External Review Team Report
March 25, 2009

College of William and Mary Program Review

Applied Science
Computer Science
Mathematics
Physics

This report is based on the materials provided to the external review team and on a campus visit by the team on February 15 to 17, 2009. The report is organized into five sections: one for each of the reviewed departments, and one addressing issues related to the entire cluster.

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Program Review for Applied Science

A. Questions for review of all departments

1. Teaching and mentoring

The Department of Applied Science is an interdisciplinary unit that provides M.S. and Ph.D. degrees in the core areas of materials science and mathematical biology and that supports graduate studies in collaboration with other science departments (biology, chemistry, mathematics and computer science). The AS department has appropriate expectations for their masters and doctoral candidates, which are spelled out clearly in the "Draft Profile of Institutional Effectiveness" and seem to be communicated effectively to graduate students by their mentors. The "Draft Profile" also lays out the "experiences" by which grad students will attain these expectations and the measures by which success in achieving these goals can be assessed. The profile of departmental effectiveness is well thought-out, and (if not already) it should be adopted formally and shared with all graduate students as a ground-plan for their studies.

The dozen graduate students with whom we met seem to be very satisfied with the education they are receiving in the AS department. For the most part, they spoke clearly, confidently, intelligently and enthusiastically about their science and its broader significance.

The graduate level courses offered by the department provide appropriate training for their graduate students. Especially impressive were the scope and sophistication of the courses in mathematical biology offered by just three faculty members at the undergraduate level as well as graduate level. The course program in materials science was equally impressive, as might be expected from such a large and successful group of scientists.

The AS department has recently instituted undergraduate minors in materials science and mathematical biology. It is good to provide undergraduates with these options, which make few extra demands on faculty time. But, in our opinion, it is less important that the department sponsor "minors" for a few self-motivated students than that it foster a spirit of multidisciplinarity among the majority of undergraduate students studying the natural and mathematical sciences at William and Mary. Multidisciplinary studies are already being supported through the program in neuroscience, the mathematical biology initiative, and the HHMI grant supporting mathematics in the life sciences. Given the excellent academic preparation of William and Mary undergraduates, the Faculty of Arts and Sciences might consider developing an optional "integrated science curriculum" for freshmen and sophomores, along the lines of the program pioneered at Princeton University: http://www.princeton.edu/integratedscience/curriculum/.

New-faculty mentoring is effective in many ways. During their first year, there is a formal program of mentoring to get them off to a good start, and it is clear that, in the department of applied science, new faculty are valued, nurtured, and expected to succeed. The young faculty members seem to be confident, comfortable, and satisfied. The committee was surprised to hear that there is no written evaluation of untenured faculty before the tenure decision is made. In our

opinion, untenured faculty should receive a thorough review of their research, teaching and service, communicated in writing, every year (or every second year).

2. Scholarly contributions

The department of applied science has high expectations for its faculty, which are clearly understood and fairly applied. Considering their mission, the faculty maintains an appropriate balance of teaching, research and service. We sensed a great spirit of collegiality and cooperation within the department, and no signs of competition between the two very different research groups (materials science and math biology).

As expected, the department measures up to the standards of research productivity, external funding and peer-reviewed publications that are expected of any first-rate research department in the nation. The research being done in the department is novel, exciting and significant. The department has invested wisely in modern, sophisticated equipment in NMR spectroscopy, femtosecond laser spectroscopy, thin-film fabrication and characterization, and single-cell fluorescence microscopy. In addition, the AS department (in combination with Physics and Biology) has impressive intellectual expertise (both experimental and theoretical) in surfaces and interfaces, atomic-molecular-optical physics, and neuroscience. The AS department has nurtured these investments in people and facilities into a productive and inventive research enterprise.

The AS department has evolved over the years, as polymer chemistry waned in importance and mathematical biology grew in scope and impact, with materials science holding a strong place. This sort of evolution is to be expected of an interdisciplinary department. The review committee feels that in future years the department should maintain its strength in materials science and build an even stronger program in mathematical biology by emphasizing natural alliances among the departments of biology, chemistry, physics, mathematics and computer science. Some areas that might be appropriate for future development are: fishery dynamics (in alliance with VIMS), synthetic gene networks, nano-biotechnology (motor proteins, surface biochemistry).

Eric Bradley is to be congratulated for providing exceptional leadership to the department over the past 6 years. The committee hopes that the new Chair will maintain the collegial atmosphere and research excellence of the department, at the same time forging stronger links with the departments of mathematics, computer science and chemistry that are not so closely integrated into the program.

3. Undergraduate and graduate programs

As mentioned earlier, the undergraduate courses offered by the department are appropriate to its mission to encourage interdisciplinary studies and to provide a minor in applied science to interested undergraduates. The minor tracks in materials science and in mathematical biology are excellent.

The relations between AS and Biology and AS and Physics seem to be strong, as might be expected, but the relations between AS and Mathematics and Computer Science seem to be unnaturally weak and unproductive, in the opinion of the external reviewer for Applied Science. From what we hear, the Chemistry department also appears not to be well integrated into an

effective science cluster. Given the importance of multidisciplinary research to science achievement and funding in the future, the Dean of the Faculty of Arts and Sciences needs to diagnose the problems here and foster closer collaboration among all departments of natural and mathematical sciences.

4. Facilities

The department has provided its faculty with the excellent (and expensive) experimental equipment that they need to succeed. The College has shown its support for interdisciplinary science by building the Integrated Science Center. ISC 1 is a great facility. With construction of ISC 2 and 3 underway, the administration and faculty need to focus on creative ways to integrate scientific teaching and research on the exciting frontiers between biology, chemistry, physics and mathematics.

5. Plan for the future

Applied Science has two strong subdivisions and plans to foster both areas in the near future. Ties between materials science and physics are strong, as are ties between the theoretical biologists and the biology department. Ties to chemistry and mathematics are weak and need to be strengthened. The problems seem to come from turmoil in the chemistry and mathematics departments rather than from any lack of cooperation from Applied Science.

6. Development

Contact with alumni was not something we discussed in detail. If a biannual newsletter is not already produced, it should be considered. A simple newsletter distributed electronically through the departmental website would be sufficient. Seeking financial support from alumni is presumably the job of the College's development office.

7. If additional financial resources are available …

The mathematical biology subdivision of Applied Science is small and inexpensive, compared to the materials science subdivision. Future spending should concentrate on building up interdisciplinary areas like bioinformatics, computational biology (molecular and cell), and synthetic biology, where a lot of exciting science and funding opportunities will be focused in coming years. To be successful in these areas will require better cooperation with the departments of mathematics and computer science. These departments need to be convinced that mathematical modeling and computation in the life sciences provide important and challenging new areas of research in mathematics and computation.

B. Questions for review of graduate departments

1. Student research opportunities

Yes, the department of Applied Science provides its graduate students with research opportunities at the forefront of materials science and mathematical biology.

2. Graduate environment

The faculty in Applied Science is excellent: the senior members are at the top of their fields; the junior members are very promising and showing steady progress in their careers. The facilities in the department are first-rate, the intellectual atmosphere is superb, and the department's connections to physics, biology and nearby research labs are productive. Mentoring of graduate students seems to be effective, because they are committed to and enthusiastic about their research, and they can communicate their work effectively and intelligently to outsiders.

One area that needs improvement is recruitment of minority students from HBCUs in the tidewater area. This issue will be addressed in the review of the cluster.

3. Graduate financial aid

Stipends and other support for graduate students in AS are competitive with national standards for research departments. Support for MS students in other departments seems to be too low. *(Is it correct that a GTA pays $10K per academic year plus tuition and fees?)*

The AS department supports its students on GRAs for the first 1.5 years, then they are picked up by faculty members on specific funded research projects. This arrangement is consistent with national standards. Although it provides a great advantage to AS students and faculty, compared to other science departments which must support beginning students on GTAs, there did not seem to be much resentment about this arrangement among students or faculty.

Perhaps this dual-funding mechanism for graduate students could be tweaked a little. The GRAs could be used to support the best applicants to the PhD program in Applied Science, whether they are destined to work with AS faculty or with faculty from physics, biology, mathematics etc. For each GRA that goes to an excellent student in one of the other departments, a GTA could be offered to an AS student lower on the applicant list. After the first 1.5 years of GRA funding by AS, some students may choose to work for a non-AS faculty member who doesn't have sufficient grant funding to support the student. Instead of AS picking up the tab (which creates understandable resentments on both sides), these students could be switched over to GTA funding in the department where they are working.

4. Career preparation

The team did not discuss this issue with the faculty. Reading between the lines, we get the impression that graduate students in materials science are well prepared for rewarding careers in industry. Non-academic careers are less abundant in the areas of mathematical biology that are presently represented in the department. This area should be given more attention because, when the economy recovers (let's hope it does!), there will be plenty of opportunities for well-trained computational biologists in pharmaceutics, biotechnology, homeland security, and other non-academic sectors. Even more promising are areas that combine molecular-cell biology with nanoscience, microfluidics, interfaces, and other aspects of materials science.

Program Review for Computer Science

Questions for review of all departments

The Computer Science faculty are dedicated teachers and mentors, productive researchers, and enthusiastic members of the research and College communities. The faculty and the Department are doing remarkably well in all key aspects of the endeavor.

Nonetheless, in terms of sustained excellence, three major issues need to be addressed:

- The space available to the Department should be significantly increased. Such an increase has important positive implications for scholarship, faculty recruiting, graduate education and undergraduate education.
- The faculty size should be increased. The faculty is currently undersized to complete its mission and an increase will have strong positive impacts on scholarship, undergraduate and graduate education.
- Graduate student stipends should be significantly increased. Such increases will have positive implications for the graduate program and for faculty scholarship.

In the sections below we provide details on these needs as they relate to the questions posed in the charge to the review team.

1. Teaching and mentoring

The faculty have a strong commitment to both teaching and mentoring at both the undergraduate and graduate levels. Faculty have appropriate expectations in regard to student learning and their use of exams, homework and projects to assess that learning is on the mark.

Student satisfaction with the faculty and the program is high. In separate meetings with undergraduate and graduate students, we heard almost exclusively positive remarks. Students appreciate the sincere interest that faculty take in teaching and advising, and very much value the generally small class sizes that allow students to frequently interact with faculty. Students felt that the undergraduate program provides a nice mix of both theoretical and applied topics and that they will graduate with the job skills they need for both the short and long term.

At the undergraduate level, concerns were raised in regard to space (see item 4 below) and in regard to a long prerequisite chain. The latter makes it difficult for students who are "out of sequence' to get in all of the required courses in four years. To try to ameliorate the scheduling issues introduced by the prerequisite structure, the department publishes lists of anticipated course offerings at least a year in advance. It is not clear however how much attention the students give to those lists.

Students also felt the environment would be much improved by having vending machines in the building ...

2. Scholarly contributions

As a group, department faculty are publishing regularly, very often with their students, in both journals and top conferences. Faculty have had good success with funding, especially from NSF and are actively seeking additional funding. In addition, faculty are very active in serving on conference program committees and in conference and journal reviewing. The review committee feels that the level of scholarly activity is quite strong.

3. Undergraduate & graduate connections

The connections between the undergraduate and graduate programs are relatively standard. These include:

- Certain 400/500 level courses that enroll both undergraduate and graduate students. In at least one of these classes there are team projects where graduate students act as the team leaders.
- Undergraduate research for Honors' Theses where undergraduates participate with graduate students as a member of a faculty member's research team.
- The five year BS/MS joint degree program.
- Graduate students serve as TAs for courses taken by undergraduates.

4. Facilities

Space, or lack thereof, is the single biggest issue facing the Computer Science Department. At present there is about 650 sq ft of space per faculty member, in comparison with a computer science standard of 1000 sq ft. This space problem impacts all aspects of department:

- *faculty scholarly activity*: Over the past two decades computer science has become an increasingly experimental science. With that there has come a need for large amounts of research lab space for each faculty member to house their graduate students and computers in a synergistic environment, and to conduct experimental research in that space. The current research lab space available to the department does not generally allow this type of arrangement, as students and equipment are crowded into small spaces, unconducive to conducting experiments, to discussions or to quiet study. This situation places department faculty at a competitive disadvantage.

- *the graduate program*: again the primary issue is research lab space. Beyond the issues discussed above, we note that with students and equipment jammed together in overcrowded space, the environment is unproductive. As one student noted "When I need to read, I have to leave the lab – it's just not possible to concentrate there".

- *faculty recruiting*: Almost all new faculty now require space for a research lab. It is not clear where this space will come from for future hires. The problem seems especially acute in view of the desire to hire faculty in computer graphics, where extra large labs are required to house cameras, computers and related equipment.

- *the undergraduate program*: The main issue is in crowding of computer lab space where students can utilize workstations to complete assignments. The current computer labs are heavily utilized and senior undergraduates noted a special frustration in not being able to get timely access to the machines they need to complete their assignments. We note that because these assignments involve specialized software and hardware, it is not possible to use standard student owned desktops or laptops – department provided computer labs are required.

In regard to *library facilities*, there is a major deficiency in that IEEE Explore is not provided by the William and Mary library. This is a fundamental resource for computer science research especially in providing timely access to a large number of conference proceedings. Since the majority of computer science publishing occurs in conferences, a large number of which are sponsored by the IEEE, the lack of access to IEEE Explore is a significant problem.

5. Plan for the future

Department plans (both formal and informal) seem reasonable and generally on the mark. The major aspects of the plan are:

- Further strengthening the graduate program and scholarly activity by sustained faculty research and grant seeking activity.

- Increasing the number of faculty. At 14 members, with 2 on sabbatical each year (on average), the Department is undersized. We understand that a search for a 15th faculty member is planned for the upcoming academic year, and it seems essential that that search go forward. Beyond that we understand that a faculty size of 18 had previously been planned and we urge the administration to move in that direction. A larger faculty would: provide course offerings in important areas not currently covered in the Department; provide more collaborative research opportunities among faculty; and, more reasonably spread the department service load. Faculty recruiting should probably target databases, computer graphics, and possibly artificial intelligence or bioinformatics. These are important needs for the department in terms of faculty expertise and hiring in one or more of these areas is appropriate. Beyond that, we urge the Department to consider focusing future hires with the idea of building a small number of externally visible research strengths.

- To revamp the graduate curriculum to more closely mirror faculty expertise. This is entirely appropriate and we urge the Department to move forward on this as soon as possible.

- To champion the role of computer knowledge in undergraduate education across the College. The present computing requirement of the College is very weak. The Department should play a major role in defining an enhanced requirement and in offering courses that meet that requirement.

6. Development

The Department utilizes its website to provide information to alumni. This is an economical and entirely appropriate approach, especially for reaching alumni from a computer science department. The website has three easily spotted links that directly relate to alumni: a link to online department newsletters; a link on "Private Giving"; and, a "Send Us Your News" link. The electronic newsletter replaces earlier hard copy newsletters – these days, this is probably the most effective way to provide department information to alumni. Relative to that newsletter, it would be better for the newsletter to appear more frequently – at present there are only three newsletters shown on the website, with the most recent being in 2007.

It would also be worthwhile for alumni to receive an occasional email from the department, pointing the alumni to the website and encouraging giving, but this requires maintaining up to date email information for alumni. Maintaining that information at the department level seems problematic.

7. If additional financial resources are available …

In looking to the future, if additional financial resources are available the top priorities should be:

- Growing the department to the target of 18 faculty.
- Increasing graduate student stipends to a level commensurate with peer departments.
- Providing a major increase in space for the department.

Key to future success is to continue to recruit strong young faculty with competitive offers. The Department has done a very good job in this regard and the young faculty of the Department are generally very active in publishing, guiding students, writing proposals, all while spending considerable time on and showing enthusiasm for, their teaching. These young faculty cite faculty collegiality, a good environment for research, a competitive startup package, and especially the 1:1 teaching load, as being key reasons for their choosing faculty positions at William and Mary.

Questions for review of graduate departments

1. & 2. The graduate environment

The Department is a very good place for graduate students to learn about and conduct research. There is considerable active publishing at top conferences and in strong journals that is joint between faculty and their graduate students.

Interviews with graduate students, some in their 6th year, some just starting and some in between, were uniformly positive in their assessment of faculty, the Department, and William and Mary in general. Students were enthusiastic not only about their research opportunities, but also about the quality of teaching and advising in the Department and about the "life and career" mentoring that they are receiving from faculty. Terms used to describe the working relationships with

faculty – advisors and teachers - were “collegial”, “close”, “supportive” and “approachable”. Student satisfaction with faculty is very high.

In our meetings with students, three major concerns were raised:

- Students felt that they were underpaid. We totally agree and discuss this issue further in question 3 below.

- Students complained about the desk and lab space provided to them. We totally agree and discussed this issue in question 4 of the prior section.

- Students felt that the selection of courses available to them each semester was too limited. Our view is that the selection is tight, but not unreasonably so. Further, the Department attempts to make known a semester or two in advance which courses will be offered so that students can do appropriate planning.

3. Graduate financial aid

Graduate student teaching assistant stipends range from $1360 to $1600 per month, thus yielding a 12-month total stipend in the $16-19K range. These stipends are *well below* those of regional peer departments where the norms for a 12 month period are $22K or more. This low level of funding places the department at a severe competitive disadvantage in attracting strong graduate students. We urge the central administration to increase the funds made available to computer science for graduate student support so that the funding levels are at least at the norm for regional peer departments.

4. Career preparation

For graduate students seeking industrial employment, or those seeking faculty positions at doctoral institutions, the training is done in the standard fashion – namely, training students how to conduct research. Teaching related work is primarily grading and leading lab recitation sections. Other than for one “teaching fellow”, graduate students are not the instructor of record for courses. Lacking actual teaching experience will place students at a disadvantage in applying for faculty positions at institutions primarily focused on teaching.

Program Review for Mathematics

In their achievements both in working with students and in faculty scholarship, the Mathematics Department is very successful. This success is documented below in more detailed comments. Following the responses to the formal questions, there is a discussion of significant concerns that will affect the Department's success in the future.

Questions for review of all departments

1. Teaching and mentoring

The College of William and Mary has a reputation for being an institution at which undergraduate students receive a good education while experiencing perceptive teaching and getting individual faculty attention. What we learned in the Mathematics Department supports this reputation. The faculty are clearly committed to excellence in teaching and mentoring and go out of their way to ensure that opportunities are available for students. The faculty have high expectations for their students both while they are at William and Mary and also after they graduate and the information concerning their success is an important part of departmental planning.

The Department's data about where their graduates go, both for graduate education and entering the job market reflects well on the quality of the students' education and the undergraduate students we talked with said they felt they were getting an education that would enable them to meet their personal goals and they were confident of doing so. The faculty feel like they are very accessible to the students and the students confirm that they are, not only during the faculty members' stated office hours, but when just walking down the hall and dropping in. Moreover, it is quite clear that the students expect this accessibility and several even indicated they came to William and Mary because they thought the faculty would be accessible here, but not at other universities that they also considered.

While the description of the advising system, at least after the more formal Freshman year, seemed to us as reviewers as being somewhat haphazard and chaotic, both the faculty and the students seem quite satisfied that it is effective and comfortable. In fact, several students suggested that a more formal system might be somewhat stifling. Moreover, the students were very pleased with the College's automated system to check progress toward graduation and praised the ease of getting unusual circumstances that sometimes confuse the system (like a course counting toward two majors) fixed quickly when reported to the Registrar's office.

2. Scholarly contributions

In addition to fulfilling the teaching mission of the College, the faculty in William and Mary's Mathematics Department are doing excellent research and are recognized nationally and internationally for their scholarship. The research and scholarship is very strong across the faculty as a whole and the reputation of the scholarship is excellent, both in the more established groups and growing in the newer areas. The collaboration between faculty in the Mathematics Department and other departments is good now and appears to be growing among faculty

members with interests across disciplinary boundaries. There seems to be more collaboration here than in many other mathematics departments around the country. There is a healthy number of faculty in the Department who consider themselves applied mathematicians and would also be considered to be so in the wider mathematical community. The breadth and strengths of the Department seem appropriate for a department of their size and in the current state of the mathematical sciences nationally.

3. Undergraduate and graduate programs

The curriculum seems strong and fairly flexible for a program without extensive graduate course offerings and the students appreciated this fact. Both the faculty and the students feel that course offerings are broad enough and deep enough to prepare students for entry into good graduate schools as well as preparing students for beginning their careers immediately after graduation. The faculty seemed to feel that this was hard to achieve given the constraints on scheduling and both students and faculty feel that having important courses offered every other year makes difficulties for students, given that mathematics tends to be more sequential than some other subjects. Students especially complained that the schedule for the offering of the upper division courses was not predictable enough to effectively plan their programs while the faculty seemed to feel that it was inevitable given the juggling that is going on in construction of the course assignments.

The Department has a long-standing and nationally recognized REU program, funded by the National Science Foundation. Given the relatively low participation, nationally, of math sciences departments in research by undergraduates, this is a very positive aspect of William and Mary's Department – it shows extraordinary commitment of the faculty to provide this opportunity, especially because, unlike in other sciences, having undergraduate research students in mathematics usually detracts from a faculty member's own research effort rather than contributing to it. Many of the students we spoke with had participated in the REU program and were very happy with it. There were other students, however, who did not find in the Department mentors who were doing work of interest to the students. This is not surprising – it is probably inevitable in any program. However, there are hundreds of REU programs across the country at institutions of all kinds. It was surprising, according to student reports, that no one had advised these students that they should apply to some of these programs to pursue undergraduate research at one of these programs that met their goals. As a result, the affected students did not have an undergraduate research experience.

A problem surfaced (which we did not have time to fully understand during the visit) concerning accounting for the faculty teaching load and covering all the classes with qualified instructors. What some on the faculty believe is that the department will need to increase class sizes in calculus and other lower division courses taught by regular faculty in order to increase average student contact hours in the Department enough that other faculty will be able to offer advanced courses to their majors. Put in this way, the problem seems artificial and handling it in the way suggested does not seem in anyone's interest. Our advice is that the leaders of the Department discuss the issues with the administration so that an accommodation can be found that will allow for lower division courses to be taught effectively and for advanced courses for the Department's majors to be offered on regular basis.

Several faculty in the Department are unhappy that there is not a regular PhD program in mathematics, but it does not appear likely that this will change in the near future. The PhD in Applied Science allows students to pursue graduate work in mathematics and a few students are taking that option. Recruitment of students to that program is difficult in general, but it is made more difficult by a chicken – egg problem of arranging funding for the students: for mathematicians to recruit a student to the Applied Science graduate program they must provide assurance of funding for the student after the first 1.5 years of funding by Applied Science. But there is currently no way for the availability of the support to be determined before a student is even accepted to the program. It would seem to be helpful for AS and Math to work out some kind of arrangement that would assure math faculty that they would have funding for some number of students they might recruit in a year presuming their applications showed that they were of acceptable quality.

We did not see evidence of significant interaction between the undergraduate students and the graduate students outside of the COR program, where undergraduates interested in that program do connect with graduate students. Since the graduate students are involved in the instructional program, it seems likely that, if there were more graduate students, there would be more interaction with advanced undergraduate students. Furthermore, if there were more graduate students working with a larger portion of the faculty, there would more likely be increased interactions in a variety of the sub-disciplines present in the Department.

4. Facilities

For the most part, the facilities of the Department are adequate, but cramped. It appears more space will be made available soon as other units move to new space. With that space, there are things the Department will be able to do that they cannot do now, both to enhance their educational program and to have more space for faculty and graduate students. The Department is suffering from the practice, not unusual but nevertheless not helpful, of getting new furniture only when moving into newly constructed (empty) space. Most members of the Department seem to have access to the computing facilities that they need, although a recently hired faculty member continues to use the facilities of his former institution because William and Mary's computers are not adequate for his needs. As is common in educational and research institutions, there are concerns about continuing access to library resources. Mathematics as a discipline has differing library needs because anything that was ever true in mathematics is *still* true: information does not go out of date as in other scientific fields. This means that mathematicians need continuing access to old research material as well as newly discovered information. Current library trends raise concerns about this continuing access to the breadth of the scholarly literature that is important to mathematics research.

5. Plan for the future

The short term goals for the Department, as laid out in the self-study document, seem appropriate and realistic. Based both on the document and conversations during the visit, the members of the Department seem to have a good grasp of its strengths and weaknesses, the goals for progress, and of the challenges that lie ahead. However, there does not seem to be a consensus of how to achieve those goals nor a way to develop that consensus.

6. Development

Based both on our understanding of the Mathematics Department and of other departments, it seems that communication with alumni could be greatly facilitated by more collaboration between departments and those in the College who are concerned with alumni relations generally. It appears that no one is keeping a good record of where the alumni are, but it would be beneficial both to the College as a whole and to the departments in particular if this information were available to departmental planners for arranging visits of alumni to classes and for making contacts between students and graduate schools or companies. It is well known and documented that alumni that are connected to their departments are more likely to donate financially and in other ways. In spite of the lack of formal data, the faculty in the Mathematics Department are aware to some extent where recent graduates have gone and have tapped them for visits to campus and other kinds of contact.

Even though there does not seem to be a well organized campaign for private donations, the Department claims that their record of attracting funding for the Department's projects, in contrast to individual faculty projects, is a form of development. There is some merit to this contention and the Department has been very successful in attracting this kind of funding and using that funding effectively to improve their programs.

7. If additional financial resources are available ...

Continuing improvement in the Mathematics Department will depend on maintaining a good faculty size so that the mission of the Department, in undergraduate teaching and mentoring and in scholarship, can be achieved. This will not be easy, both because of financial pressure and because of the difficulties of retention and hiring, but it will be critical to persevere in maintaining a good size. Beyond, this there would appear to be significant benefits if funding for graduate students could be made more predictable and be expanded if possible. It seems likely that this would improve morale as well as bring positive educational and scholarly benefits to the programs of the Department.

Issues facing the Mathematics Department

The most serious problems facing the Mathematics Department have to do with the hiring and retention of faculty and the disagreements among the faculty regarding these issues. It should be pointed out again that, in addition to fulfilling the teaching mission of the College, the faculty in William and Mary's Mathematics Department are doing excellent research and are recognized nationally and internationally for their scholarship. In addition, there is considerable evidence of collaboration between faculty in Mathematics and faculty in other departments on campus, more here than in many other mathematics departments around the country.

Some members of the faculty are extraordinarily productive by any standard, producing more than ten papers a year, while other faculty members, also doing excellent scholarly work, publish much less than that. It is very important for the leaders among the faculty to recognize that there are many ways to be excellent in research and it is important for faculty members to value the contributions made by their colleagues, whether their contributions are of the same type or of a

different kind than one's own. It appears that these differing ideas concerning the meaning of excellence form part of a division among the faculty that affects morale and contributes to the retention problem: some faculty feel they will not be able to succeed at William and Mary because their scholarship is of a different form than that valued by the Department. Over the past few years, there has been an emphasis on broadening the kinds of mathematical research done by the faculty and also in expanding the kinds of applied mathematics that is done. This is a very important step for the Department, one that will pay dividends in the future. Mathematics is becoming increasingly diverse and there is a growing emphasis on applied mathematics so it is important for this Department to reflect that diversity. Unfortunately, these changes and different styles of scholarship in these different areas are also contributing to the division in the Department.

Problems in retention are always difficult to address, not least because when someone leaves there are usually a number of issues that contribute to the decision and not all of them are discussed with former colleagues and administrators. The apparent division in the Department and the mixed messages about how successful young faculty members are, because of different ideas of excellence or different ideas of what fields of research are important, surely contribute to the problem. In the case of some faculty members who left in the past few years, their dissatisfaction was not recognized early enough for the College to respond before they applied for positions elsewhere. In general, a proactive and early response is the best preventative in such cases.

Two other issues were mentioned to us in connection with the retention problem. First is the fact that William and Mary does not have a PhD program in Mathematics, and second is the teaching load. There is no doubt that both of these, along with salary and the emphasis on undergraduate teaching at the College, affect the pool of applicants that you get: if people want to mentor PhD students, want to have a 1-1 or 2-1 teaching load, or want to teach in an institution that puts minimal emphasis on undergraduate teaching, they are not likely to apply to William and Mary. It is less clear that these are important parts of the retention problem unless the messages applicants get about expectations in any of these factors are inaccurate or the Department is not trying to match their hiring to their goals for potential faculty members. To clarify the teaching load issue: teaching loads are market created and therefore, for the most part, are specific to each discipline. Currently, teaching loads in mathematics vary from 1-1 to 4-4 for different kinds of institutions, primarily varying by research expectations. A few years ago, the teaching loads in mathematics at most top 25 public research institutions in the country were 2-2, but over the past decade or more, there has been increasing pressure, and partial success, to reduce this to 2-1 (we are told that about half of the top 25 have a 2-1 load.) The 2-2 load is quite common at public research institutions ranked 26 to 100 and is also common in private undergraduate colleges that value research highly. One difficulty for William and Mary is that there may be some variation in teaching load expectations between pure mathematicians, applied mathematicians, and statisticians. It does not seem to us that the 2-2 teaching load in the Mathematics Department is out of line for elite undergraduate institutions like William and Mary.

Regarding the effect that these considerations have on retention, it is certainly true that people entering the job market may misjudge their attractiveness to various segments of the market and not be able to get a job where they think they "deserve" one. In this case, they will choose the job they are offered that they believe best matches their goals. If later the market changes, or

changes its opinion of them, they may have an opportunity and choose to leave. There is little the College or the Department can do to prevent this beyond trying to match their goals for faculty to their perception of the potential faculty members' goals for themselves.

Questions for review of graduate departments

There are two separate parts to this review: one for computational operations research and one for the PhD program in Mathematics via Applied Science.

Computational Operations Research

Summary: Although COR is serving a valuable function both for Math and for its students, it is in a precarious position: small changes in personnel, politics and admissions could threaten its viability.

1. Student research opportunities

Computational Operations Research (COR) is the graduate program of the Mathematics Department (Math), providing a Masters degree that can be earned in three to four semesters of study. Operations Research (OR) is a field of applied mathematics that uses mathematical and computer models to design and improve the performance of business, manufacturing, service, financial, health care and telecommunications systems. Masters programs in OR are most often found in industrial engineering and operations management departments; however, William and Mary is not unique in providing such a program based in mathematics. COR is a practice-oriented, rather than a research-oriented, program.

COR supports Math's undergraduate teaching mission by supplying teaching assistants, particularly for the large load of calculus classes. Approximately 9 courses of faculty teaching load are expended by Math to offer the COR program; an occasional course is taught by the Computer Science (CS) faculty.

2. Graduate environment

The incoming COR students are of high quality as measured by standardized tests and the schools where they did their undergraduate studies. From 4 to 9 new students matriculate each year. The review team spoke to *all* students currently in the program; they were universally pleased with the program content and the faculty, and were challenged by the curriculum.

For historical reasons, COR resides in CS, not in Math, and the OR courses all have CS course numbers. COR imposes a light administrative load on CS (primarily for admissions paperwork) that the current Chair of CS finds entirely acceptable, but this need not be the case for all future chairs since COR is not essential to the teaching or research mission of CS. Of equal importance, a computer science department is *not* a typical home for OR, making the COR program difficult for potential students to find and perhaps leading to confusion (since COR is no more

"computational" than any first-rate OR Masters program). All of this has an impact on recruiting students, a topic described further below.

COR is heavily leveraged on the efforts of a small number of faculty, especially Professors Kincaid and Leemis. Nearly every student we spoke to was personally recruited by Prof. Kincaid, and most pointed to his efforts as being instrumental in bringing them to COR. Further, there appears to be no reliable pipeline of students other than the supply of military students. To the best of our knowledge, each non-military student was a special case, finding the program by some fortuitous happenstance that brought them to the attention, and cajoling, of Prof. Kincaid. If either Kincaid or Leemis were to abandon the program it would be in serious jeopardy.

The review team supports the desire of COR to obtain both a more stable, and modest increase in, enrollment. This would provide a richer environment for students in the program, enhance the research and retention of the OR faculty in Math, and alleviate more of the teaching pressure on the mathematics faculty. Because the program is of very high quality, COR graduates enhance the reputation of William and Mary. Clearly additional College funding is one way to achieve this objective. However, not only student funding is necessary, but also a modest budget for advertising. Small adjustments in the curriculum (in particular adding electives in data mining and financial mathematics) would make the program more appealing to students desiring jobs in business analytics, an employment area that is likely to grow for many years to come.

A different tack is for the program to take an entrepreneurial approach. The review team believes that with a two-year investment of start-up funds from the College, and some mechanism for Math retaining a portion of tuition revenues from full-tuition-paying students, COR could support its expanded size without additional College funding. There is a strong job market for students with this degree, and industrial engineering departments have experienced significant growth in full-tuition-paying Masters students. COR can be particularly attractive to B.S./B.A. mathematics graduates who may find employment in business and industry limited. This includes Mathematics students at William and Mary who might be attracted to attaining a Masters degree by going on for a fifth year. Further, if it is successful, this approach could provide a source of funding for Math Ph.D. students through Applied Science.

3. Graduate financial aid

The College provides support for 3.5 students per year, or a total enrollment of 7 students in the two-year program. At this level the program is barely viable. The faculty involved in the program have overcome this deficiency in several imaginative ways: The approximately $42K in annual funding for stipends is split creatively among more than 3.5 students, apparently achieving just the level required to get each student to enroll. In addition, a strong connection has been established between COR and the U.S. Coast Guard and Army so that there is a reasonably steady flow of such students (0 to 3 per year) who are fully supported by the government. (Of note, COR is on a short list of programs approved by the Army for officers who will teach at West Point, a list that includes Georgia Tech, the #1 ranked industrial engineering program in *US News & World Report.*) While not contributing to Math's teaching mission, these students do help maintain workable class sizes and smooth out enrollment fluctuation; they are also of high quality and have a strong work ethic. Clearly there is no way to guarantee this pipeline will persist indefinitely.

4. Career preparation

Placement after graduation does not appear to be a problem, and this makes sense as there is a thriving market for OR analysts, especially in services (including the financial sector) and government. Placement is aided by the fact that most non-military students have a relevant summer internship between their first and second years of study.

Math Ph.D. Program

Summary: Math houses no Ph.D. program of its own, but Math faculty who desire to work with Ph.D. students may do so through the Applied Science Ph.D. program. A more predictable funding mechanism is necessary for this option to thrive.

1. Student research opportunities

The primary barrier to wider use of the Applied Science Ph.D. program by Math faculty is student funding. In brief, a Math professor cannot secure the internal (3-semester) Applied Science funding without having a student, but cannot typically recruit a student without providing assurance to fund the student after semester 3. Ways around this barrier include self-funded students (e.g., government funded military students), or the faculty member having an existing grant when the student enters the Applied Science graduate program. The former is a special case that will most often be feasible for OR faculty (there is currently one such student), and the latter is difficult logistically since research needs to commence almost immediately after funding is obtained, not a year later after recruiting a student.

2. *Graduate environment*

The review team spoke to two Math students currently in the Applied Science Ph.D. program. Although these students confessed to feeling a bit isolated, and cited some logistical issues (such as obtaining an agreement as to what subjects would constitute their qualifying examination), this mechanism seems to work.

3. Graduate financial aid

The review committee recommends a "set-aside" of at least one funded student per year in Applied Science to which the Math faculty could recruit. Math would be responsible, through a combination of grant and teaching assistant funding, for support beyond the first three semesters. An entrepreneurial COR program could generate some of this funding. And the possibility of occasionally recruiting a Ph.D. student would help with retention of junior faculty who are attracted to Ph.D.-granting programs.

4. Career Preparation

Math Ph.D. students have very little coursework available to them, since Math does not have a graduate program and therefore also no graduate courses. Ideally a student comes to William and

Mary having already obtained a Masters degree covering the most relevant coursework so that their focus is on research with their faculty adviser. This is the case for the two students currently in the program.

For career preparation, these two students represent best case scenarios: The military student, whose Ph.D. research is focused in OR, has already been assigned to teach at West Point. The pure math Ph.D. student hopes to obtain an academic job, and Math has facilitated her career preparation by supporting her as a "teaching fellow." This combination of teaching and research experience should make her competitive with students graduating from math departments with Ph.D. programs.

Program Review for Physics

Questions for review of all departments

1. Teaching and mentoring

The high quality of undergraduate teaching is one of the most significant strengths of the Physics Department in the College of William and Mary. The members of the faculty in the Department are all committed to high quality education and are willing to put in a great deal of time and effort to achieve these goals. In our discussions with the Physics undergraduates they all invariably praised the faculty members for their excellent teaching and for their accessibility to students. The student evaluations of the Department's teaching are very high, most of the rankings being in the 4.0 to 4.5 range.

A unique and important aspect of the physics curriculum at William and Mary is the requirement that physics majors write a senior thesis based on independent research under the supervision of a faculty member. All of the faculty members participate in the program and the program is universally praised by the undergraduates. Some of the students do their theses under supervision of faculty members from the Applied Science Department, and there are no barriers in the way of those who choose to do so, a policy that we applaud. We want to point out that successful execution of this program does impose an additional burden on the faculty which is not taken into account in calculating the formal teaching load.

The curriculum currently being offered is somewhat lean but it does cover all of the essential and standard undergraduate physics courses and thus is able to provide good preparation for students to go on to graduate studies in physics. For future reviews it would be useful to list the undergraduate course sequence in the written material provided to the review committee. About 50% of physics students appear to want to pursue continued education in physics and a significant fraction of the rest plan for graduate studies in related fields. In our opinion the training provided at William and Mary is very well adapted to both choices.

The program would be strengthened by the addition of few more faculty members so that the curriculum could be broadened. Some of the additional topics we would like to see covered in the undergraduate curriculum are modern optics, nuclear and particle physics, condensed matter, and more extensive coverage of astrophysics and cosmology.

At the present time the effectiveness of the undergraduate physics education is evaluated only through formal examinations. The review committee urges undertaking an effort to follow up on William and Mary graduates in physics to see what and how they are doing 5 and/or 10 years after graduation. In our opinion that is the best metric for the evaluation of any educational program.

2. Scholarly contributions

The research activities in the William and Mary Physics Department focus on a few areas and try to emphasize quality over quantity. This is an appropriate strategy for a small physics department

in an institution heavily committed to undergraduate education and thus limited in the scope of its research activities. The faculty members, however, are all involved in frontier research and thus are able to provide the students with opportunities to participate in solving some of the most interesting problems in the field today.

Based on the information provided to us we concluded that the Physics faculty ranks high in scholarly research. All of their members are receiving external grants and their total sum is quite impressive given the nature and the size of William and Mary. Based on the compilation of various statistics by the American Institute of Physics, the William and Mary Physics Department compares quite favorably with its peer institutions. A list of publications and citations for the last 3-5 years would be most useful. It would also be helpful if faculty members included 3-5 earlier publications they felt to be particularly notable. This information should only be provided for the specific department being reviewed.

3. Undergraduate and graduate connections

Graduate students in Physics serve as Teaching Assistants in elementary courses and thus can provide undergraduates information about graduate level education in physics from a different perspective than that of the faculty. In many instances there are also individual interactions between undergraduates and graduate students within the framework of research activities connected with the senior theses. Thus graduate students can serve as mentors and informal advisers to the undergraduates through the interactions in this forum.

4. Facilities

The current Physics building will undergo expansion soon by adding two new wings and, at the same time, complete renovation of the existing structure. We feel that this is an important opportunity to address some of the crucial space needs in the Department and also plan for the requirements that will likely exist in the future. The current research space seems rather limited; many faculty members are quite cramped and some of the recent hires do not even have laboratory space of their own. Some of these problems need to be remedied as soon as possible and cannot wait till the planned completion and renovation of the building. One might need to reevaluate how much space should be allocated to the emeritus faculty. There are a lot of advantages in maintaining intellectual involvement of the retired faculty with the Department, but if that involvement is absent there is no justification in allocating to them significant amounts of space at the expense of the needs of the active faculty.

We did not have the opportunity to discuss in any detail the plans for the new structures and for the renovation. We urge a careful forward-looking plan that anticipates the needs of the future as well as the modes of doing research in the future. For example, the current library occupies a significant amount of space. Given the trend towards electronic publication of the journals and availability of many older articles in the electronic form, the role and needs of the library in the future might well be quite different from what they have been in the past.

The needs of the research groups will also undoubtedly evolve in the future. Thus special attention should be paid to the requirements that might be imposed on the building by anticipated future research activities. We were impressed by the recently constructed NMR building and the

associated instrumentation and see it as a good model to emulate.

The Department still has machine shop facilities and three staff members working there. Such facilities are rapidly disappearing from universities, but we feel that they are quite important both to the educational process in physics and for the support of research activities. We urge that they be maintained if at all possible. The Department's desire for an additional computer professional staff person seems quite appropriate in light of the rapidly expanding use of this technology and constant new developments.

5. Plan for the future

The Department has recently drawn up a long range plan which on the whole appears to be quite sensible and appropriate. The Department places top priority on hiring faculty to fill the currently vacant slots and subsequently expanding in the areas of Condensed Matter physics and Atomic, Molecular and Optical (AMO) physics. We think that hiring a top condensed matter experimentalist should be a top priority of the Department. It is a very active field and well suited for frontier work in the university environment. The startup costs are non-negligible, however. The University should be prepared to spend in the vicinity of $1M for that purpose if it wants to obtain a first rate person.

Given the nature of William and Mary, the strategy of concentrating on a few (four) core areas makes sense to the review committee. But at the same time one should not lose sight of new exciting developments in other areas. Probably the best example of such an area today is the subfield of Astrophysics and Cosmology; there is essentially no presence in this field at William and Mary. It is unlikely that sufficient resources could be made available to form an active and viable group in this area (3 to 4 faculty positions). But one might consider in future searches the possibility of looking for people with at least a peripheral involvement in that subfield. Conceivably a replacement for the recently deceased member of the hadronic-nuclear group might be a candidate for such a role. We appreciate the unique opportunity William and Mary has in the hadronic-nuclear area due to the proximity of the Jefferson Lab but the group is already very strong there and diversion of some of that strength elsewhere should not jeopardize its effectiveness.

6. Development

There does not seem to be any formal effort currently in the development area. We urge the Department to be more proactive here but at the same time want to emphasize very strongly that these efforts have to be coordinated between the Department and the College (or Arts and Sciences) Development Offices. One effort must not "step on the toes" of the other and undoubtedly the Development professionals can provide good advice to the Department about how to optimize the effectiveness of their efforts. Some of the mechanisms to consider might be an annual newsletter, annual alumni reunion - both for undergraduate and graduate alumni, and maintaining records of what is happening to the alumni and of their current addresses.

7. If additional financial resources are available …

If additional resources are available they could be put to good use in the Physics Department. The most ambitious use of such resources is to enlarge the size of the faculty, to provide a better coverage of modern research in physics and to provide valuable interdisciplinary links. The first priority should be to enlarge the condensed matter research effort. Approximately 40% of American physicists are condensed matter physicists, and it is an area of physics that holds fascinating intellectual challenges and the prospect of economically important advances. The department has already identified this area as its priority, and we agree completely. A second area of faculty growth is in the area of atomic, molecular, and optical physics, which can make valuable connections with both condensed matter physics and chemistry. Laser cooling of atoms has made it possible to realize, using cold atoms, ideal solid state systems, and atomic and condensed matter physics are beginning to overlap, to the benefit of both areas. Similarly, laser control of molecules is opening new research areas in chemistry, and by making judicious hires in the area of laser spectroscopy it should be possible to strengthen interdisciplinary efforts among the Departments of Physics, Chemistry, and Applied Science. We note that the department has also identified this area as a desirable area for growth. Finally, one of the more intellectually exciting areas of physics is astrophysics and cosmology, a developing area of high energy physics, which is not represented at all. Given the present size of the department it is prudent to focus on a few areas and cover them well, but if resources are adequate it would be worth expanding into such a "gee whiz" area of physics.

The Physics Department at the moment is very sparsely staffed, and the lack of staff support leads to real inefficiencies. There is no electronic technician or computer technician. As a result, faculty members spend their time fixing electronic instruments and setting up computer networks, tasks which can be done much more quickly and cheaply by trained staff personnel. Providing such personnel would increase the productivity of the Department at a fraction of the cost of hiring new faculty.

In Physics all undergraduates conduct independent research projects, which is the best possible introduction of an undergraduate to research and is only possible in a department with a strong research program. Advising a student conducting an undergraduate research project requires effort on the part of the faculty member, and it may require resources, in the form of materials and supplies. At the moment faculty members receive no explicit recognition for supervising these projects, which is a source of some unhappiness. An appropriate recognition of the effort required for faculty supervising independent research is a small, $2-3k, unrestricted grant for research support for each independent research project supervised. Other forms this recognition could take are credit towards sabbatical leave or reduced formal teaching loads.

If no new resources are available, the department should focus its faculty hiring in the area where the additions of faculty will have the most effect. In the short term the focus should be on condensed matter physics. Hiring technical staff would improve the department's productivity, and it is inexpensive compared to hiring science faculty. Furthermore, a significant cost of hiring technical staff could be paid from grants. The college and department should discuss such an approach.

Questions for review of graduate departments

1. Student research opportunities

The Physics Department provides excellent research opportunities in four areas of physics: high energy physics (HEP), nuclear physics (NP), condensed matter physics (CMP), and atomic molecular, and optical physics (AMOP). Within each subfield the offerings are limited, but of high quality. There are two quantitative measures of the quality of the department's research. It is well funded, at an annual level in excess of $5M/yr , and more than one third of the faculty are Fellows of the American Physical Society. One half of one percent of the membership is elected to fellowship annually. In experimental CMP the research opportunities are limited, but this is an issue the department is keenly aware of and planning to rectify.

2. Graduate environment

The faculty is committed to conducting a vigorous graduate program. They are engaged in activities to expand their intellectual horizons and those of their students. An excellent example is the joint mathematical physics seminar conducted with the Mathematics Department. The department offers the standard graduate courses, although the number of electives is limited, due to the relatively small size of the faculty. As for the undergraduate program, a listing of the graduate course requirements and offerings would be quite useful to the reviewers. Advising of students working on their theses is done in a well defined manner, with an annual presentation to a committee, an excellent way to ensure that students are making satisfactory progress. Advising of graduate students prior to their becoming thesis students is apparently informal. The course requirements and qualifying examination requirements are clear, and it is understood by both students and faculty that the first summer and the first semester in a research group are exploratory, in that a student can at that time move to another research group with no bruised feelings. Students are aware of the fact that they need to determine which faculty members have funding and can support students, and they apparently communicate among themselves well enough that this information is widely available. A possible improvement would be introducing research talks by the faculty to inform students of current research in the department. While the present system is informal, it works. The graduate students are happy with it, and they feel comfortable approaching faculty members. All in all, graduate education in the Physics Department is a positive and productive experience.

3. Graduate financial aid

The stipend of $22,000 for 12 months plus tuition, fees, and health insurance, is competitive.

4. Career preparation

Preparing for a career in or using physics requires mastery of physics research and communicating the results and importance of the research in both oral and written form. An important part which is often neglected is oral presentation of the work. The William and Mary program addresses this issue well by means of the annual graduate student reviews. The department provides students with exposure to a broad range of physics research through its active research programs. Specifically, students work at national facilities and attend scientific

meetings, both of which provide students with valuable information about career opportunities. The best measure of student preparation is what students do after they graduate. In physics a postdoctoral position is a prerequisite for a faculty position, and from a postdoctoral position it is possible to go into either academia or industry, so it is the most common career path for Ph D physicists. Many of the William and Mary students go on to postdoctoral positions at excellent research universities such as MIT and Stanford, and national laboratories such as Oak Ridge National Laboratory and Jefferson Laboratory.

Program Review for the Cluster

Questions related to the entire cluster are addressed in this section.

1. Contributions to the undergraduate core curriculum

These departments contribute well to the undergraduate mission. We noted only a few structural problems that provide impediments to students:

- William and Mary's "Digital Information Literacy Proficiency" and haphazard "Major Computing Requirement" are not sufficient to prepare students for 21st century citizenship or scholarship. William and Mary does its students a disservice by not establishing a "GER" requirement in this area, giving the Computer Science Department (not Interdisciplinary Studies) the responsibility for developing appropriate syllabi in consultation with the other departments at William and Mary.

- The process for undergraduates to obtain permission to take a graduate course seems unnecessarily burdensome. Permission of the course instructor, along with the student's advisor or department chair, should suffice.

- There were reports that some Physics courses did not have appropriate Mathematics prerequisites. Specifically, that students were expected to have linear algebra and differential equations knowledge before having had a chance to take the Mathematics courses covering those topics.

2. Student advising

Freshman advising seems to be handled in a structured and effective manner. Advising for advanced undergraduates is more haphazard, but students seem quite satisfied with the feedback that the Banner system gives them and the good access they have to faculty members.

3. Undergraduate research

The committee was impressed with the number of students who participate in undergraduate research. The form of research varied from individual projects with a single faculty member (common in Mathematics, for example) to participation in research teams involving faculty and graduate students (common in Physics). Both of these models seem effective in leading to senior theses and, sometimes, research publications. Physics is especially committed to undergraduate research, requiring a senior project from all majors. Undergraduates also reported that the faculty were helpful in informing them of internship opportunities and REU opportunities at other institutions, and some William and Mary undergraduates participate in REU programs at William and Mary.

In addition to individual undergraduate research projects and undergraduate collaborations within an established research group, some universities have had success with team undergraduate research projects mentored by one or two faculty members, and this model might work well at William and Mary. One example of such a model is the Gemstone project at the

University of Maryland (http://www.gemstone.umd.edu). Such programs build interdisciplinary teams for multi-year collaboration on projects. For example, Gemstone teams finishing this year have built and evaluated a navigation system for the blind and developed and evaluated the usefulness of a cage for protecting terrapin nesting sites. Such projects are particularly effective in engaging students in research before they have enough background to make useful discoveries within their own disciplines, and they are excellent at allowing students to learn to appreciate the contributions of other disciplines to societal problems.

In order to ensure the health of undergraduate research at William and Mary, student mentoring should be a criterion for promotion and salary considerations, along with teaching, service, and research.

4. Service learning

We saw no evidence of such projects, but see the Gemstone suggestion above.

5. and 6. Interaction, collaboration, and interdisciplinary activities

In a college the size of William and Mary, the missions of undergraduate education and scholarly activity can be greatly enhanced by maximizing faculty interaction at the interfaces of traditional disciplines. Such interaction enables groups to achieve the critical mass that can be impossible to attain within the confines of a single department and to pursue funding opportunities that are otherwise outside their reach.

The units we reviewed are to be congratulated for their substantial and impressive interdisciplinary efforts. Cooperation was evident in research interactions (e.g., mathematical physics, mathematical biology) and efforts to fund undergraduate research (e.g., CSUMS). The ties to Jefferson Lab, ARC, NIMS, National Aerospace Institute, and Virginia Nanotech Consortium are unique and invaluable to the life of departments such as Physics and Applied Science.

There are tremendous opportunities for additional interaction and some institutional impediments to these interactions:

- Although some individual faculty members reach across departmental boundaries, the attitude at the chairs' level was predominantly, "We wait for others to come to us." This is bound to cause missed opportunities, and the culture will only change with impetus from the Dean.

- Strong research in the Biology and Chemistry Departments would open the doors to additional opportunities.

- The Applied Science Program is well positioned to serve as the glue for interdisciplinary interaction, but some structural problems inhibit its effectiveness. For example, the educational mission of the Applied Science faculty is primarily (and appropriately) graduate, while that of the other departments is primarily undergraduate. Applied Science graduate students receive assistantships that enable them to do research, while

graduate students from other departments, funded from the same source, are employed as teaching assistants. This two-tiered system is bound to cause some friction.

- The Dean is in a unique position right now to enhance collaboration in the coming years. There are a great number of unfilled positions, due to the budget situation, so it is an ideal time to engage in strategic planning across the sciences to see where bridges can be built between departments. Coordinated hiring efforts could be planned, in which two or more departments hire a small number of faculty members with potential for interaction and potential for exploiting funding opportunities over the next decade. Such a coordinated crosscutting hiring plan could lead to important undergraduate education initiatives.

- There are also opportunities for interdisciplinary activities between these departments and strong departments in the humanities, social sciences, education, and arts. For example, Computer Science research in natural language processing could have links to linguistics and psychology. Work on image processing, graphics, and material science can be linked to art and archeology. Possibilities such as these should be considered when formulating a long-term hiring plan that builds on the strengths of William and Mary.

- The Dean could also encourage collaboration by calling for proposals for hiring postdoctoral fellows in interface areas. With a relatively small and time-limited investment, long-term research collaborations can be seeded.

- Beginning an interdisciplinary research project requires a faculty member to make a substantial investment, overcoming barriers imposed by lack of background, inscrutable jargon, and cultural barriers (e.g., mode of publication of research and assignment of credit). Departments must recognize and reward this investment.

- Departments should be encouraged to cross-list their courses. This in itself encourages interaction among the faculty and makes students aware of connections across disciplines. For example, Numerical Analysis (Math 413, 414) has a role to play in computer science, and some Computer Science faculty members are well qualified to teach it. This needs to be encouraged by a policy, at the Dean's level, for assigning student credit hours equitably among departments that share the listing and teaching of courses. Such a policy would also encourage the development of courses at the interfaces, which would be a valuable addition to the curriculum.

- Similarly, students with double majors form important links between departments. If such students have research mentors in two departments, bridges are built. Currently the reward system for departments works against such arrangements, since the student is credited to a single department, while the other department incurs costs without credit. This impediment requires fixing at the Dean's or Provost's level.

7. Diversity

Despite good intentions and some successful efforts, diversity does not seem to be getting the attention it deserves.

Diversity of Faculty:

One area of strength is the recent hiring of several women faculty, and the departments are to be congratulated for identifying and recruiting these candidates.

On the other hand, the record of retention of women (and of junior faculty in general) is troubling.

- Although there is an excellent mentoring program for first-year faculty (gathering them all together to talk about teaching, grantsmanship, etc.), mentoring beyond that year is spotty at best. Several programs that are successful at other institutions seem to be absent: assignment of a faculty mentor, periodic gatherings of junior science faculty for mentoring events, annual discussion of the person by those who will vote on tenure, and annual mentoring by the chair based on this discussion. All of this improves the chances that the faculty member will succeed and increases loyalty to the institution.

- The most common systematic feedback, other than the 3rd year review, seems to be a number arising from the salary review process. For an institution that emphasizes personal interactions, this is ironic and demoralizing.

- Because of the design of the salary review process, junior faculty are not always rewarded by appropriate salary increments. It is important to recognize that any quantitative measure that is easy to do (paper counts, citation counts, page counts, etc.) is deeply flawed, since it does not assess quality of work and does not account for reasonable variations in expectations across subfields (noting, for example, that there should be different publication expectations for theorists and experimentalists, core researchers and applied researchers).

- From one department we heard an opinion that women applicants would not be welcomed, and from another we heard a report of overt bias in one influential faculty member. This is indeed troubling.

- No departments seemed to have hope of finding African-American or Hispanic-American candidates.

Given the size of the departments, it would probably be a good idea for the Dean to have more involvement in the search process. Two procedural changes might be helpful:

- Put an outside member on all faculty search committees, charged with monitoring the fairness and inclusiveness of the search.

- Require a report of efforts to find qualified candidates from underrepresented groups, and a justification of the short-list, before any candidates are invited to campus.

Student Diversity:

On this point, data is quite sparse. We heard no mention of organizations to support women and minority students. The committee was given the following statistics (in the table ??? indicates 'no data was provided', while N.A. indicates 'not applicable'):

	Faculty Women	Faculty Afr.Am.	Faculty Hisp.	Grad. Women	Grad. Afr.Am.	Grad. Hisp.	Undrgr. Women	Undrgr. Afr.Am.	Undrgr. Hisp.
Appl. Sci (p14)	???	???	???	???	???	???	N.A.	N.A.	N.A.
Comp. Sci (p45)	21%	???	???	25%	4%	???	25%	???	???
Math. (p98)	5%	???	???	40%	???	???	40%	10%	???
Physics (p151)	12%	???	???	???	???	???	???	???	???

Given the population density around William and Mary and the proximity of multiple HBCUs, we would expect a much more successful emphasis on training, recruiting, and retaining minority students.

Some suggestions:

- Exploit William and Mary's location by establishing more partnerships with neighboring institutions. This should include more partnerships like the Howard Hughes program that brings faculty and students to campus for summer research and a joint detector-building project with HBCUs. Such efforts should be recognized and rewarded.

- Establish local chapters of organizations such as Association for Women in Science, Association for Women in Mathematics, and Association for Women in Computing.

- Send students and faculty to meetings such as the Grace Hopper Celebration and Tapia Celebration of Diversity in Computing.

- There is a danger when small graduate programs are filled primarily by one-on-one recruiting. Establish a system of checks and balances to make sure that recruiting is broad and fair.

One final issue related to the review process and all departments in the cluster:

- It is impossible for William and Mary to evaluate the effectiveness of its educational programs without having placement data for its graduates, perhaps 6 months, 5 years, and 10 years post-graduation. Without this information, it is impossible to measure what really matters.