution of Oceanography; Principal Reviewer for Joint Committee for Biological Oceanography (JCBO)

Estella Atekwana, University of Delaware; Principal Reviewer for Joint Committee for Marine Geology & Geophysics (JCMG&G)

Eric D’Asaro, University of Washington; Principal Reviewer for Joint Committee for Physical Oceanography (JCPO)

Jean Lynch-Stieglitz, Georgia Institute of Technology; Principal Reviewer for Climate

Ted Dengler, Risk Strategies, LLC; WHOI Trustee representative (At-large Member)

Written input given to the committee prior to its visit, and during its time at MIT and WHOI, included an extensive self-study document describing the history, structure and operation of the JP, while also containing response to specific findings and recommendations from the previous (2014) academic review. Additional documents provided historical and statistical information about the recruitment, retention, progress, support (funding), and future career tracks of JP students over the past several years.

Introductory overviews from the perspective of each institution were given by Rob van der Hilst (MIT, 28 October) and Mark Abbott (WHOI, 29 October). Meg Tivey provided a more detailed overview of the JP following the presentation by van der Hilst at MIT. Over the course of 28 and 29 October the entire committee heard reports from representatives of each of the five educational divisions incorporated into the JP. PDF files of the slides used in each report were provided to the committee as reference material. Interspersed with these presentations, each disciplinary representative on the committee

had the opportunity to meet independently at each institution with students, and also with faculty, in their respective discipline.

The charge to the committee, provided in advance of the review, identified 11 specific topics to be addressed by the committee. However, time constraints limited the attention provided to some of these topics, in large part due to the emphasis placed on topics highlighted during the 2014 review (e.g., health and jointness of the program, enrollment levels and trends, interdisciplinary research, diversity of students and faculty, general exams/student evaluations) during each of the plenary sessions as well as during individual meetings with faculty and students. The JP is making good progress on the first group of topics, and if progress on these topics continues at its recent historical pace over the next few years, then it is **recommended** that the next review committee devote a greater portion of its attention to those topics that could not be addressed adequately in 2019. Specific findings and recommendations are summarized in Section 2 below, while a summary of the recommendations is provided in Section 3.

The overview document (self-study) of the JP given to the Committee in advance of the review provided an excellent summary of the appropriate background material, as did the review of 2014. For this reason, we do not repeat this background here. Rather, we launch directly into our findings and recommendations. In many cases the findings and recommendations for one topic holds implications for another, so cross referencing is provided where this occurs.

2 Findings

2.1 Vision of the Joint Program

The Joint Program is a resounding success, as manifest by the large number of leadership positions at major ocean research institutions and government agencies populated by JP graduates. MIT and WHOI can take great pride in this achievement. Nevertheless, over time, pressures exerted on the program change while research opportunities evolve to follow societal needs as well as technical advances. Consequently, the committee **recommends** that establishing an updated vision of the JP should be a high priority for the immediate future. Existing JP committees seem to be inward looking, concerned about exams, curricula and student funding, for example. While these are important, the committee **recommends** that the JP set up a working group to explore the role of the JP within the institutions with which it is associated. First, what is, and what should/could be, the role of the JP in the WHOI and MIT mission, and in that context what can be done to elevate the position of the JP within the WHOI and MIT mission? Does this role need to be clarified? Could it be strengthened? It is clear to the committee that the worldwide prominence of JP graduates is of benefit to WHOI/MIT and their missions. Similarly, the committee could examine the potential role of the JP in broader MIT activities. This broader exploration of the role of the JP at MIT would increase the visibility of the JP (and WHOI) at MIT, and identify potential new areas of collaboration, thereby strengthening the health of the program (see Jointness, below). For example, can opportunities for WHOI collaboration with the new Schwarzman College of Computing be identified? If these are found, then the working group could be restructured to encompass MIT faculty as appropriate. Other institutions or entities could be explored as well. This

was brought up in the external review of 2009, and mentioned in the Strategic Plan of 2011, and could be used to strategically look forward to seek new opportunities.

2.2 Jointness (Health of the MIT-WHOI partnership):

2.2.1 General introduction

This topic was highlighted in the 2014 academic review, discussed at length in the 2019 self study (Document 3, “OverviewProgressER2019”), and featured in virtually every plenary presentation and disciplinary discussion held during the 2019 review. The retirement or departure of a number of senior faculty at both institutions who have been strong supporters of the JP for many years has raised legitimate concerns about the implications for the health of the program, which, in turn, has consequences for the future of the JP at both institutions.

The JP is widely recognized as a valuable asset to both MIT and WHOI. Students are attracted by the intellectual depth of the combined faculty of the two institutions, by opportunities for conducting research within a critical mass of the leading experts in the field, and by the opportunities to develop professional networks associated with the large number of leading scientists. Students are also attracted by the prestige of each institution, which in many cases complement and reinforce each other. For example, many undergraduates with prior exposure to ocean sciences are drawn to the WHOI moniker whereas their families are often unaware of the name. These family members, however, often have a general awareness of MIT as a leading center of science and engineering, and that awareness leads to family support of a student’s decision to attend the JP. Altogether, the combined strengths of the MIT-WHOI Joint Program draw the top students in the field to apply for admission. As anyone who has been active in the field for a significant period of time can attest, access to the top students is an invaluable asset. Not only are the top students far more productive than others, but they also often take leadership roles in identifying and developing new research opportunities. Consequently, it came as no surprise that the committee heard from a number of faculty that access to such high caliber students was a major factor in their recruitment. Maintaining a vibrant and healthy JP, therefore, is clearly a major contributor to the quality and success of research conducted at MIT and WHOI.

2.2.2 Progress since the last review

Steps taken since the last academic review, together with ongoing activities, illustrate progress toward strengthening the JP-related bonds between MIT and WHOI. These include:

- Space on the 8th floor of MIT Building 54 has been created for JP activities related to EAPS (Earth, Atmosphere and Planetary Science), increasing the visibility of the JP while also providing space for courses and administrative support (however, this space seems to have been created for EAPS JP students, not for other branches of the JP; dedicated office/activity space for students from all branches of JP is needed on the MIT campus);
- Adding two JP Associate Directors from Engineering (Phil Gschwend and John Leonard) has led to increased engagement of MIT engineering departments in JP activities;
- EAPS (Earth, Atmosphere and Planetary Science) fellowships are available for JP students advised at MIT;

- The MIT Aeronautics and Astronautics engineering department has become engaged in the JP, expanding opportunities for JP students;
- Thanks to a growing number of microbiologist faculty in the EAPS department, some of these now serve as advisors to JP students in Biological Oceanography, often offering more relevant research expertise than was previously available from advisors in the Biology department; consequently, 3 JP Biological Oceanography students now have their primary advisor in EAPS, while 17 of 24 MIT members of JP BO student advisory committee members are in EAPS;
- The number of JP students in MG&G having their primary advisor at MIT has increased from 3 in 2014 to 7 in 2019, reflecting the addition of new faculty in EAPS who are engaged in JP activities;
- The WHOI board's executive committee met with Maria Zuber (MIT VP Research) to explore new partnerships between MIT and WHOI, and Mark Abbott has held follow-up meetings; JP involvement could explore strategies to strengthen MIT-WHOI bonds while also contributing to new research and education partnerships;
- Mark Abbott and Rick Murray have met with administrators in the MIT Lincoln Laboratory, and Meg Tivey and Rick Murray have met with Rob van der Hilst and John Fernandez (Director of the MIT Environmental Solutions Initiative) to similarly explore partnerships, including opportunities related to climate change (see Recommendations below).

2.2.3 Opportunities

A number of initiatives currently underway also provide opportunities for enhancing MIT-WHOI interactions within which the JP partnership can be strengthened, including:

- An Earth and Environment Pavilion at the MIT Building 54 is in the planning stages as part of the MIT Environmental Sciences Initiative, with completion of construction anticipated for 2024; JP presence within the pavilion offers an excellent opportunity to publicize JP activities to MIT students and staff, as well as to visitors;
- The new MIT initiative embodied within the Schwarzman College of Computing offers a number of opportunities for JP students, especially in AOSE, as well as for scientists at WHOI; for example, since WHOI lacks the resources to launch new initiatives in Artificial Intelligence or in Machine Learning (areas of emphasis in the College), providing potential advisors and opportunities for JP students to undertake thesis research in these areas that would otherwise not be feasible;
- Similarly, despite hosting a longstanding Ocean Policy group, WHOI lacks the resources to launch a major policy initiative; students are showing a growing interest in being involved in establishing environmental policy, so here, too, JP students may be able to find advisors and opportunities within MIT policy initiatives to undertake thesis research that would otherwise not be feasible;
- The Beaverworks initiative of the MIT Lincoln Labs is designed to offer undergraduates an opportunity to apply new technologies to “old” problems; it is unclear if this initiative provides an opportunity for JP students, either for research or through opportunities to TA courses, but it could serve as a feeder program to interest MIT undergraduates in Ocean Sciences;
- The review identified a need for improved courses in ocean instrumentation (see Curriculum); the committee sees an opportunity to involve the new maker space facility being constructed on the Quissett Campus as an opportunity to combine new initiatives that engage faculty at MIT with scientists at WHOI while also representing a training facility

servicing a new course in ocean instrumentation, although further discussion is needed to determine how these related goals might be accomplished.

2.2.4 Overriding recommendations regarding “Jointness”

Throughout the review two principal **recommendations** surfaced repeatedly:

- 1) Enhance the awareness among MIT faculty about the benefits of participating in the JP, and
- 2) Increase and improve the opportunities for face-to-face interaction between faculty and students from both institutions.

MIT participation in the JP can be enhanced through advertising and promotion of the benefits of participation. The JP is a small drop in the MIT ocean of high profile research. MIT faculty can prosper without participating in the JP, finding top quality students while avoiding the extra administrative burden of participating in an additional educational program. The JP is therefore encouraged to identify ways to make participation in the JP more appealing to MIT faculty (e.g., reducing the administrative burden of participating in the JP; opening opportunities for new research initiatives).

A regular annual event that brings together faculty and students from both institutions is felt to be desirable, by students and faculty interviewed as well as by the committee. However, the nature of the event that would attract the most people is unclear. One option would be a half-day science symposium that involves short talks from scientists and/or students at both institutions, followed by a nice dinner (or a reception with sufficient food to serve as a dinner) to provide an opportunity for social engagement. Transportation could be scheduled to reduce traffic congestion delays (e.g. to/from late morning/ after dinner). Perhaps the first event would focus on the optimum design of the subsequent annual events. Some questions to be addressed in developing a strategy to increase interaction include: Are science talks the strongest attraction? Or would more people attend an annual picnic with family activities? Or should these be combined, with science talks given before the picnic?

Leaders from both institutions need to demonstrate that integration is important, so these leaders should participate in these annual events. Other senior leadership at MIT are encouraged to participate as well, whether from engineering departments or at the provost level when planning for new initiatives.

At a more immediate level, the committee heard repeated calls for better A/V quality for web-based conferences, seminars and courses, including a greater number of rooms equipped with A/V technology as well as improved quality of the equipment. No arguments to the contrary were presented, so the committee **recommends** this as an early step toward enhancing the engagement of students and staff at the two institutions.

MIT participation in the JP can also be strengthened through selective recruiting of new MIT faculty hires. Understandably, MIT seeks the most qualified candidates through open searches, but the evaluation process would benefit by input from WHOI scientists with recognized expertise in areas represented by leading candidates. More importantly, WHOI scientists can shake the bushes to identify top candidates in oceanography and encourage them to apply for MIT searches, and, in particular, to help identify candidates

who are motivated to participate in the JP. MIT searches are often very broad, so the JP can help itself by encouraging excellent candidates in ocean sciences to apply for MIT searches.

On several occasions during the review the question was raised as to whether providing temporary housing in/near Woods Hole available to MIT faculty would raise the level of participation in JP education as well as in collaborative research projects involving scientists from the two institutions. Nothing was resolved about this issue, but it is **recommended** for consideration.

In considering the concerns about the “jointness” of the JP identified above, together with some of the issues raised in discussing topics such as enrollment, professional development and diversity (see below), the committee discussed at length the potential value of using “**climate**” as a unifying theme of education and research encompassing both institutions on which the JP could take the lead. As an existential threat to humankind, the topic of climate change is an urgent area for research. The growing interest among young people in climate change is well established, as is the attraction of this topic to young members of underrepresented groups in ocean sciences (see Diversity, below). Consequently, a focus on climate is viewed as an opportunity shared by recruitment efforts as well as in efforts to increase collaboration among scientists at MIT and WHOI.

For these reasons, the committee **recommends** that CLIMATE be explored as a broad integrative umbrella. The initiative could begin within the JP and later spread throughout the structure of the research administration. Each discipline within the JP has a place under this umbrella. Focusing on climate would foster interdisciplinary collaboration, both within WHOI and to open up partnerships with more disciplines at MIT. Participation by scientists working on atmospheres and oceans could begin almost immediately, and later, once these are established, this initiative could spread among broader fields (engineering, economics, policy, etc.). Initially, students would still be administered under traditional disciplines, but they would benefit from diverse expertise and coursework offered in the JP. If it is successful then the faculty can consider revising the curriculum to better support the needs of the students working under the CLIMATE initiative. It is anticipated that this emphasis in the JP on CLIMATE would encourage more MIT faculty to engage in the JP education – at least in those aspects under the climate initiative. Successful integration of WHOI and MIT research on climate would then provide a template for WHOI and EAPS to engage other departments and schools at MIT to collaborate on new initiatives related to climate (assessment, prediction, adaptation, mitigation, policy, education, etc.).

If the JP adopts this recommendation, then the committee further **recommends** offering a “Certificate” or other recognition of a student’s having completed a body of research that contributes to our understanding of the physical climate, as well as of the many related fields that include, but are not limited to, sustainable energy, coastal zone security, climate-related hazards, adaptation, mitigation, policy, education and communication. Creating a certificate in CLIMATE would bridge all of these disciplines. The certificate would integrate research, faculty and students from various disciplines at WHOI and MIT. The committee sees this as a potential strong benefit to both institutions, and as a mechanism that would contribute to their “jointness,” including an enhanced partnership with the MIT Program on Oceans, Atmosphere and Climate (PAOC).

With these general recommendations in mind, the committee noted that climate is not well represented in JP recruitment materials. While some of the recommendations above will require lengthy discussion and a substantial implementation process if the recommendation is acted upon, in the near term the JP can strengthen its overall recruitment, including its appeal to students with a diversity of backgrounds, by promoting climate research as a broad umbrella under which interdisciplinary research of many forms is readily accommodated. If enacted, the JP leadership is encouraged to consider how best to locate JP students interested in interdisciplinary climate research within the traditional departmental structures of the partnering institutions.

2.3 Enrollment and recruitment

The JP currently enjoys an overall healthy level of enrollment, although statistics show substantial variability among disciplines. Currently, the number of students in the Chemical Oceanography program is high, while the number in MG&G has dropped to a point of concern about maintaining a critical mass (see additional comments below). Among all disciplines, independent of current enrollment, the overriding concern for maintaining a healthy number of students is the high cost of supporting students on grants. This cost is particularly challenging for assistant scientists/professors who are at an early stage of establishing their professional career. For WHOI scientists in particular, covering their own salary leaves little funding left to support a graduate student.

The 2014 academic review recommended that the solicitation of funds for student fellowships be set as a priority for institutional development initiatives. This request was voiced repeatedly throughout the current review, as well. The committee recognizes that development efforts are necessarily broad, endeavoring to match donors with targets of personal interest to them. Historically, student fellowships have not held a high level of appeal to donors. The committee **recommends** that this be revisited, especially if targeting fellowships to underrepresented minorities appeals to an as-yet untapped population of donors.

The endowment funds that enable the Academic Program Office to pick up the cost of JP students who fall off grant support, or whose 3-year fellowship ends, serves as a powerful recruitment incentive. Recruitment could be strengthened even more if the support of all first year students could be decoupled from grants. Fellowships are available for first-year JP students whose principal advisor is in EAPS, providing leverage for recruiting top student candidates while also allowing MIT faculty to better match the interests of incoming students to available research projects. A limited number of fellowships is available for students whose principle advisor is at WHOI, but currently the number is small (5). The committee reiterates a point from the 2014 review, emphasizing that increasing the number of first-year fellowships would strengthen the recruitment process, both through its appeal to prospective students and by decoupling the admissions process from the need to have funding in hand to accept a student. The current requirement that an advisor must have 12 months of funding in hand to take on a new student limits the ability to match incoming students with projects of interest. Relaxing this requirement with a larger number of first year fellowships would enhance the ability to attract the most qualified students regardless of their advisor's funding status. Discussions with WHOI faculty revealed widespread (although not universal) support for the allocation of new

fellowships to early career scientists to accelerate the development of their research portfolio.

Declining enrollment is seen as a particularly worrisome problem for MG&G. The current enrollment is suboptimal in that there are insufficient students to meet the 3-JP student minimum enrollment required to allow a JP course to be taught. To illustrate, 12 of 31 MG&G scheduled course offerings since 2016 were cancelled due to insufficient enrollment. To some extent this can be addressed by combining courses to increase the number of registered JP students in each course, thereby exposing students to the material that they need to master as part of their professional development. However, MG&G students lack the numbers to create a cohesive cohort of peers that both enriches the graduate school experience and provides the foundation for a professional network that will follow the students throughout their career.

Visiting students at the open house can see that the MG&G department is small and that it consists of fragmented research groups with poor integration of students. The faculty believe that prospective students are disenchanted by this situation. MG&G students in fields other than paleoceanography feel poorly integrated with the rest of the JP, both at WHOI and at MIT. A fundamental problem is how to make MG&G students feel integrated into the JP when the field of solid earth MG&G seems to be experiencing declining interest and declining funding. The committee **recommends** that the JP consider whether the above recommendation for an overarching climate initiative could help unite JPMG&G students into a more coherent group by linking a greater range of topics (e.g., coastal geology – sustainable infrastructure; marine geology – renewable energy production and/or carbon sequestration). Meanwhile, the committee was pleased to see a growing number of EAPS faculty involved in mentoring MG&G students, as well as plans in place to intensify recruitment through a range of mechanisms that offer personal interaction with prospective students, including summer intern programs and open house.

The concern about course cancellations due to an insufficient number of registered JP students is not limited to the MG&G program. In some cases, these courses may have MIT (not JP) students registered, but since the JP does not recover tuition from MIT for these students, their presence does not help meet the 3-student minimum enrollment for a course to be taught. Meg Tivey and others in the JP leadership indicated that this situation is unlikely to change (i.e., MIT is unlikely to release tuition funds for MIT-only students taking JP courses). Therefore, the committee wondered if it would be possible, or even a preferred solution, to encourage qualified MIT students to register for the JP. The committee did not have the opportunity to discuss this option with JP leadership, but recommends that the possibility be explored. For example, as a first step the committee **recommends** that the JP talk about the JP with the MIT-only students taking JP courses and with their advisors, and then poll them to express their views about transferring to the JP. Depending on the outcome, the JP may then wish to launch a more vigorous effort to encourage these MIT students to become formally associated with the JP.

The committee considered other factors that could affect tuition recovery and the general financial status of the JP. For example, the number of guest students (students from other institutions conducting research at WHOI) is often substantial, at one point approximately equaling the number of students in the JP. Many of these students assist

WHOI scientists with their research at a cost much less than that of a JP student. The committee heard concerns that these guest students may be displacing JP students, with consequences such as reducing the enrollment of JP students in courses that lack the minimum number of registered students to be taught (see above), reducing tuition recovery for the JP, and reducing overhead recovery for WHOI. The committee learned that the guest students also provide a number of benefits that may offset the liabilities, such as enhancing the research that can be accomplished, while integrating well with JP students and adding to the diversity of students on campus. Mark Abbott and Meg Tivey are currently developing a policy for guest students that will address many of these issues, and the committee endorses this effort.

The committee also asked if adding a masters degree program could serve as a source of tuition funds, and whether WHOI might benefit from launching a PhD-granting program on its own, independent of MIT. In response, the committee was informed that these options have been considered at length, and found not to be worth pursuing. Therefore, the committee makes no recommendations, but notes these discussions to document their occurrence.

2.4 Curriculum

During the course of the review, committee members participated in several discussions concerning the merits of maintaining the historical disciplinary structure of education when some of the most exciting research, as well as much of the funding for research, involves combining expertise from multiple disciplines to address interdisciplinary problems. A variety of opinions were expressed on this topic without reaching a consensus. However, one noteworthy point is that an in-depth training within a discipline enables a person to apply their knowledge to a wide range of interdisciplinary problems. For example, a study of the spring bloom in the North Atlantic Ocean, and its impact on ocean-atmosphere CO₂ exchange, requires coordinated contributions from experts with high levels of training in ocean physics, biology and chemistry.

A corollary issue is the need to find the right balance between breadth and depth in a student's coursework. The courses offered within each discipline provide students with a well-balanced selection, so attaining depth is within reach for most students. Breadth is similarly achievable by taking courses in disciplines other than the one with which the student is affiliated, as well as by taking courses at other departments at MIT or at Harvard. Oceanography is inherently an interdisciplinary field, as noted above, so it is to the benefit of a student's professional development to reach out beyond their immediate research area to obtain training in the areas of oceanography that will support them throughout a career of 30 to 40 years duration. Of course, the benefits of attaining a sound training in diverse areas of oceanography must be weighed against the risk of becoming spread too thin, and of taking an excessive amount of time away from research.

The overall strengths and weaknesses of the JP curriculum are difficult to evaluate when the course requirements vary as much as they do among the disciplines. This is especially true in AOSE where the four partnering MIT departments have very different requirements. With the exception of engineering, the other JP disciplines have relatively few courses that all students within the discipline are required to take. This flexibility, together with the healthy variety of courses offered within each discipline, allow a student's

training to be tailored to their individual interests and intended career track. In principle, this is a positive situation that can be used to attract independent-minded self-motivated students. The primary question that remained unaddressed during the review is “Is it working?” That is, are JP students receiving the appropriate training for their chosen career paths? If an assessment of this issue has been done, then the committee did not see the results. The committee was informed that the JP tracks its graduates throughout their careers, so it **recommends** that these graduates be polled at specified intervals (e.g., 5, 10 and 20 years) to request feedback on the professional training that they received in the JP, including recommendations for adjustments to the curriculum that would have better prepared them to succeed in their current career track.

Several specific concerns about the curriculum were registered throughout the review. As noted above, several MG&G courses have been cancelled over the past few years due to insufficient enrollment, raising the concern that the students are not given the opportunity to learn material that is critical for their professional development. The committee **recommends** that MG&G faculty explore strategies to combine existing courses to attain the minimum number of registered students, while also providing students with exposure to a minimum set of essential principles and concepts. Incorporating material into “topics” courses, as used successfully in biological oceanography, represents another strategy to be explored, as it allows tailoring of the material to be presented to the specific needs of the student currently enrolled in the course.

Faculty in other disciplines also expressed an interest in adding topics courses to their curriculum. Benefits include providing the opportunity to introduce new material into the curriculum without going through the formal process of proposing a new course, and the flexibility to cover material that may hold unique timely significance, for example, in preparing to launch a new research initiative. Having heard positive comments about topics courses from faculty in most disciplines, the committee **recommends** that the JP administration take the appropriate steps to facilitate the addition of new topics courses.

The committee also heard several concerns about the need for more appropriate introductory-level courses, such as would be designed for students entering graduate school with little prior exposure to ocean sciences. For example, MG&G students expressed dissatisfaction with their required courses because the material was felt to be too basic for students entering the program with some prior knowledge of the field, whereas at the same time students from other disciplines with no prior exposure to MG&G principles were often lost, unable to keep up with the material being presented. Similarly, the committee heard that physical oceanography courses are designed for specialists in the field, with the consequence that many students from other disciplines take no PO courses during their tenure as PhD students. The committee did not have the opportunity to determine how students in each discipline obtain a minimum knowledge of essential principles from other disciplines, but as noted above, oceanography is inherently an interdisciplinary field, and exposure to these principles should be an essential part of student training. Over the course of a career, an individual is likely to be involved in numerous situations that require a minimum knowledge of broad areas of oceanography. If necessary, each discipline may wish to offer introductory courses designed for students entering the program with little background in oceanography. Alternatively, interdisciplinary courses can be offered that incorporate essential information of this nature. The committee does not intend to prescribe

a specific strategy, but rather **recommends** that JP faculty examine whether or not the existing curriculum conveys sufficient interdisciplinary breadth (but within ocean sciences) to prepare students to participate in interdisciplinary projects in which they are likely to be involved later in their careers.

A final point about the curriculum that the committee wishes to raise involves courses on instrumentation. WHOI has been a leader in advancing ocean sciences through the development of novel instrumentation, so it was surprising to learn that no lab space is available to train students in the design and construction of instruments. Students and faculty agree that adding a hands-on lab course on the design, construction and testing of instruments would be a valuable addition to the curriculum. With this in mind, the committee **recommends** that the individuals responsible for the new maker space under construction at the Quissett Campus explore the possibility of including labs with sufficient flexibility that instrumentation courses can periodically make use of the space.

2.5 Teaching and mentoring

No student complaints about the quality of the teaching and advising were registered during the course of the review. This is an improvement over previous reviews, and suggests that students are learning how to get the most out of each instructor's individual strengths. A teaching and learning lab is available to help instructors gain additional skills when it is apparent that improvements are needed. Instructors pay attention to the course evaluations, and use this information to make adjustments as well. Course evaluations are open access so that prospective students can see them when making decisions about which courses to take. These steps seem to be working well.

The committee notes that it would have been informative to have had access to an overview or synthesis of these course evaluations, and **recommends** that they be provided to the next academic review committee. Clearly, the individual course evaluations may contain personal, sensitive or proprietary information, but a statistical compilation broken down by discipline and by individual questions will give a better sense of where the instruction is succeeding and where improvements can be recommended.

The committee also learned that exit interviews are routinely conducted with recent graduates, but that the results of these interviews are not shared with faculty. Feedback from recent graduates represents a valuable resource to be used in making improvements to the overall education process. Therefore, the committee **recommends** that results from the exit interviews be made available (in aggregate so as to remain anonymous) to the faculty, and also that a summary of feedback from exit interviews be provided to the next academic review committee.

2.6 Assessment of student preparedness (General exams and thesis proposals)

Assessing student preparedness for PhD research is a common source of concern and the JP is no exception, as reported by previous academic review committees. Responding to previous reviews, the joint committees of the JP have taken steps to improve the examination process, and they continue to evaluate alternative strategies (e.g., substituting a written exam for a report on a second research project). The joint committees are commended for sustaining their efforts to assess and improve these evaluations of students. Although the committee can see advantages of introducing a more standardized

general exam procedure, there was no evidence to indicate that any one process was clearly superior to those used in other disciplines. Consequently, the committee commends the faculty for their efforts, and **recommends** that an assessment of the exam format and structure remain an ongoing process.

Regardless of the procedure followed, the committee received multiple indications that the overall process, encompassing research reports, oral and/or written exams, and the thesis proposal, could be streamlined. Students from more than one discipline indicated that they may be drawn away from their research for as much as 6 to 8 months while completing the process, and asked if this is truly necessary. Each step of the qualifying process provides information of value in assessing a student's progress and preparedness for PhD research. The committee makes no recommendation for eliminating any specific portion of the process, but makes the general **recommendation** that reducing the amount of time that students are away from their research would be of value.

Although the committee did not have the opportunity to investigate in detail the factors that consume so many months of a student's time, there was speculation that the students may be unaware of the purpose or the expected outcome of each step. As evidence, it was noted that on multiple occasions students expressed frustration that advisors are not permitted to have greater involvement in the preparation of research reports or thesis proposals. For example, students noted that research reports would be more nearly ready for submission for publication if advisors were allowed to have greater input during their preparation. These comments suggest that the students may be unaware of the purpose of the research report, which, together with the outcome of the exam(s), is to assess the student's preparedness to conduct PhD level research. Similarly, the thesis proposal provides the faculty with the opportunity to assess a student's ability to synthesize and critically analyze recent literature while developing an idea, question or hypothesis for further investigation. The purpose of each step is articulated in the handbooks prepared by the JCs, but it may still be helpful for each student to discuss in person with their advisory committee the goal of each step and its desired outcome. The committee **recommends** that this discussion be held in person, toward the end of the student's first year, to help students reduce the amount of time devoted to the evaluation process, while simultaneously offering guidance about best strategies to prepare for each step.

Exit interviews have determined that by the time of graduation, students generally appreciate having had the opportunity to review material, consolidate knowledge and clarify concepts while preparing for their exams. Conveying this longer-term outlook to entering students may also help them prepare for their exams. A related step to help students review, consolidate and clarify would be to add a section to each course syllabus that defines the expectations and learning goals of the course. The committee was provided with access to course syllabi, and found that learning goals are generally not defined. The committee **recommends** that syllabi be standardized to include learning goals as a step that could be taken immediately to help students prepare for their general exams.

One concern brought to the committee's attention is that the existing policy that limits an advisor's input on research report and thesis proposals may give an advantage to students with strong peer-group support, while discriminating against students working on topics outside the mainstream of the field, those from non-traditional backgrounds, or those

with other responsibilities (e.g., families), who may lack a strong student support network. The committee was presented with no evidence to indicate that this is currently a problem, but recognizes it as a possibility that may also affect minority students, and thus **recommends** that the JP take note of any correlation between student success and factors that may influence their level of support from fellow students.

All of the disciplines provide annual reviews of each student by the respective JC. It is not clear if a similar process is followed by every discipline. In principle, such an annual review is a good opportunity to offer the student feedback on their past performance and guidance for the future. However, the committee received no information to assess the success of these annual reviews. Therefore, the committee **recommends** that the JP evaluate the effectiveness of these annual reviews, for example using feedback from students, and present a brief summary together with recommendations for improvement at the time of the next external academic review.

2.7 Professional development

Joint Program graduates are leaders in the field of oceanography, holding high-level positions at universities, in government agencies, and at research institutions worldwide. This success lends strong support to the view that JP students are well prepared for careers in academic (basic) research.

Less clear is the level of preparation for non-academic positions. Increasingly, PhD students nationwide are seeking non-academic careers, and those at the JP are no exception. For example, a growing number of JP students interested in policy-related career tracks was noted by faculty. It was reported to the committee that the MIT career office offers advice to students on non-academic career tracks, while WHOI brings in panels to speak with students about non-academic careers. These opportunities are commendable, but the committee received no information about their effectiveness. In light of the growing interest in non-academic careers, the committee **recommends** that the JP provide the next external academic review with an overall assessment of the professional preparation of JP graduates, including information about their success in seeking careers in policy and in other non-academic career tracks.

The JP has always offered a research-intensive educational opportunity. Therefore, it is reasonable to ask if JP graduates emerge from the program with sufficient training to succeed in a position that involves a significant amount of teaching. At other universities, PhD students obtain teaching experience by serving as teaching assistants, but TA opportunities are relatively rare in the JP, at MIT as well as at WHOI. It was noted that JP students have found TA opportunities in other departments at MIT, but the committee received no information about the number of students involved or the quality of the experience that they received. It is **recommended** that the JP poll these students to assess the outcome of their experience. If it is determined to be generally positive, then the JP can establish an information resource to help JP students locate these TA opportunities.

The committee **recommends** that the JP explore opportunities for JP students to develop experience in teaching. For example, WHOI could offer a 2-week course for undergraduates during the Independent Activity Period (January) that recruits from URM (underrepresented minority)-intensive schools. Perhaps JP students could be offered the

opportunity to develop the curriculum as well as to lecture, thereby providing instructional experience for those students moving on to academic positions. An added benefit is that the personal contacts made through this program may help JP students later in their careers if they find themselves in a position at a university seeking to recruit students from a more diverse population.

The previous academic review committee (2014) recommended that the JP poll alumni to ask about their preparation for teaching and about how to improve teaching skills among JP students. There was no information in our package to indicate that this **recommendation** was pursued, so we reiterate that it would be good to poll alumni to ask (a) if they would have benefited by having had more opportunity in graduate school to develop teaching skills, and (b), if so, then what opportunities would be most useful. This recommendation, combined with that noted above under “Curriculum,” may be merged into a broader recommendation that JP alumni be polled at regular intervals to seek feedback on their preparation in graduate school for all aspects of professional development (e.g., research, teaching, mentoring, public outreach and communication) that support their career, as well as seeking feedback about steps to improve the training provided by the JP.

2.8 Diversity

Efforts throughout the Woods Hole community to increase diversity among faculty, students and staff were presented during the review. These efforts, partially summarized below, are to be commended and the community is encouraged to sustain and even expand these efforts. Where the committee saw evidence of the greatest need for improvement is in the degree to which MIT, WHOI and the JP provide a welcoming and inclusive environment for people from URM backgrounds. This, too, is described in greater detail below.

The diversity-enhancing activities described to the committee include an anti-racism workshop encompassing all of the institutions within the Woods Hole research community. A Woods Hole diversity advisory committee has been established. At WHOI, Mak Saito and Annette Govindirajan co-chair a committee charged with improving the work environment, with a view toward supporting diversity. JP students take a training course to help them better recognize and address unconscious bias. Increasing diversity is a factor used to allocate JP fellowships among entering graduate students with primary advisors at WHOI. Each of these steps is to be commended.

Concerns involving unconscious bias were also brought to the attention of the committee, including a perceived sense of elitism displayed in the web presence of both institutions, as well as in recruiting material of the JP. Many students from culturally diverse backgrounds have had fewer opportunities for advancement than others, and consequently may be made to feel unwelcome or excluded by elitist language and attitudes. One recommendation suggested by WHOI faculty to address this situation is to encourage scientists to receive additional training about best practices for interacting with URM, although no specific programs were identified. The committee further **recommends** that the JP examine its recruitment materials to consider new ways to convey the high quality of the educational opportunity offered without falling into language denoting elitism or arrogance that can discourage candidates from disadvantaged backgrounds, as well as

candidates from other nations where “being number one” is less often promoted than in the U.S.

Approximately one third of the summer undergraduate interns at WHOI are URM. As noted above (Enrollment), the personal contact provided by the intern program represents a valuable recruitment tool to help bring a greater diversity to the JP. Concerns about elitism were found to occur within the summer intern program as well. WHOI faculty recounted incidences where URM interns participating in their first internship were made to feel unwelcome or inferior by white interns who made a point to speak about their accomplishments and prior internships in which they had participated. Although these were anecdotes without accompanying statistics, the committee **recommends** that the JP (and WHOI and MIT) consider that adding sensitivity training to the summer intern program may improve the success rate for using the program as a pipeline to feed URM into the JP. Training, for example, may be as simple as letting the interns know that self promotion is more appropriate for their CV or in discussion with advisors than in social interaction with their peers. This can be a good opportunity to convey the value of a culture of collaboration rather than competition in the scientific endeavor.

Of course, addressing concerns involving elitism is a delicate issue. The most qualified candidates, whether for graduate programs or for faculty positions, are often attracted to opportunities to work or study at a high-caliber institution. Indeed, it is the opportunity to learn from, and collaborate with, the top scientists in the fields of oceanography and engineering that attracts students to the JP. Here, the committee has no specific recommendations, but generally encourages the JP to seek strategies to create an inclusive and welcoming environment without sacrificing the message that the program offers some of the most exciting opportunities available for research and education in ocean sciences.

Other policies and practices of the JP were also thought to discourage URM students. For example, cruises aboard research or sailing vessels and field trips are used as recruiting tools because of their great appeal, but they can be intimidating to students from less economically advantaged backgrounds who have no prior experience with such activities. The admissions process selects from students who have already taken the most quantitative and challenging courses, many of which URM students have not had the opportunity to take. The practice of encouraging JP students to find their own way to a research project was also noted to discourage students from disadvantaged backgrounds who may need additional assistance. In this context, the policy that restricts the advisor’s input on research reports submitted in advance of the general exam or on thesis proposals was suggested to discourage URM. With each of these items in mind, the committee **recommends** that the JP seek an appropriate balance between pursuing research and education at the highest possible standards of scholarship while also providing a welcoming and inclusive environment that will encourage participation by individuals from disadvantaged backgrounds.

The committee **recommends** that the JP continue to use the summer intern program as a pipeline to attract qualified URM, while also seeking ways to increase the sense of inclusion among URM students. Other programs exist to help entrain a greater diversity of students, such as the AGU Bridge program, but these also have drawbacks. For example, it

was noted that the AGU Bridge program requires a substantial level of student support services that may be difficult to provide. This additional support is particularly challenging for WHOI scientists whose soft money positions limit the amount of time that they can devote to mentoring and providing additional training to account for different levels of undergraduate preparation that is often a part of these programs. Similarly, the faculty noted that they are simply unable to support on grants those students who are required to devote a year or more to taking undergraduate courses to catch up with the larger body of students entering the program.

This is not a situation with a simple solution, but the committee **recommends** that the JP think broadly about strategies to increase diversity, including development initiatives that target support for additional training of graduate students entering from disadvantaged backgrounds at the institutional level rather than relying on individual advisors. Greater involvement of the JP in the recommended course for undergraduates held during the Independent Activity Period that would draw from minority-serving institutions, as recommended in the section on Professional Development, represents another opportunity to attract a greater diversity of JP applicants. Increasing support for high school intern programs, such as the one led by Woods Hole SeaGrant and WHOI, in collaboration with Earthwatch, would also generate more opportunities to provide meaningful and inspiring experiences for students with diverse backgrounds. The earlier the age at which students can be entrained into a quantitatively intensive academic track the more prepared they will be by the time they are ready for graduate school.

Two additional strategies to increase diversity were identified during the review and it is **recommended** that the JP take account of these factors. First, a more welcoming environment is created by bringing in URM as clusters, both for the summer intern program and for the JP. Second, URM students are often attracted to issues that involve a high level of social relevance. Here, the committee reflects back to the recommendations above that the JP explore an umbrella climate initiative (Jointness) that would logically involve a strong policy component (Professional Development) as a strategy to increase diversity among JP students.

MIT, WHOI and the JP all enjoy the prestige to draw the most qualified candidates for faculty positions and for graduate school from among a global pool of applicants. But competition for this pool is intense. Every major graduate program in the country is in a similar situation, competing for the most qualified URM candidates. With this in mind, the JP is **encouraged** to exploit its prestige in the context of a well-supported intern program to continue drawing URM students. A high priority for development is to enhance these efforts with additional endowment-supported fellowships that provide a powerful advantage when competing with other institutions for the top students from diverse backgrounds.

2.9 Student life

Entering graduate school is often a stressful experience. In addition to starting life in a new location, surrounded by unfamiliar people, graduate school is a complex system involving many activities that require an accurate knowledge of how to navigate the system. The committee learned that a system of peer mentoring has been established, whereby an entering student is paired with a more senior student who knows their way around the system. In principle, this seems like a positive step toward improving the quality of life for

incoming students. Having a designated contact person who can be asked questions comfortably about any aspect of graduate student life can be an effective stress reducer. However, the committee was provided with no information about the extent of peer mentoring (i.e., is it applied systematically throughout the JP?) or about its effectiveness. Within this context, the committee **recommends** that the JP assess the effectiveness of the existing peer mentoring program, and implement it systematically throughout the JP (if not already done) if it is found to be helpful. A brief report on its effectiveness to the next academic review committee is also recommended.

Access to a designated location to gather informally and interact with one's peers also enhances the quality of student life. Interests are shared, questions are answered, and networks are formed that can support a scientist long into their career. Whereas JP students in EAPS and at WHOI expressed no concern in this regard, it was recommended to the committee that space be found at MIT where JP students can gather, especially for students in AOSE who experience a greater sense of fragmentation and less a feeling of being part of a cohort than other JP students. In principle, this seems like a positive step, so the committee **recommends** that the JP look into options for such a space.

The committee was informed that students are confused about their health care options, but no details were provided. A person's health is a critical factor affecting quality of life, so the committee **recommends** that the JP ensure that all students are provided with clear information about their health care options.

Confusion about the relationship between the JP and the Program on Atmospheres, Oceans and Climate (PAOC) at MIT, and the implications for students, was presented as a factor affecting the quality of life of JP students. On several occasions the question was posed as to whether being a part of the PAOC offers advantages that would favor certain students over others. Such an advantage could also influence students to choose to enroll in MIT rather than in the JP. For example, one advantage would be access to discretionary funds that could be used for travel to meetings or to purchase a computer. Questions were also raised about access to discretionary funds among JP students enrolled in different disciplines. The committee did not receive a complete summary of the policy for allocating discretionary funds, but nevertheless **recommends** that efforts be made to ensure that discretionary funds be distributed equitably among JP students, even if the sources of funding require that different accounting principles be applied to students in different disciplines (e.g., a lump sum distributed at one time vs. equal distributions spread out over 3 or 4 years).

3 Concluding Comments and Recommendations

The committee finds the Joint Program to be in an overall state of good health. The JP continues to attract the top students in the fields of oceanography and ocean engineering, and JP graduates continue to enjoy success in securing career opportunities following graduation. Recognizing that the social, political and academic landscape is undergoing a period of change, the committee believes that certain adjustments may be necessary to sustain the strong position that the JP has enjoyed for the past half century. With this in mind, the committee has made a number of recommendations intended to help the JP adjust to this changing landscape as described throughout the report. Those recommendations

have been extracted from the main body of the report and organized below according to the main topics that were addressed during the review.

Principal Recommendations:

1. Establish a working group to prepare an updated vision of the JP that explores the role of the JP within the institutions with which it is associated. This new vision should respond to evolving research priorities, technical advances and societal needs.

2. Create an overarching climate program, as a recruitment tool and to bring together researchers in climate at all levels from students to PIs. This program could engage areas of MIT that have not previously been associated with the JP, such as policy, infrastructure engineering or atmospheric carbon capture.

- Offer a “Certificate” or other recognition of a student’s having completed a body of interdisciplinary research that contributes to our understanding of the physical climate, as well as the solution space (including e.g. policy, education, communication).
- Unite JPMG&G students by linking the breadth of climate-related topics (e.g., coastal geology – sustainable infrastructure; marine geology – renewable energy production, carbon sequestration)

3. Incentivize the participation of MIT students and faculty in the JP. This can help build enrollment for JP courses, and keep all of the units within the Joint Program “joint.”

- Enhance the awareness among MIT faculty of the benefits to participating in the JP.
- Increase and improve opportunities for face-to-face interaction between faculty and students from both institutions.
 - Better A/V equipment and more rooms for web-based conferences, seminars and courses to facilitate interaction.
 - Explore temporary housing in/near Woods Hole available to MIT faculty.
 - Look into options for space to be found at MIT where JP students can gather.
 - Social and/or scientific gatherings that unite the two institutions.

4. Break down barriers to interdisciplinary training, including the development of courses that are accessible to students in other departments.

- Consider the development of introductory courses to ensure broad exposure to all JP students of key oceanographic processes and to interested MIT-only students.
- Examine whether the existing curriculum conveys sufficient interdisciplinary breadth (within ocean sciences) to prepare students for their careers.

- Solicit periodic feedback from JP graduates on their graduate training, requesting recommendations for adjustments to the curriculum.

5. Encourage JPPO to market their graduate program as an ocean and atmosphere program to reflect the inclusion of atmospheric scientists in the PO department of WHOI. This could include a name change to reflect the broader scope. It is also recommended to include atmosphere and climate oriented faculty at MIT in the newly imagined JPPO.

6. Keep working to create an inclusive atmosphere in both the Joint Program and the Summer Fellows Program. Particular attention to the JPPO and Engineering programs is warranted.

- Encourage students to join peer-groups and to welcome new students into existing peer-groups.
 - Assess the effectiveness of the existing peer mentoring program, and implement it systematically throughout the JP (if not already done) if it is found helpful. A brief report on its effectiveness to the next academic review committee is also recommended.
- Continue to use the prestige of the JP program to attract qualified URM in the summer intern program, while also seeking ways to increase the sense of inclusion among URM students. The summer intern program is a proven valuable pipeline for graduate school.
- Think broadly about strategies to increase diversity, including development initiatives that target support for additional training of graduate students entering from disadvantaged backgrounds at the institutional level rather than relying on individual advisors.
- Examine recruitment materials to best convey the high quality of the educational opportunity offered without falling into elitist language that can discourage candidates from disadvantaged backgrounds or from other cultures.
- Consider that
 - A more welcoming environment is created by bringing in URM as clusters, both for the summer intern program and for the JP.
 - URM students are often attracted to issues that involve a high level of social relevance.
 - Adding sensitivity training within the summer intern program may improve the success rate for URM students.

7. Continue the ongoing assessment of the student experience and training.

- Clarify the role of guest students at WHOI and their potential impact on the JP.
- Make an overview of course evaluations and exit interviews available to faculty and the next external academic review committee.
- Continue the ongoing assessment of the qualifying / general exam process
 - Explain the goal of each step and its desired outcome to students in their first year.
 - Consider options to streamline the process so students are not disengaged from their primary research for a lengthy period

- Standardize all syllabi to include learning goals. (Easy for quick implementation)
- Evaluate the effectiveness of annual reviews.
- Follow the recommendation of the prior review to poll alumni
 - if they would have benefited from more opportunity in graduate school to develop teaching skills, and
 - if so, then what opportunities would be most useful.
- Provide the next external academic review with an overall assessment of the professional preparation of JP graduates, including information about their success in seeking careers in non-academic career tracks.
 - Explore options and experiences for TA opportunities in other MIT departments
 - Explore options for teaching in schools and other outreach experiences

8. Explore ways to ensure the proper course opportunities

- For example, the new maker space under construction at the Quissett Campus could be an opportunity to host periodic instrumentation courses.
- Provide information to MIT-only students taking JP courses and their advisors about benefits of registering for the JP and poll them to learn their views.
- MG&G faculty could explore strategies to combine existing courses to attain the minimum number of registered students, while also providing students with exposure to a minimum set of essential principles and concepts.
 - “Topics” courses can also be helpful, as they allow tailoring of the material to be presented to the specific needs of the students currently enrolled in the course.

Other recommendations

1. Given the rate of progress on high priority topics, the next review committee might want to devote a greater portion of its attention to those topics that could not be addressed adequately in 2019.
2. Seek an appropriate balance between pursuing research and education at the highest possible standards of scholarship while also providing a welcoming and inclusive environment that will encourage participation by individuals from disadvantaged backgrounds.
3. Solicitation of funds for student fellowships should be a priority for institutional development initiatives, especially targeting members of underrepresented groups.
4. Take note of any correlation between student success and factors that may influence their level of support from fellow students (e.g., effectiveness of peer support networks).
5. Efforts should be made to ensure that discretionary funds be distributed equitably among JP students, even if the sources of funding require that different accounting principles be applied to students in different disciplines (e.g., a lump sum distributed at one time vs. equal distributions spread out over 3 or 4 years).

Disciplinary Reports

Physical Oceanography

The Physical Oceanography component of the Joint Program (JPPO) remains one of the premier educational programs in physical oceanography, offering a broad range of classes and research opportunities. It continues to attract high quality students with those students continuing to successful careers in academia, government and industry. The curriculum and exam structure continues to contain traditional core courses in physical oceanography, but remains sufficiently flexible to encompass the broad range of physical oceanographic studies. The number of students has increased significantly since a low in 2015, with a particularly good recruitment year in 2019. Student morale appears high both for students residing based at MIT and at WHOI. The combination of a high quality program, the stunningly broad range of opportunities available in the Joint Program and the short time to Ph.D. is a powerful combination and impressive achievement. Despite this continuing success, the most important problems described in the 2015 report remain, with little apparent progress.

Jointness in the JPPO is an increasingly critical problem that requires focused attention by JP and WHOI leadership. EAPS, the Department of Earth, Atmospheric, and Planetary Sciences at MIT, has historically had a strong physical oceanography faculty with a firm commitment to the Joint Program. Most of these faculty have now retired, so that it is now difficult to find a JCPO member from MIT. Without new hires, anticipated retirements will likely reduce the number of physical oceanographers in EAPS to 1 within a decade. Both EAPS and WHOI have been aware of this problem for a long time. Despite many efforts, there has been little progress and the problem is becoming more critical.

Both the EAPS and WHOI components of JPPO have broadened their faculty and research areas to include oceanic, atmospheric and biogeochemical aspects of the climate system. This is explicit at EAPS with the formation of PAOC (Program in Atmospheres, Oceans and Climate), but is also occurring at WHOI without a formal structure. The result is that students do not view the JP as a place to study climate. Atmosphere and climate focused JPPO faculty at WHOI have thus had difficulty attracting students.

The common breadth between EAPS and WHOI offers an opportunity to both renew JPPO and to rebuild the JP jointness on a new base. As outlined in the major recommendations, we recommend a new climate component of the JP to begin this process.

Regardless of how a JP climate component might evolve, it is recommended that the JPPO consider how they are marketing their graduate program, and make sure that students are fully aware that this is an ocean and atmosphere program. This could include a name change to reflect the broader scope. Revisions and updating of the curriculum should also be considered as part of this effort.

While it is clear that the JPPO has made great strides in ensuring a climate that is welcoming to both male and female students at WHOI, the environment at MIT seems less welcoming. It is recommended that the JPPO regularly check in with the students to identify and address these concerns and ensure that these issues are remedied. Female students report being warned away from the JPPO, and the program is likely to lose strong students while this remains an issue.

While students are required to have a set of mathematics skills to fully benefit from first semester coursework, not all students are admitted with the same preparation. Although there is now some summer coursework designed to address this issue, more effort is needed here. It is recommended that students requiring additional preparation in mathematics be identified before the start of the first semester and a plan be developed to ready these students for their fall semester classes.

Biological Oceanography

The JCBO appears to be running quite well, with high-quality students, a responsive curriculum, invested faculty, and few major issues apparent. Many of the problems identified were common to all disciplines and both institutions in the WHOI-MIT JP. However, there were some points particular to the JPBO that deserve attention:

Faculty:

Both WHOI and MIT faculty expressed a desire for more interdisciplinary hiring of Biological Oceanographic faculty in EAPS to support the JPBO mission. We further recommend the inclusion of WHOI-based faculty on the relevant MIT faculty search committees.

Admissions:

Several JPBO students expressed the opinion that all Biological Oceanography students should be automatically admitted to EAPS, rather than Biology at MIT, based on the relevance of the curriculum and research in the respective departments at MIT. Students should be able to request admission to Biology at MIT if they so choose, but the default should be EAPS. Furthermore, the Biological Oceanography students should be in the Program in Atmosphere, Oceans and Climate (PAOC), and should have access to the resources and events in that group that the PO and CO students currently enjoy.

Faculty at both MIT and WHOI expressed an interest in increasing the student enrollment of the JPBO. This could be accomplished both through enhanced recruiting, fellowships, and hiring of new JPBO faculty at both institutions (particularly MIT).

Funding:

Both JPBO students and faculty urged that first-year student fellowships be made a priority. Removing an earlier “18-months of funding in hand” requirement has helped in admissions. We also recommend the implementation of diversity-based fellowships to enhance the diversity of the JP student body.

Curriculum:

The new (since 2012) curriculum appears to be working well for both the students and the faculty. The long list of electives and the flexible, individually tailored curricula were appreciated by the students, and reduced the teaching burden on the faculty. The topics courses, in particular, appear to be a strength of the JPBO, and could be profitably adopted by other JP groups.

General Exam:

Students and faculty both favor the research-report format of the general exam. The report is thorough enough that it often ends up as a thesis chapter and/or a published paper. We were struck by the lack of formal faculty mentoring during the writing of the thesis proposal. Not only is this

potentially a missed mentoring opportunity (students have no experience in writing a thesis proposal, and often require experienced guidance), but having the students seek mentoring from their peers has the potential of creating barriers for students with other commitments (families, etc.), who cannot be physically present when the students are meeting. This could be a particular disadvantage to URM students, whose outside-academia commitments might be quite different than those of other students.

One issue that was raised was whether the JPBO students were clear about what they were being examined on. That is, what is the scope of the fundamentals of biological oceanography that the students are expected to know and understand? Laying out the learning outcomes explicitly may focus the exams, and help to improve consistency across different student's exams.

It was also suggested that having faculty (particularly junior faculty) participate in the general exams may motivate their subsequent participation in the JP.

Student Teaching Opportunities:

Many of the JPBO students will seek faculty positions where teaching is a requirement. The lack of formal teaching opportunities in the JPBO make present a significant detriment to the competitiveness of their graduates. We suggest that students be encouraged to take advantage of the IAP to teach short courses, and to work with the WHOI and MIT faculty to explore other teaching opportunities (and pedagogical training opportunities) in the geographic areas.

Jointness:

Both WHOI and MIT faculty expressed a need for more “jointness” of the JPBO – in particular, having more MIT faculty (and more junior faculty, specifically) engaged in the JPBO. More opportunities should be made to hold joint MIT-WHOI faculty meetings to improve collegiality. At MIT, service in the JP should be explicitly called out in faculty academic reviews – in particular, in the Chair's letter, where the candidate's activities in the JP should be considered in, for example, tenure decisions. This is an opportunity to make the importance and scope of the JP known to the MIT administrators.

Diversity:

The issue of low diversity in the JPBO student body was brought up by both the students and faculty. We encourage both MIT and WHOI to explore mechanisms for enhancing the diversity of the student body through active, targeted recruiting and outreach, student fellowships, and a careful examination of potential cultural barriers in the program. This will have to be an active and ongoing investment, engaging experienced professionals to pursue some potentially uncomfortable conversations and activities.

Applied Ocean Science and Engineering

The Joint Program in Applied Ocean Science and Engineering (JPAOSE) is one of the very top graduate programs worldwide combining ocean engineering and oceanographic science. The JPAOSE is able to achieve this because of its unique confederation of world class WHOI and MIT researchers, educators, and students. The longevity and productivity of the program is impressive, and many of the graduates are at the leading edge of discovery and innovation in ocean science and engineering. This success is clearly linked to the deep engagement and dedication of the researchers

and staff, who are primarily associated with four MIT departments including Mechanical Engineering (ME), Civil and Environmental Engineering (CEE), Electrical Engineering and Computer Science (EECS), and the Department of Aeronautics and Astronautics (AA), and at WHOI it involves the faculty and students primarily of the Department of Applied Ocean Physics and Engineering, and also includes scientific staff in other WHOI departments such as Biology.

The committee met with the leadership of the Joint Committee Applied Ocean Science and Engineering, members of the WHOI Scientific Staff and MIT faculty who are active in the JPAOSE, and with current JCAOSE MS and PhD students on the MIT campus as well as at WHOI. Below are the impressions that resulted from these meetings.

The JPAOSE offers the PhD degree and the AOSE Navy Master of Science degree in Mechanical Engineering for U.S. Naval Officers. The JPAOSE PhD offers four PhD degree tracks that align with the four primary MIT engineering departments associated with JPAOSE. Unlike the other four Joint Program disciplines, students in JPAOSE must satisfy all the degree requirements of their home MIT department, as well some additional Joint Program requirements.

Over the past decade the JPAOSE statistics have been stable with 40-60 applicants per year, with 5-12 admissions per year, with almost all offers of admission being accepted. The gender and ethnic diversity of the JPAOSE student body is below that of the nationwide demographic statistics gathered by the American Society for Engineering Education for PhD programs in ME, CEE, EECS, and AA [1]. Some program practices (both at MIT and at WHOI) involve outdated ideas that have been shown to favor those who are members of the dominant culture and disadvantage those who do not have access to informal mentoring networks. For example, students reported that they are often left to work through issues on their own to see “what students can do on their own.” Such a practice can result in higher success rates for students who have strong social mentoring networks (usually the case for students from dominant groups) and disadvantage those who are perceived to be different. Joint program faculty should consider employing more inclusive teaching and advising practices before recruiting more diverse students into the program.

Perhaps not surprisingly, JPAOSE students expressed concern about the lack of diversity within the student body and faculty, and perceive a lack of effort to address this issue among the JP leadership. They perceive that existing efforts are essentially led by students (e.g. a recent connection program, and a letter to the trustees arguing for more diversity) rather than faculty and perceive the lack of leadership on the part of the faculty around topics related to diversity to be disappointing. Although encouraging student-led efforts (and providing funding) is commendable, student-led efforts in the absence of meaningful participation by faculty cannot achieve the required culture change to make the joint program more welcoming and inclusive for students from a variety of backgrounds.

The JPAOSE graduate student population has grown over the past five years from 24 to 36, with growth in enrollment both in the PhD program and in the Navy MS Program. WHOI faculty commented that they perceive the Navy students to be a significant asset. A significant majority (66%) of JPAOSE students are ME, and a significant number of MIT ME faculty are engaged with the JPAOSE. This is, at least in part, a consequence of the legacy of the former MIT Ocean Engineering Department, which historically was very active with the JPAOSE, merging into Mechanical Engineering in 2005. The faculty advisors of 75% of JPAOSE students are either from WHOI or MIT ME. Engagement with MIT faculty in EECS and CEE is particularly limited. Retention rates of PhD students in the JPAOSE is concerningly low at 63%, significantly below that of the other programs which report retention rates of 82-100%.

A significant concern for the future of the JPAOSE is the diminishing number of MIT faculty who are actively engaged with the JP. With the attrition of MIT faculty in the areas of acoustics and coastal engineering, the center of expertise in these areas is now primarily located at WHOI. Retirements of MIT faculty who once were active in the JP have not been balanced by junior MIT faculty engagement with the JP. The seniority distribution MIT faculty presently engaged with the JP is skewed toward more senior faculty. As a result, it appears important to the health of JPAOSE program to specifically encourage the new MIT faculty to engage with the program. This can occur through targeted activities geared towards building connections between the two faculty bodies. The work involved in strengthening the connections might disproportionately fall on the WHOI faculty and leadership, given that their motivation to have a vibrant joint program is naturally higher.

Conversations with students and faculty clearly revealed that PhD student course selection and a significant component of their overall PhD experience is reported to be driven by preparation for Qualifying Exams, especially for students in ME. ME students expressed concern that ME Qualifying Exam topics do not map directly onto JP student research areas, particularly in the case of interdisciplinary JP research. Faculty at WHOI echoed this concern and had ideas that appeared to them to be relatively minor modifications that apparently have not achieved traction with the MIT faculty. Frustration with the Qualifying Exam process was significant enough for faculty to consider a migration of PhD students to AA because of AA's less onerous qualifying requirements. It appears fair to conclude that the PhD experience of the JPAOSE students appears to be distorted by excessive preoccupation with qualification exams. The following observation from the 2014 JPAOSE review report remains true today: *"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."* The overall rigidity in the academic programs appears to be a significant barrier, and it appears clear that targeted conversations between the WHOI and ME leadership need to take place to take a critical look at qualification exam requirements and their impact on the joint program students.

JPAOSE students expressed the need for cohort office space similar to the space devoted to JP students in EAPS, and described the cubicle space in building 5 between 3rd and 4th floors as "awful." This shortcoming appeared to significantly affect the morale among the students, as well as their ability to interact with other students and reap the benefits of peer mentoring. Students and faculty both also expressed significant frustration with inadequate teleconferencing between MIT and WHOI, and expressed an urgent need for improved classroom teleconferencing facilities at both WHOI and MIT. It was noted that most EECS classes are not teleconferenced.

MIT EECS faculty noted that the JPAOSE PhD application deadline falls after the EECS PhD application deadline and before the ME deadline and, in consequence, EECS faculty generally do not consider JP applicants - EECS deadline is December 1 and offers are made in January, while JP deadline is December 15 with offers being made in February. It was suggested that the JPAOSE application deadline could be staggered by track to align with the disparate MIT Departmental PhD application deadlines. It was reported that WHOI faculty review both JP and MIT applications, while MIT faculty generally do not review JP applications.

WHOI faculty expressed an interest in teaching more and, in particular, teaching short-courses in the summer. There appear to be administrative barriers that make this difficult or impossible. The faculty also contributed a plethora of other ideas on how the program could be improved, student support could be enhanced, incentive funds administered, and connections with MIT strengthened.

It seems clear that the WHOI faculty are engaged and invested in this program, and their energy could be tapped to help improve the program in a variety of ways.

JPAOSE students expressed interest in having as program requirements (a) a general oceanography class and (b) an oceanographic instrumentation class. Student opined that the existing oceanographic instrumentation course is a survey course of instruments and platforms but does not actually involve original instrument or platform design and, moreover, that it is difficult or impossible to take this Tuesday-Thursday course before Qualifying Exams.

The JPAOSE faculty expressed much satisfaction with the quality of the graduate students, and most students expressed satisfaction with the JPAOSE graduate programs. Most expressed satisfaction with the “hands on” mentoring they receive from their primary PhD advisors and the oversight that ensures so they can complete their degree in a timely manner. The morale of the students at WHOI appeared significantly higher, suggesting that their satisfaction with their degree program increases as their research progresses. Overall, the impression of the reviewers was that this is a vibrant program with much potential to evolve, improve, and grow.

Marine Geology and Geophysics

The 2019 Review Committee (RC) reviewed the JP Marine Geology & Geophysics (JPMGG) program at WHOI October 28-30 2019. The committee held a series of discussions with WHOI senior personnel, MIT & WHOI JP faculty, educational staff, and MIT & WHOI students. The JPMGG has maintained its reputation for producing, recruiting and retaining excellent graduates and performing excellent research. The department needs to continue to be recognized for its marine geology and geophysics research and education in the country. To achieve this distinction, MG&G must continue to expand and diversify its students and faculty/scientists and invest in better integration of its diverse programs both on the WHOI campus and at MIT.

Students:

The JPMGG program is the most diverse in terms of disciplines of the JP program. The students see this diversity in disciplines as a definite strength of the program. Students were pleased with the supervision they were receiving and liked the fact that the faculty were engaging. Students were also pleased with their stipends, support services provided to them from professional development to mental and health services available through MIT. Students were generally pleased with the two project model of the general exam because it allowed them to explore other research interests outside their fields. However, the general exam required more standardization across the disciplines. The program had minimal course requirements providing students with the flexibility to customize their degree programs. The program does a great job sending out job opportunities and students noted resources at MIT are excellent but less access at WHOI.

Despite the above positive response from the students, we have several concerns.

- 1) Enrollment trends: Of all the programs reviewed, the JPMGG program had experienced significant declines in enrollment. Since 2014, except for coastal geology, every discipline in the JPMGG program had experienced a drop in enrollment (average -29%) with significant drops in petrology and geochemistry (67%). The enrollment decline is also concurrent with the decline in yield. Of the 9 students admitted for fall of 2019, only 3 (33%) accepted the offer. *We recommend**

that the JP continue to encourage and enable JPMGG faculty to extend offers to potential students in order to restore a critical mass of students in this program. We recommend that the JPMGG faculty find out the reasons for students declining their offers. To curtail the drop in applications and yield, JPMGG should be proactive in recruiting. One way to do this with little effort is for EAPS faculty to consider offering more general education courses (e.g., climate change) that are appealing to students and that fulfill a breadth requirement. Such courses could provide opportunities to recruit students into the JP. In addition MG&G faculty can optimize their messaging and enhance student experiences during open houses for prospective students.

- 2) This drop in enrollment is adversely impacting the quality of the programs. In the 2014 external review report, JCMGG faculty and students expressed concern about the required enrollment of 3 JP students for a course to be offered. During our review, students and faculty expressed this same concern indicating that this problem has not been resolved by WHOI. *We recommend that EAPS and WHOI work to eliminate the 3 JP student rule and make it possible for courses to be taught with 3 students especially if EAPS students bring the enrollment to greater than the required 3. Further, MIT should remove any barriers that prevent revenue sharing for instructor of record.*
- 3) *Topical Courses: Students expressed an interest in topical courses. Consistent with the 2014 review committee, we also support that JCMGG introduce topics courses similar to the format provided by JPBO program to their students.*
- 4) Funding for Junior Faculty: There has been significant turnover in the faculty. A total of 9 faculty had either retired or left since 2014. The national reputation of the PI/advisor was a strong pull why students chose the JP program. Although the departure of some well-known senior scientists in geodynamics (e.g., Mark Behn) may have adversely impacted the enrollment, funding appears to be a major factor. WHOI Students expressed some level of undue stress due to perceived pressure on them to finish quickly as faculty mentors run out of funding. While eight new faculty both at MIT and WHOI had joined the program, the task of raising funding support for graduate students is a daunting task for any new faculty. *We recommend that WHOI/MIT provide some level of student support to the junior faculty. We also recommend that WHOI development office work with faculty to diversify their funding portfolio to include industry and private foundation sources. This may require that faculty emphasize the broader impact components of their work by linking their science to societal problems.*
- 5) Integration among the different disciplines: The students saw the diversity in disciplines as a major strength of the JPMGG, especially students with interdisciplinary interests (e.g. Climate). Nonetheless, the lack of integration was a major concern to the students and this was apparent to the committee. It appears that the diversity in disciplines was not translating to interdisciplinarity. This lack of

integration/interaction was apparent at several levels- among the WHOI students, the WHOI and MIT students, the WHOI faculty and the WHOI-EAPS faculty. This lack of interaction has resulted in student isolation with interactions limited to lab groups rather than across disciplines. For example, seminars were irregular and not well advertised or attended. Although students would have liked to attend EAPS seminars (which were also not regular) the seminar room at MIT did not have video link to an equivalent room at WHOI. Based on some anecdotes, we have a sense that this lack of integration was apparent to prospective students and maybe a factor in the declining yields. The lack of integration was felt by students in all fields, but particularly acutely in the solid earth geosciences, while students in paleoclimate were more able to find links to other aspects of the Joint Program (JPPO, JPCO). *We recommend that MG&G have integrated seminars on both the MIT and WHOI campuses. Faculty can assign students the responsibility to jointly organize the seminars. This has the added benefit of building leadership skills in students. Department chairs should emphasize the importance of the seminars as part of the student's education and encourage faculty mentors and their students to attend the seminars more regularly. To address the linkage problem, we recommend that the MIT seminar room should have a direct video link to an equivalent seminar room at WHOI. Establishing an interdisciplinary program in Climate will help to integrate the JPMGG paleoclimate and coastal geology students with other Joint Program students, but care should be taken to also build community within JPMGG so as not to further isolate the students whose work does not directly relate to climate.*

Chemical Oceanography

The Chemical Oceanography (CO) portion of the Joint Program (JPCO) is viewed by faculty and students alike as being in a sound state of affairs. Graduates of JPCO continue to fill high-level positions at the most prestigious universities and research institutions worldwide. Even with increased competition from a growing number of schools producing PhD graduates in oceanography, the quality of students, the quality of their research, and their job prospects on graduation, are very good. As was the case during the previous review, 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.

Each of the vital statistics covered during the review indicate good health. Over the past decade the number of applicants to the JPCO has varied between 38 and 50 with no clear trend. The number of students admitted and accepting enrollment has varied more over time, perhaps reflecting variability of available funding more than any other factor. Thanks to successful recruitment in recent years, the CO program currently (at the time of the review in October 2019) has 34 enrolled PhD students. Average duration to PhD (5.5 years) is unchanged from the previous academic review, and informal statistics suggest this has been close to the average throughout the life of the program. Retention of students once enrolled in the program remains excellent, with approximately 90% of the students who enrolled during the 5-year period of 2010-2014 continuing to receive their PhD. While all of these statistics look strong, the large number of students currently enrolled in the JPCO program may increase the incentive to provide counseling to students about opportunities for non-academic career

tracks. Professional societies, such as the American Geophysical Union, are expanding their resources to help young investigators seek careers outside of academia and basic research, and it would be of benefit to the students to have similar resources within their home institution. The committee was informed of some resources at MIT that help fill this need, but WHOI and the JP may wish to invest into more of these resources on their own.

Curriculum and courses: The JPCO offers an enviable selection of courses that provide students with an excellent opportunity to gain significant expertise with regards to depth and breadth within the discipline. Students expressed satisfaction with both the quality of the CO courses offered, and with the commitment on the part of the instructors. As noted in the general report, the primary challenge facing the students is the physical separation of the two campuses. Students recognize the lost opportunities for networking and general integration across the two institutions, and expressed a desire to have more events that would physically bring individuals together for face-to-face interaction. These expressions on the part of the students are consistent with the more general recommendation within the overview report that the JP implement a greater number of activities that involve individuals from both institutions. A logical option would be to implement a joint colloquium series that engages faculty and students from both institutions, but other events could be envisioned as well.

One area that would benefit from greater attention is in providing students with advice about selecting courses in physical oceanography (PO). Most oceanographers readily recognize the need for a basic understanding of physical oceanography, but the specific needs of a given student may vary from descriptive to quantitative to theoretical. Some CO students reported that they would welcome more advice about which PO courses are appropriate for their needs (although other CO students seemed to have this information in hand). Given the strong dependence of marine biogeochemical cycles on ocean physics, it is recommended that the JPCO examine whether their students would benefit from additional information resources about the appropriate PO courses to meet their needs.

Another opportunity to be encouraged is to direct students to the Aquatic Chemistry course Desiree Plata teaches at MIT in the Civil and Environmental Engineering department (CEE). The principles of aquatic chemistry apply across a broad spectrum of research areas, so this course provides students with a sound foundation onto which they can build future research projects regardless of the direction taken in their career. In addition, it was reported to the review committee that participation in the JP by CEE faculty has declined in recent years. Increased enrollment by JP students in Aquatic Chemistry may help initiate new interdisciplinary projects that benefit students and faculty alike, both at WHOI and at MIT, while strengthening joint activities and networking.

Research projects: Students expressed a favorable view of the opportunity to complete two research projects prior to their qualifying exams. Some CO students indicated that they were grateful for the opportunity to explore interdisciplinary research projects, e.g. in engineering or policy, while others indicated that they were unaware of such opportunities. In the context of the broader efforts of the JP to expand interdisciplinary research among the students, the JPCO may want to compile and distribute information about research project opportunities that engage other JP disciplines.

Faculty demographics: Throughout the history of the JPCO, students have benefitted from the high level of commitment to the educational process by faculty at both institutions. Over the past four decades, Ed Boyle has been a commendable mainstay of JPCO, and currently holds leadership responsibilities that benefit the entire program. He has amassed critical knowledge of the intricacies and nuances of the JP, and one can easily see advantages of partnering new faculty with Ed to learn

from his experience while also sharing the workload currently managed under Ed's supervision. At the other end of the demographic spectrum, the WHOI CO program has recently added seven new hires to its staff. During the review the question frequently arose of how best to incorporate these junior scientists into the broader process of education and mentoring. It is particularly difficult for junior scientists who are focused on building their own research portfolio to find funds to support PhD students while also raising their own salary. No specific recommendation was resolved from these discussions, but it is apparent that with so many young scientists recently added to the MC&G program at WHOI that some coordinated effort will be needed to help them launch their roles as PhD advisors if the current health of the JPCO is to be maintained.

General exams and student assessment: As was the experience during previous academic reviews, much of the discussion with faculty and students this year was directed at the assessment process of student progress and preparation for PhD research. CO students generally reported that they find the expectations for the general exams to be clear. They also reported that the preparation for general exams offers a good opportunity to review material covered in courses while also consolidating and clarifying important concepts in chemical oceanography. Students understand and appreciate the benefits of having opportunities to practice and develop their writing skills, as well as the opportunity to exercise their critical thinking about relevant literature when preparing their thesis proposals.

CO students seemed to agree about two general concerns. First, the complete assessment process, beginning with the submission of their research report in the winter of their second academic year and concluding with the oral presentation of their thesis proposal during autumn of their third academic year, takes them away from their research for too long a period of time. Second, the feedback provided to students at each step of the exam/assessment process varies substantially from student to student. In some cases, students expressed concern that their time was being wasted if their research report could not be quickly turned into a publication, or if their thesis proposal did not directly support their dissertation research.

While some students recommended a move toward an exam process more like that employed in Biological Oceanography, most recommended that the principal adjustment to the procedure followed by the CO program involve streamlining the process and offering more consistent, and sometimes greater, feedback at each step of the evaluation process. Some students also expressed a need for clarification of the extent to which options could be changed throughout the assessment process. For example, to what extent can students change exam topics after their abstracts are submitted at the end of their first year? Are students obliged to limit the material covered in their oral presentation during the general exam to the material presented in the written research report, prepared some months earlier, or can students update their presentations with new data generated closer to the time of the exam?

The JPCO may want to consider various options to address these concerns, but one possibility is to develop a "Feedback Rubric" that is applied to all CO students, and which covers the entire assessment process from the initial abstract submission at the end of the student's first academic year through the completion of the thesis proposal. The rubric would define the goals of each stage of the assessment process as well the expectations of students in terms of assessing how well they have met those goals. Clear definitions of these terms will help students avoid spending time pursuing unnecessary work, thereby streamlining the process. A second essential component of the rubric would encompass an explicit description of the feedback that a student can expect to receive at each stage of the assessment process. Documenting these expectations in such a rubric would help examiners and advisers provide more consistent feedback to students, while also giving students a

basis for requesting feedback in cases where it is incomplete or otherwise insufficient to comply with the rubric.

In summary, the JPCO is healthy and strong, producing students who successfully compete for the top positions in the field. Students currently enrolled in the JPCO benefit from the strong personal networks developed during their tenure as JP students, including fellow students, faculty at MIT and WHOI, and the many prominent scientists encountered through the course of their association with the JP. The geographic separation of the two institutions remains a challenge, as is the current state of funding in the U.S. for ocean research. Despite these challenges, the dedication of faculty and staff to the success of the JP promised a bright future for JPCO graduates.