

***Decadal Review of the Department of Applied Mathematics,
University of Washington***
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Executive Summary

The Department of Applied Mathematics (hereafter “Amath”) has been focused on interdisciplinary research and graduate training since it was created in 1985 largely from faculty in Engineering and Oceanography. There are 10.5 faculty, half of whom are new since 1997, and 50 graduate students. In addition to its vigorous PhD curriculum, Amath recently began a Professional Masters Program with 15-20 students. It presently teaches an array of 300- and 400-level courses but does not have its own undergraduate majors program. These courses contribute to Amath's role in the interdisciplinary Applied and Computational Math Sciences (hereafter “ACMS”), a broad undergraduate degree program.

The Review Panel of 1997 used “remarkable” to characterize their view of Amath’s research productivity, lucrative grant support, intellectual climate, and its dynamic impact on many disciplines and departments within U.W. We concur and extend that adjective to characterize Amath’s leadership, internal enthusiasm, newly launched ACMS and Professional Masters Programs, the nationally pre-eminent VIGRE and GK-12 grants, the engagement of undergraduates in research, and the assimilation of its new faculty who have replaced fully 50% of the existing Amath faculty in 1997. We can add buoyant, confident, energetic, responsive, and innovative as general descriptors of this department.

In view of the history of Amath (§I), and after a careful analysis of the present state of the Department, various academic and administrative improvements within its reach, and the changes in applied mathematics (§II), the Panel is confident that Amath is poised for an exciting future. Consequently, *the Panel unanimously recommends that the Department and its PhD, undergraduate, and Professional Masters Programs be extended by the U.W. Administration and fully supported by the University for the next decade.* We conclude in §II.P that, although Amath has forged forward with new initiatives in the past decade, addressing strategic needs while sustaining its present momentum will require additional people and stronger support from the University.

We offer a suite of interconnected recommendations that identify some pathways to progress (§III). Five of them are urgent and should be addressed aggressively: (1) Amath must plan carefully for strategic success in the upcoming decade in collaboration with the College and Provost, and (2) the University must invest in the requisite human capital that will be the means to grasping key strategic goals. Amath and the College must set priorities jointly, and Amath and the College must commit to implementing staged growth to meet key objectives.

Additionally, we suggest several areas for which increased faculty-level leadership is essential in order to (3) meet the full range of needs of U.W.’s undergraduate students who will find deep satisfaction in a career in applied mathematics and (4) assure successful outcomes of students in the Professional Masters Program. Finally, we target a recommendation to the U.W. Administration to (5) clear the air on the issue of any imposed merger of Amath with the Department of Mathematics (hereafter “Math”)—a cloud that has darkened the future of Amath and strained their relationship with Math since 1996.

Our remaining recommendations are (6) to revitalize the administrative services within the Department at an important time of transition to a new Chair; (7) to consider how an array of service courses might be implemented for students from other disciplines who are finding the modern techniques of applied mathematics to be powerful tools; (8) to continue the aggressive pursuit of diversity; and (9) to focus on the recruitment of top new graduate students with increased fervor. We do not make recommendations about other successful enterprises within Amath; however, we acknowledge the hard work that made them possible and encourage their continued support by the Department.

Part I. Overview & History

The Charge to the Decadal Review Panel (hereafter the “Panel”) was established in a letter dated 11 April 2007 (revised) from Suzanne T. Ortega, Vice Provost and Dean of the Graduate School, and Melissa A. Austin, Associate Dean for Academic Programs of the Graduate School. Although broad in its scope, the charge before the Panel was to comment on the health, vitality, and improvement of the graduate programs of the Department of Applied Mathematics and a recommendation for its status over the next ten years. A list of guiding questions and an invitation to comment as the Panel saw fit about all aspects of the Amath “enterprise” were also provided.

In this section we describe the history of the Department of Applied Mathematics (hereafter “Amath”) and provide a snapshot of the people and the program in 2007. We will analyze Amath’s Strategic Plan, their Self Study, and other information that we have gathered through interviews and discussions with its (now former) Chair K.K. Tung (§II) and synthesize a set of recommendations (§III).

The issue of the merger of the Amath and Math was not an explicit part of our charge. However, the issue was raised repeatedly during interviews, and it became a substantive portion of our post-meeting debriefing with U.W. officials. While we do not dwell on it, as did the Review Panel of 1996, we feel that the issue remains more than “academic” even after a decade. We shall briefly address this issue.

A. Sources of Information

The Panel collected factual information from interviews with faculty, staff, and students of Amath; a “Self Study” prepared by the Department in 2006 and revised and expanded in a new version dated 23 April 2007; various appendices of that self study; and a very detailed and insightful report of the previous Decadal Review Panel dated June 1996. The Strategic Plan of the Department of Applied Mathematics (c. 2000) and considerable amounts of additional data were provided in written form in response to our many requests by the Chair of Amath, K.K. Tung. In addition, the Graduate and Professional Student Senate (GPSS) provided summaries of anonymous comments from graduate students in Amath solicited by them in May with a significantly expanded update in June.

In the interviews, the Panel met with each person or group below for approximately 30 minutes, with two exceptions. The interviews were largely conducted *in camera* on 23-24 April 2007. In order of their appearance before the panel, the interviewees were Amath faculty K.K. Tung (Amath Chair, 60 minutes), Robert O’Malley (Graduate Advisor), Bernard Deconinck, Nathan Katz (60 minutes), Loyce Adams, Bill Criminale, Chris Bretherton, Randy LeVeque, Hong Qian, and Mark Kot. Students in the PhD program, the Professional Masters Program (a relatively new 1-year terminal Master’s degree program; hereafter “PMP”), and the undergraduate Applied & Computational Mathematical Science program (hereafter “ACMS”) were interviewed in groups. Chris Whip and Crystal Peterson represented the technical and administrative staff of Amath. Faculty outside of Amath, namely, Loveday Conquest (Aquatic and Fishery Sciences), Jim Burke (Math), and Karol Bomszyk, (Medicine) were also interviewed. Balick and Galluci also spoke with Tom Daniel, the Chair of Biology and Selim Tuncel, the Chair of Math. We did not interview department chairs from Statistics or from Engineering. Werner Stuetzle, the head of the ACMS program, declined to be interviewed, presumably because of a conflict of interest in his dual role as the Interim Associate Dean of Natural Sciences in the College of Arts & Sciences and Director of ACMS.

B. A Snapshot of Amath

Applied mathematics develops tools to describe, model, and solve contemporary problems, not necessarily to generate theorems and proofs. It uses the philosophies of science—empiricism, or “whatever works”—more than the strictly logical methods of mathematics. Applied mathematics is intrinsically interdisciplinary; it is symbiotic with science and engineering, much as succulents depend on other plants for nutrients. Mathematics could flourish even if science vanished, but applied mathematics would not. As Samuel Clemens might have said, applied mathematics and mathematics are two disciplines divided by a common name.

Thus it is no surprise that Amath was formed in 1985 by uniting faculty from several departments, mainly in Engineering and Oceanography. Most of these people were senior researchers with international reputations, so the young department—small and elite in selected areas of research—was quick to develop national recognition. All of these original department members have now retired. Leadership of Amath is passing from the second to the third generation of its faculty, some of whom are extremely well established and others of whom are still building their own national reputations.

The faculty of Amath maintain very active research programs spanning many types of methodologies and fields of application and involving many interdepartmental collaborations. The previous decadal review panel wrote, “The department [sic] is notable for its research productivity and for its ability to attract reset [sic] grant funds.” Ten years later this remains the case in spite of retirements of all of the original senior faculty members.

Amath’s Strategic Plan and day-to-day activities have always emphasized their mission of graduate teaching and mentoring. Since the last decadal report, Amath has greatly enlarged the scope of these activities. These include the formulation of and participation in an impressive undergraduate program called ACMS (jointly with several other departments), a new one-year Professional Masters Program with 15-20 additional students, and a project to engage in K-12 collaborations with teachers in the region. During this time, Amath received large grants for improving graduate training (VIGRE) and to support its K-12 activities. In addition, the research landscape has become far richer, with new opportunities in biomathematics and scientific computing (note the prescient predictions of the past decadal panel report).

Amath has a faculty allocation of 10.5 FTEs at this time. Starting in January 2008, Amath will have one Assistant Prof, two Associate Profs, and 6.5 Full Profs (several of them widely recognized for their research), leaving one position vacant. Sporadic temporary faculty vacancies have arisen intermittently owing to leaves of various sorts. One faculty member is becoming increasingly interested in administration. Thus the faculty members of Amath have been challenged to continue their many collaborative research programs, to maintain their teaching and mentoring obligations, to meet the support needs of their graduate students, to participate in the large VIGRE and K-12 grant programs, to support the new PMP, and to open new or larger undergraduate classes. Faculty age distribution is not an issue at this time, but it is one that bears watching. Faculty diversity is a more pressing issue since only one of the faculty is female and one is an underrepresented minority. This paucity in faculty diversity is typical nationally.

There are 51 graduate students in Amath as of April 2007. Thirty-four of these are in various stages of advancement through Amath’s traditional PhD program, and the rest are in the one-year PMP. Forty-one are U.S. citizens and 20% of the graduate students are female. Of those who have chosen to reveal their ethnic backgrounds, 20% are Hispanic or Asian. The time to the PhD, slightly under 6 years after acceptance, is typical for science departments. The ratio of PhD students per faculty member is unusually and perhaps dangerously large. Amath does not have an undergraduate degree program or major of its

own. Its undergraduate offerings are incorporated within ACMS, which is jointly operated with Math, Computer Sciences & Engineering, and Statistics. Amath has $3\frac{1}{3}$ administrative FTEs, consisting of one technical/computer administrator and $2\frac{1}{3}$ positions in the front office. The faculty, graduate students, and staff will soon re-occupy renovated contiguous space on the top floor of Guggenheim Hall.

Throughout the interviews the Panel discovered an impressive level of love and enjoyment of the job, mutual respect and support, effective channels of communication at all levels, a sharing of many responsibilities, and a huge reservoir of goodwill and enthusiasm. This attitude is pervasive among Amath's faculty, graduate students, and most of the staff. This esprit de corps and confidence in the future has served Amath very well and will continue to do so in the future as its leadership changes, endeavors are made to fill open faculty positions, and its strategic priorities are pursued and realized.

The Panel also notes that prior to the previous decadal review, Amath had undergone years of uncertainty in their long-term future. This was documented in the previous decadal report and need not be reviewed here. The Panel feels that Amath has emerged from this uncertain era in outstanding shape, thanks in large part to K.K. Tung's consistent and sensitive guidance and the strong and united support of the faculty. Tung's departure from the position of Chair in July 2007 will be bittersweet. His successor initially will take the helm of a basically healthy and cooperative department. At the same time, we must point out that progress towards implementing many of the strategic goals endorsed by the previous Review Panel has been hampered by a decade of marginal funding and lingering uncertainty about an unwelcome merger with the Department of Mathematics, both of which have darkened the Department's view of its future and its relationship to the University.

The entire field of applied mathematics is expanding in relevancy and significance internationally as the need to realistically model complex physical, biological, medical, and economic systems increases. An applied mathematics department is a vital and necessary response by a top university to these opportunities. Despite the funding and merger issues of the last decade, Amath is a department that has optimism, confidence, and enthusiasm for its future. Its goals are clear and strongly supported internally. The upcoming changes in its faculty and the anticipation of the normal bumps in the road are taken as challenges, not setbacks. We share the Department's excitement.

In view of the history of the Department (§I) and the changing pressures from inside and outside the Department (§II), the Panel feels that carefully planned progress is the obvious course for Amath in the next decade. To this end we will compile and analyze the facts at hand (§II) and synthesize a set of recommendations (§III). It is incumbent on Amath, in collaboration with the College to determine the resources, timetable, and the faculty strength needed to implement strategic success over the next decade.

Part II. Analysis: Facts, Observations, and Interpretation

We now begin our analysis of the Department of Applied Mathematics. Our overarching goal is to help Amath realize its very considerable potential in pursuing the core objectives of the University of Washington. In this section, we review the facts made available to us in various reports, interviews, and subsequent requests for information. This discussion builds the foundation for our conclusions and recommendations in the final section of this report.

Our observations and interpretations of the facts are shown *in italics* throughout Part II.

A. Department Mission & Strategic Plan

Summary of Amath's Strategic Plan (c. June 2000)

Service Teaching: The goal is to better serve the practical needs of undergraduate and graduate students from other departments who are taking 300 and 400-level Amath classes in mathematical and numerical methods.

Undergraduate ACMS Program: Review and adjust the role of Amath in the ACMS Program.

Undergraduate Curriculum: Incorporate the most significant computational tools and methods into existing coursework already required of undergraduates, e.g., special introductory sections of Calculus and Advanced Calculus with computational emphasis, intended for engineering and science majors.

Technology: Increase support for students and instructors using web-based tools. Introduce video streaming technology for presently oversubscribed courses.

Graduate Program: Decrease time for PhD degree by 1-2 years. Place grad students in local K-12 classrooms after suitable training.

Faculty Size: More faculty needed in order to implement the strategic goals of expanding and improving undergrad and graduate curricula, increasing additional technology in the curricula, and mentoring the Masters and PhD students. "We envisage a department of 15 FTE to allow us to expand our courses and the teaching of applied mathematics from 300- and 400-levels to the 100-level, while maintaining strength at the graduate level and introducing more scientific computing throughout our curriculum. ... With [ultimate faculty staffing of] 15 FTEs, we can provide the needed continuity of graduate programs and create more synergy among different research areas, while allowing our faculty to devote more energy to undergraduate teaching and toward achieving a coherent undergraduate program for both the non-majors and the ACMS majors."

New Hires: The criterion for new hires is a demonstrated expertise in mathematical themes common to diverse fields, rather than a narrow specialization. Strength in Mathematical Biology or Numerical Analysis/Scientific Computing is critical.

Retention: Invest revenue from video courses in the salaries of faculty and PhD students.

A.1. Summary of the Mission Statement and Strategic Plan. The success of a department must be measured, in part, within the context of its mission and strategic plan for self-improvement. The core of Amath’s mission statement is “The Department of Applied Mathematics discovers, applies, and promotes the use of mathematics to model and solve practical problems in many disciplines, ranging from engineering and science to medicine and business.... By nature our research is interdisciplinary. By exploiting the common underlying mathematical framework, we initiate the cross-fertilization of ideas and techniques from one discipline to another.” (Self Study p 3). The statement continues to discuss Amath’s teaching and learning missions at the graduate and undergraduate levels. *There seems to be unified enthusiasm for this mission within the Department and an eagerness to pursue a complementary Strategic Plan.*

Amath’s strategic plan is summarized in the box above. It is more of a wish list than a serious plan constrained by funding, staffing, or space (as it should be). The goals seemingly have not evolved significantly since the decadal report of 1996 and a departmental reaffirmation in 2000. Its focus is largely on faculty breadth and depth—12-13 faculty FTEs in ten years and ultimately 15 FTEs. The strategic areas that are identified for increased emphasis have remained the same for the past decade: scientific computing and mathematical biology. Each of these areas plays to traditional strengths within the department and elsewhere at U.W. Both sub-disciplines are well funded by grants, and they provide excellent opportunities for post-PhD employment. *For all of these reasons, the Panel strongly endorses the precepts of the Strategic Plan, as did the Review Panel of a decade ago.*

A.2. Progress and Implementation. *There has been obvious visible progress towards implementing the strategic plan in the past ten years.* The Department developed new programs at the undergraduate and Masters levels, to name just two of many areas in which progress is clear. However, budget limitations at the College level have led to a short-term goal of increasing the faculty size from 10.5 to 12 faculty FTEs.

Amath is an increasingly vital area of modern scientific research and engineering at U.W. Student demand for well-taught courses in Amath at the advanced undergraduate and graduate levels seems strong and growing. Although a detailed justification for an ultimate value of 12.5 or 15 FTEs was not made in documents or in interviews, we believe that a full analysis of the Strategic Plan will show that the larger number of FTEs will be appropriate as the scope of the field widens.

Table 1: Strategic Research Areas and Goals for Faculty Staffing

| Strategic Subject Area | Faculty FTEs: Goals | Expectation for Early 2008 |
|--|----------------------------|-----------------------------------|
| Mathematical Biology | 3 | 3 (Kot, Qian, Shea-Brown) |
| Scientific Computing/ Numerical Analysis | 4 | 2 (LeVeque, Adams) |
| Atmospheric Sciences/ Geophysical Dynamics | 1.5 | 1.5 (Tung, Bretherton 0.5) |
| Nonlinear Waves | 2 | 2 (Kutz, Deconinck) |
| Core areas (Differential Equations; Fluids) | 2 | 1 (O’Malley*) |
| Totals | 12.5 | 9.5 |

* Probable next retirement.

There is progress in attaining strength in strategic subject areas, but more is urgently needed if the Department is to maintain its strong national reputation as senior faculty are replaced by junior faculty with less national exposure. The present faculty staffing situation is summarized in Table 1. Assistant Prof. Eric Shea-Brown will arrive in January 2008 filling the vacancy from Bill Criminale’s retirement a year ago, thereby adding strength to one major facet of the strategic plan that called for maintaining strength in Mathematical Biology. However, Peter Schmid’s resignation to take a very prestigious and

lucrative position at the CNRS and L'Ecole Polytechnique, Paris in 2007 creates a serious deficiency in the field of scientific computing. Amath is negotiating with the College to fill this position with a junior hire in this area. *Given the strategic significance of scientific computing and other issues identified later, we urge that the College approve a search for Schmid's replacement expeditiously. This is a major finding in the present report.*

Moreover, we understand that one successful mid-career member of the faculty plans to leave research in order to pursue a career of academic administration. *The impact of such a career change by one very active member of a small department is likely to be substantial at this juncture in the Department's history. The impact must be fully mitigated.*

The Strategic Plan contains an ambitious and forward-looking view of the future. Although there has been some progress, the Strategic Plan of 2000 needs to be implemented at a far faster rate. To this end, the Plan should be accompanied by an implementation plan developed by the Department. Some sort of an implementation roadmap which recognizes realistic impediments (such as College resources and space), and which sets out milestones against which progress can be measured would help the Department to move ahead with realistic expectations. Any well-managed project will have such a set of tasks, an analysis of needed resources, and a timetable.

A.3. The Long-Term Future. A possible merger was considered in depth in the decadal report of 1996 (pages 6 and 7), so we need not belabor it here. That report argued that cultural apartheid of Amath and Math faculties is necessary to avoid the deleterious, stressful clash of cultures between one small group whose interest is in solving real science and engineering problems in many interdisciplinary programs and another group whose interest is far more philosophical and, strictly speaking, logical. We heard from several people—including Interim Dean Ron Irving, Amath faculty of all ages and ranks, and some graduate students—that a possible merger of Amath with the larger (and nationally outstanding) Math continues to be an issue of occasional discussion since the topic first arose in the early 1990s. Selim Tuncel, Chair of Math, informed us that senior faculty in his department raise the subject occasionally.

Amath perceives that no discernible benefit to students and faculty would derive from a merger. The feeling is unanimous. On the contrary, given the deep philosophical differences between mathematics and applied mathematics, any discussion of a merger is perceived as a threat to its vitality. (Amath and Math are wary of each other when cooperation would best serve the needs of undergraduate education.) This quote by K.K. Tung, extracted from the report of the previous Review Panel, still rings true today:

“The view held by the Math Department that Applied Mathematics is just a branch of mathematics, although semantically correct, has been harmful to us. There is no more truth in this statement than to say that chemistry is a branch of physics. I hope that we can reduce future conflicts with a proper recognition of the maturity of applied mathematics as a distinct field. The battle between, say, Biochemistry and Chemistry has long been forgotten and friendly cooperation is now flourishing in this University. I hope the same can happen between Math and Amath.”

We echo the sentiment of the previous Review Panel that a merger serves no constructive purpose. We feel that Amath has established itself as a lithe, independent entity in the past decade and has amply justified its present status. The very presence and longevity of this issue is unfortunate since it is deflecting energy from the research and teaching efforts of the Amath faculty at a time of frustration over other critical issues (see below). Long-term commitments to important new initiatives are diminished by the tension. Ultimately, the stresses created will impair the recruitment and retention of top faculty and injure the national reputation of the Department. The antidote is simple: clarity about the intentions of the College and Provost vis-à-vis Amath's long term status as an independent department at the U.W. This is a major finding of the present report.

B. Department Reputation

An excellent national reputation is precious. Success in the recruitment of top faculty and graduate students is directly related to reputation. Self-confidence within the Department builds upon its reputation. Prestige indirectly affects outside reviews of both individual and group funding proposals.

U.W.'s Department of Applied Mathematics is listed in the top-ten group of departments of applied mathematics in a 2005 study by Academic Analytics that was published in 2007¹ in the *Chronicles of Higher Education*. Amath also has a strong historical reputation (1996 Decadal Report, p. 8), and many of its vital statistics are solid (Self Study p. 6). In the 1996 Report, the Panel was told of the outstanding reputation of the then-senior faculty and the promise of its younger faculty.

Over the past 10 years, there has been a significant turnover of faculty (created by the retirements of Murray, Pearson, Kevorkian, and Criminale) rendering Amath's reputation vulnerable. With the exception of Bob O'Malley, the senior faculty are now gone. These are the people who first built the reputation of Amath. The reputation of the Department inevitably suffered upon their departure. Our concern was that it has not fully recovered. We note also the resignation and departure of Peter Schmid in 2007, mentioned earlier.

Fortunately, the junior faculty hired between 1986 and 1996 have established themselves as accomplished senior faculty. We are very pleased to report that the national reputation of Amath has been preserved through the past decade of transitions and under a huge load of mentoring and administration. The Department can take great pride in this accomplishment.

There is ample evidence for this conclusion. As discussed later, the 2005 study cited above showed that paper citation rates per faculty member are extremely high. The present faculty has been awarded some huge and very visible collaborative grants, including the VIGRE Grant from NSF, its renewal, and the GK-12 grant for education. Excellent young faculty and graduate students are being recruited. Graduate applications have increased significantly. The Department has thrived.

Another perspective of Amath's reputation derives from the Panel's interviews with people in other U.W. departments. The comments that we received are laudatory. Collaborations in several departments with Amath faculty have all been very productive. The most relevant comments from U.W. faculty outside of Amath are these:

- The need for applied mathematics is pervasive in many areas represented on campus, including science, engineering, and medicine.
- It is hard to imagine a more successful Chair than K.K. Tung under the tumultuous circumstances under which he took the office 13 years ago.
- Amath, being a small department, has few but excellent good faculty collaborators.
- There is great need for people with strong applied mathematics skills inside and outside of academia. Amath is training them well.
- U.W.'s relatively small faculty in Amath cannot possibly cover every base of active research at U.W. in which applied mathematics plays a significant role.
- Amath people doing research in Medicine are developing clever, breakthrough research methods.

¹. The peer group consists of Michigan, Cornell, Texas, Princeton, Stanford, Brown, Washington, Columbia, Carnegie Mellon, and Georgia Tech. See <http://chronicle.com/stats/productivity/>.

C. The Faculty

Amath has had 10.5 FTEs “on the books” for a decade. Half of the faculty has been replaced in the past decade by outstanding and productive people in more junior positions. This substantive turnover did not appear to cause turmoil, thanks to the mentoring of more senior faculty. The present faculty consists of 6.5 Full Professors: Adams, Bretherton (0.5 FTE), Kutz, LeVeque, O’Malley, Qian, and Tung; and two Associate Professors: Deconinck and Kot. Shea-Brown will be an Assistant Professor when he arrives in January 2008 to fill Criminale’s slot. The open FTE created by Schmid’s resignation is unfilled. (Like all faculty vacancies in the College of Arts & Sciences, this position has officially reverted to the College of Arts & Sciences. There is no certainty of its return.) There are no Research Faculty in Amath at this time. Hong Qian was a member of Amath’s Research Faculty in the past, so the Department is aware of the value of hiring people in this job stream.

C.1. Research Areas. The Department evolved from the Applied Mathematics Program in 1985 which itself had been formed by various faculty within the College of Engineering. The research areas represented among the founding faculty members of Amath were focused on Classical Applied Analysis, Fluid Mechanics, Optimization, Elasticity, and Numerical Analysis. Over the ensuing years, these research areas have changed as a result of changes in personnel as well as new applications, methods, and computers. Robert O’Malley’s arrival in 1990 brought into Amath significant expertise in singular perturbation and asymptotic methods to complement those of Jerry Kevorkian who focused on perturbation methods for differential equations. U.W. instantly became a center for Mathematical Biology in North America when James D. Murray moved to Amath from the University of Oxford in the late 1980s. Fred Wan worked in biomathematics and numerical methods of solving differential equations.

The first generation of Amath faculty is now gone. These were researchers who were more interested in mathematical methods than in their applications. With the retirement of Bill Criminale, Fluid Mechanics per se is no longer a primary research field within Amath. However, Fluid Mechanics will remain a strength in Amath because it is an essential component in Atmospheric Sciences, which is strongly represented by Bretherton and Tung and in the work of Deconinck and LeVeque.

*Over the past decade or more, the focus of the research in Amath has evolved from mathematical methods to solving research problems from applied areas.*² Broadly speaking, the research among the current 8.5 faculty FTEs³ in Amath can be divided into broad basic areas in Applied Mathematics, including Asymptotic and Perturbation Methods; Linear and Nonlinear Ordinary and Partial Differential Equations; Quantitative, Qualitative, and Numerical Methods for Analyzing Ordinary and Partial Differential Equations; Applied Analysis; and Mathematical Modeling, and into diverse areas of Application, including Fluid Mechanics; Atmospheric Science; Optical Sciences, Linear and Nonlinear Waves; Mathematical Biology, including Ecology, Evolutionary Biology, Systems Biology, and Molecular Biology; and Scientific Computing. The faculty in Amath have expertise that connects and cross pollinates many of these areas of research.

C.2. Faculty Specialties. In general, it is not easy to classify the research fields of individual faculty members in terms of their research because of the broad spectrum of concepts they bring to their discipline. However, here is a rough classification of the current and future FTE faculty in Amath with their major research areas:

² The founders of Amath had a strong focus on Classical Applied Analysis and Differential Equations. These common threads held Amath together until recently. Academic departments must always evolve; still, they must be keenly aware of their roots and national perceptions of their strengths.

³ As of this writing, there are officially 8.5 FTEs in Amath as a result of Peter Schmid’s resignation, and this number will rise again to 9.5 FTEs when Eric Shea-Brown arrives in January 2008.

Loyce Adams (Numerical Linear Algebra)
 Chris Bretherton (1/2) (Atmospheric Science, Fluid Dynamics, Linear and Nonlinear Waves)
 Bernard Deconinck (Nonlinear Waves, Fluid Mechanics, Differential Equations, Numerical Computation, Asymptotics)
 Mark Kot (Mathematical Biology-Ecology and Evolutionary Biology, Integro-difference Equations)
 Nathan Kutz (Nonlinear Waves, Optical Sciences, Dynamical Systems, Nonlinear Waves)
 Randy LeVeque (Numerical Analysis/Scientific Computing, Wave Propagation)
 Robert O'Malley (Differential Equations, Singular Perturbation Methods, Asymptotic Methods)
 Hong Qian (Mathematical Biology-Computational Systems Biology, Physical and Biophysical Chemistry, Molecular Biology)
 K.K. Tung (Atmospheric Science, Geophysical Fluid Dynamics)

The inventory also includes:

Peter Schmid (recently resigned) (Numerical Analysis/Scientific Computing, Fluid Mechanics)
 Eric Shea-Brown (arrives January 2008) (Dynamical Systems, Mathematical Biology-Neuroscience, Neural Networks and Populations)

Numerical methods and determination of computational accuracy are used throughout areas of application in applied mathematics. Only Randy LeVeque and Loyce Adams represent numerical Analysis/Scientific Computing⁴ since Peter Schmid has resigned. *Thus, there is a severe deficiency within the area of Scientific Computing, one of Amath's strategic areas of expertise (Table 1).*

Another focus area of historical significance in Amath is Mathematical Biology. The retirements of Murray, who was one of the founders of this academic discipline, and Wan have left a void in research coverage, graduate student mentoring, and leadership. *The U.W.'s international reputation in medicine could be positively and strongly reinforced by expanding the interactions between faculty in Amath and in Medicine, as emphasized to the Panel during our interviews with senior faculty in other departments in biology and medicine. In other words, Shea-Brown's arrival in 2008 should be considered just the first step towards sufficient expertise in this growth area.*

C.3. Research Balance. With small faculty numbers in Amath, there is an issue of research balance. Is there too much emphasis in one area? Are the research areas within a major area correctly balanced? Are the needs of graduate students and the wider U.W. research community being met? These are all important questions for which the Panel's interviews drew some insight rather than strong conclusions.

A comparison of the growth potential in each of these major research fields in Amath based on the merits of each field is a fruitless exercise. During our interviews with the chairs of other departments, we heard that the methodologies of applied mathematics are in ever increasing use in research, and that their students needed more expertise in modern methods of both applied math and statistics. The Panel does not have the expertise to judge whether the full range of needs at U.W. are being met—or whether the faculty and graduate students from a small interdisciplinary department could possibly satisfy all of them.

⁴ Adams is presently the PI on two interdepartmental grants, VIGRE and K-12, as described later. She is unable to devote more than a fraction of her time to research.

In addition we have used Amath's Strategic Plan as the most authoritative guide to the Department's view of appropriate topical emphasis. (This is based on our confidence in the Amath faculty to develop a plan that looks forward while recognizing their own needs and strengths.) It is safe to conclude that the current major research fields in Amath are all relatively classical areas in applied mathematics. All of them can be expected to remain active, lucrative areas of research for some time in the future. In addition, the Strategic Plan carefully considered trends in the field and how to respond through faculty staffing in the future.

In summary, we find that the spectrum of research interests represented by Amath's faculty is highly appropriate, but that more depth is needed in certain strategic areas that are presently thin—to wit, scientific computing. We are confident that the Strategic Plan, if fully implemented, will serve the need for expertise and balance in applied mathematics in Amath's program.

However, there are other needs and constraints that play important roles in balancing the faculty. Foremost among them is that new fields develop almost overnight at times, as in many areas of modern research. Also, Amath relies heavily on current long-term interdisciplinary collaborations at U.W. in exciting and always shifting fields of modern research. So balance may be defined in part by shifting trends in other departments. Thus, hiring priorities must necessarily be somewhat opportunistic.

D. Faculty Quality: Grants, Publications, and Honors

D.1. Research Grants to Individuals. We received a spreadsheet of research grant information in June from Amath listing extant individual research grants. Ignoring grants to Schmid (who, as noted above, has resigned from Amath), and weighting grants to Bretherton by 30% (a guess regarding the fraction of his funds used in Amath), the total amount of active grant funds presently awarded to individual investigators is \$9.3M.⁵ Dividing this by 8.5 FTEs indicates an average of \$1.1M in research grant support per faculty FTE, a very impressive number. Deconinck and Qian, the two youngest members of the faculty, have both built a strong foundation of grant support.

In the 2006-7 academic year, new grants to Amath totaled \$1.6M, of which \$0.9M was awarded to individual members of the faculty and \$0.6M was awarded to GK-12. Bretherton, Kutz, LeVeque, Qian, and Tung are the PIs of the largest individual grants.

We attempted to compare average federal research grant funds per individual faculty member in Amath with the corresponding numbers for faculty in other U.W. science departments. This effort was not successful owing to many factors, the most significant of which is that we could not isolate individual research grants from grants to departments (such as VIGRE) or to large groups that operate on-campus labs for which much of the funding goes for infrastructure (e.g., the salaries of administrators or rented space). Amath can be compared to Astronomy, Math, and Statistics that do not have large labs. Amath has no research faculty, so its grant income will not include 9-12-month faculty salaries other than for summer and graduate students. Total federal grant funding in these departments in FY2006⁶ and grants per eligible faculty applicant are shown in Table 2. *Among math-oriented departments Amath has more than twice the grant support of the others. The last row in the table illustrates that Amath has a healthy rate of grant income among all science departments at U.W.*

⁵ This is the total value of all individual grants, not the annual expenditure rate. Many are multi-year grants. The \$9.3M includes multiple collaborator grants on which Amath faculty serve as a co-PI, so the official grant amount credited to Amath by the College is different. VIGRE and GK-12 grant funds are not included in this sum.

⁶ http://www.washington.edu/research/annualreport/2006/ar_fy06.pdf

Table 2. 9-month Avg. Federal Grant Income per U.W. Science Department and Grant Income per Eligible PI (2005-06)*

| UW Science Dept | Grant Income | # Qualified PIs† | Avg Income per PI |
|-----------------------------------|------------------|------------------|------------------------|
| Applied Mathematics | \$931,648 | 10 | \$93,165 |
| Astronomy | \$1,560,681 | 14 | \$111,477 |
| Mathematics (incl VIGRE) | \$2,300,510 | 58 | \$39,664 |
| Statistics | \$79,5642 | 18 | \$44,202 |
| <i>All 11 science departments</i> | | | <i>Avg = \$118,385</i> |

* Includes Tenure/Track and qualified Research Faculty.

† We do not include non-Federal sources of funding since Astronomy receives significant non-competitive state operating support for various observatories. The VIGRE grant to the Math Department is included since we could not determine how to remove it.

D.2. Grants for Major Department-Wide Programs. Two extremely prestigious educational grants have been awarded to Loyce Adams as the Amath PI. One particularly prestigious grant is the NSF Vertical Integration Grant in Research and Education (VIGRE; joint with Mathematics and Statistics). Initial funding began in 1998 and U.W. was awarded a five-year extension (\$3.9M through summer 2009). Among other positive direct benefits of VIGRE are that about 5 Amath graduate students receive RAs for two quarters per year and another seven receive summer support. A second grant is a U.W. GK-12 Grant, which supports graduate students to help K-12 classrooms with mathematics lessons (\$2.0M through summer 2009). Again, Adams is the Amath PI.

Amath is keenly aware that these two grants will expire in a few years. Tung, Adams, Kutz, LeVeque, and Deconinck are forming faculty teams that are actively planning for next-generation proposals that build on the foundation of experience provided by VIGRE and GK-12, and that will have similar impacts on the health and vitality of the faculty and students from Amath. For example, a “Research Training Award” offered by the NSF will be proposed.

In summary, we find that support for individual research support in Amath is in very good health. Levels of support are far above other math-oriented departments at U.W. and similar to other science departments in the College.

D.3. Publications. Compiling quantitative data on faculty publication rates has turned out to be exceedingly cumbersome since Amath does not have the clerical staff to maintain the requisite records. The Chair of Amath advised us that reasonably accurate and reliable information could be obtained from the Faculty Scholarly Productivity Index by Academic Analytics published in the Chronicles of Higher Education. Their web pages⁷ report data for Amath and nine peer groups or departments from 2005. Eight of the Amath faculty had at least one refereed publication in that year. They published an average of 6.7 papers each, slightly below the average rate in ten peer departments. The citation rate for these papers was higher than at all institutions other than Princeton. The citation rate per faculty member was the highest of all ten peer institutions. *We conclude that papers published by U.W. Amath faculty are widely read and cited: the importance of their papers more than compensates for their moderate average rate of publications, about 6-7 papers per year.*

⁷ <http://chronicle.com/stats/productivity/>

D.4. Recent Honors. Schmid and Criminale received Humboldt Fellowships. Tung and Murray are Guggenheim Fellows. Bob O'Malley served as President of SIAM (Society of Industrial and Applied Mathematics). LeVeque and Bretherton were Presidential Young Investigators. Kutz received an NSF CAREER award. Criminale is a Fellow of the American Physical Society. Bretherton is a Fellow of the American Meteorological Society. Tung is the Chief Editor of the flagship journal, the Journal of Atmospheric Sciences, of the American Meteorological Society. *This record of international peer recognition for Amath faculty is very impressive.*

E. Faculty Quantity: Numbers, Demographics, and Diversity

E.1. Critical Mass. As noted earlier, Amath has 10.5 FTEs “on the books” with some number of these unfilled at any time by leaves, retirements, or resignations. This 10.5-FTE “capacity” has not changed in the past decade. During this decade, the variety and breadth of faculty activities and responsibilities in teaching, research, mentoring, and service, including outside collaborations (see below), have increased dramatically. Examples include the recent Professional Masters Program (1998) and the GK-12 grant (2002). Four new faculty, who are building their research careers, have come on board and have become highly productive, and Shea-Brown arrives in January 2008.

The Panel looked closely to determine if the faculty is meeting the full set of responsibilities to Amath’s graduate and undergraduate students. In effect, this is the heart of our charge.

Finding an answer involves an assessment of the quality and the quantity of the faculty as well as the scope of work that they are expected to perform. We considered the quality of the faculty in §II.D and found a high degree of individual excellence by every measure, all of which is reflected fairly in the Department’s strong national reputation. We have also noted outstanding leadership by K.K. Tung.

The Panel heard repeatedly, at every rank from Chair to student, and from within and without, that Amath cannot attain its strategic goals without more total faculty depth in critical areas of research and administration. *We have carefully investigated this charge with the time and resources available to us, and we wholeheartedly concur: We find that the quantity of the faculty today is best summarized as adequate to meet the routine needs of the Department. However, the demands on faculty time are precariously close to overwhelming them, placing considerable stress on everyone. This is the single most important finding of the Panel.* The elaboration of this observation appears throughout §II in several subsections, all of which are compiled and summarized in §II.P.

In order to develop our own analysis, we looked in various areas to see whether faculty numbers are inhibiting the enterprise of Amath. The broad answer is blatant and, perhaps, even banal: the demands on faculty time are overwhelming them.

One key area, mentoring, emerged quickly as a problem during the interviews with students in the PMP and faculty alike. Students must be well mentored if they are to maximize their learning experiences and, for PhD students, to contribute to the research mission of the Department. Only faculty can provide this mentoring. However, faculty have a variety of other demands on their time, many of which cannot be deferred (like teaching). *Table 3 shows that an obvious problem for Amath students is the student-faculty ratio, which is higher in Amath than almost every other science department in the College⁸, even when the faculty are at full strength (see the next section).* This statistic pointed the Panel to look further into the issue of student mentoring.

⁸ National statistics for mentoring levels in peer departments would have been more useful, but we were unable to locate such data.

Table 3: Pre-post PhDs and Supervisory Faculty for U.W. Science Departments*

| Department | Pre-PhD Candidates | PhD Candidates (post General) | Graduate Faculty† | Students per Grad Faculty |
|---------------------------|--------------------|-------------------------------|-------------------|---------------------------|
| Applied Math | 29 | 11 | 9 | 4.4 |
| Astronomy | 20 | 9 | 13 | 2.2 |
| Atmospheric Sciences | 50 | 9 | 27 | 2.2 |
| Biology | 40 | 51 | 53 | 1.7 |
| Chemistry | 140 | 95 | 44 | 5.3 |
| Earth & Space Sciences | 45 | 21 | 46 | 1.4 |
| Mathematics | 56 | 20 | 50 | 1.5 |
| Physics | 79 | 40 | 53 | 2.2 |
| Psychology | 69 | 44 | 59 | 1.9 |
| Speech & Hearing Sciences | 46 | 16 | 15 | 4.1 |
| Statistics | 33 | 9 | 28 | 1.5 |

* Attribution: Augustine McCaffery and the U.W. Grad School. We note that these data differ slightly from others supplied to us by Amath. Even so, departmental comparisons are presumably indicative.

† Graduate faculty are those who have been qualified by the U.W. Graduate School to supervise PhD thesis research. Figures in this column combine Graduate Faculty from tenure/track and research classifications.

Interviews with the PhD students showed that they are very pleased with the mentoring they have received. They find that the faculty are accessible, interested, and pleased to work with their research students. (We shall address this further in §II.I, J, and K.). The most negative comment from the PhD students is one heard throughout campus: the faculty are difficult to reach in the first year of the PhD program when PhD students are sharing courses with students in the larger PMP and students from other disciplines.

However, the students in the PMP saw the issue of limited mentoring from a different perspective. For these students, the distance between faculty and student in the first year persists for the entire duration of their stay. We shall return to this issue in §II.L. *If faculty size affects the quality of student mentoring, then the students most affected by this are in the one-year PMP.*

Undergraduate advising is another problem area that we will discuss in §II.M. Until recently Amath had taught solely service courses at the undergraduate level, so the need to mentor undergraduates didn't exist. Although there still is no undergraduate major, there are many undergraduate students who plan a career in applied mathematics, some of whom are doing outstanding research with Amath faculty. They are not receiving adequate career or strategic mentoring at U.W. The root cause of this problem is not related to a shortage of faculty time, at least for now. Rather, it is an unintentional structural flaw in the advising system available to undergraduates (see §II.M.1).

Turning to research activities, the quantity of faculty obviously determines the depth and breadth of research opportunities for students. The Strategic Plan (§II.A) nicely lays out the research areas needed for a balanced and modern curriculum in applied mathematics at U.W. This is more than a list of disciplines. The strategic plan recognizes the role and experience of Amath's faculty in building interdisciplinary research projects in many other departments. We heard that building research teamwork and collaboration requires a rich mix of faculty expertise so that the skills brought to interdisciplinary collaborations can be tailored to match the needs of research projects. Here too, the quantity of the faculty is one key parameter.

The position of Amath faculty is clear from the Strategic Plan: More faculty FTEs are the only way to bridge the gap between the research coverage that is needed and that which exists. *Members of our Panel from outside of U.W. echoed the unanimous sentiment of the Amath faculty on this topic. One of our highest-priority recommendations (§III) is that the Strategic Plan should be expanded to carefully justify and quantify exactly how many faculty are necessary to fill this gap.*

E.2. Measured Mass. Amath has not had a full complement of 10.5 faculty FTEs for many years. Next year seems typical. K.K. Tung will be on sabbatical leave for two quarters. Mark Kot will become the Acting Director of Quantitative Ecology and Resource Management (QERM), an interdisciplinary graduate program at the U.W., for one year. (He will continue to teach classes.) Chris Bretherton has accepted a three-year term as the Director of the Program on Climate Change that will take him out of the classroom. Loyce Adams administers the VIGRE and GK-12 grants and will be granted a quarter of teaching relief. Recently, unexpected extended medical leaves have arisen. These may continue. All told, the effective size of the Amath in 2007-8 will be approximately 7 FTEs. This number appears to be typical for many of the past several years. Eric Shea-Brown will add capacity when he arrives in 2008.

Leaves like those in 2007-8 are important for the University and the people who take them. They should be encouraged under normal circumstances, particularly in a department with a strong focus on interdisciplinary research. However, we found that leaves have been impairing the basic duties of the small department, including obligations to PhD students working on thesis research and the needs of first-year graduate students. The impacts of these leaves need to be fully mitigated before they can be scheduled in order to maintain and build the momentum of an outstanding, forward looking, and extremely busy department.

This resulting stress on the available faculty isn't sustainable. A small department can't take all of these leaves in stride. People will respond in crisis mode as the duties of their peers are distributed. Faculty must scramble to teach courses they haven't taught before by "borrowing" time from research and mentoring. Research and mentoring suffer. The faculty don't have enough time to fully engage incoming students. The writing of grant proposals is deferred. The Chair is diverted from important leadership functions. Eventually morale is certain to suffer as frustration builds. Recruitment and retention are impaired once this frustration becomes palpable. Grant projects suffer, thereby jeopardizing future funding. (The feedback loop has a very positive sign.)

Fortunately, this doomsday scenario is simply a prediction, more incipient than realized at this time. Like global warming, the shrewd move is to tackle the problem immediately before morale slides.

E.3. Diversity. Faculty diversity covers representation by gender, underrepresented minorities, and age and rank distribution. The basic data are these: There is one female on the faculty, one underrepresented minority (Hispanic), and two people of Chinese ancestry. (Asian-Americans of Chinese descent may add diversity, but they are generally not considered an under-represented group.) These data are not unusual for mathematics departments. *The Panel found no trace of any bias or prejudice in hiring, support, esteem, or promotion.*⁹

Nonetheless, there is an obvious need for added representation by women and minorities. Gender diversity should remain high on Amath's list of hiring priorities, but not at the expense of quality. Amath is keenly aware of this need and has been proactive in remedial efforts. For example, Amath offered a position to an outstanding female applied mathematician last year but was unsuccessful in recruiting her.

⁹ We noted that one or two people use "he" as the pronoun to represent a generic person

E.4. Demographics. Amath will soon have 9.5 faculty: 6.5 Full, 2 Associate, and 1 Assistant Professor. *Despite the disproportionate number of Full Professors, there is no major demographic problem, at least for now.* The Amath faculty are spread over a large range of years in rank. The relative number of faculty in age groups is reasonably even—except for young faculty. Bringing in Eric Shea-Brown at the Assistant Professor level greatly expands the age and rank distribution. *We find that adding one or two junior faculty members would assure demographic balance for at least a decade.*

F. Faculty Recruitment and Retention

F.1. Recruitment. Amath has strong recruitment assets. Its national reputation remains strong despite the fact that many of those who built this reputation have left. Most of the current faculty members are excelling in their careers and are becoming recognized. The award of a VIGRE grant (with a rare renewal) and the GK-12 grant are large plusses. The cohesiveness of the department, including the students, is a major strength. Another advantage in recruiting new Amath faculty is the strength and diversity of related research programs at the U.W. in Biology, Medicine, Genome Sciences, Atmospheric Sciences, Physics, and many other fields in which new and existing Amath faculty can engage. Salaries, though certainly contentious (see below), are not wildly disparate from those of the competition.

We conclude Amath is in a very good position to attract new faculty as space and resources permit.

Replacement opportunities will arise, and *the Panel was pleasantly surprised to see unanimity amongst the faculty in their hiring priorities.* None of the animosity, empire building, and protection of territory present at many other institutions was evident in any of the interviews that the Panel conducted. However, discussions and decisions on the areas of research strength within Amath will be needed. Such decisions need full and open discussions amongst the Amath and adjunct faculty with student input. The Strategic Plan provides a good sense of priority and sequencing for growth in strategic areas.

F.2. Retention. *Thus far, retention doesn't seem to have been a major issue for Amath.* All of the vacancies have been the result of normal retirements. The exception is Peter Schmid's departure that stems from a very lucrative professional offer at the École and a personal desire to live in Paris.

It is the Panel's observation that there is no discontent within the Amath faculty, but rather a strong sense of pride of their excellence and respect for each other. Everyone was enthusiastic when asked about job satisfaction. No one on the faculty mentioned their own salary as an issue. Nonetheless, good outside offers generally emphasize salaries. Thus, faculty salary can become a point of vulnerability for retention. Salary statistics contained in the 2006-2007 Annual Survey of the Mathematical Sciences Salaries by the American Mathematical Society¹⁰ show clearly that the average salary of (seven) Full Professors in Amath is 10% below that of their peers in doctoral degree granting departments of applied mathematics, while salaries of (two) Associate Professors are about 10% above. A better comparison of salaries among peer institutions is difficult without knowing salaries as a function of years in rank for both the national and U.W. samples.

Although we tentatively conclude that salaries in Amath are competitive nationally, we temper this with caution that the lack of detailed data leaves lots of room for ambiguity.

Any comparison of faculty salaries in Amath with other science departments at U.W. is beyond the scope of this report since no data were provided to us by the Graduate School, the College of Arts & Sciences, or Amath (nor did we request such information).

¹⁰ see the Group Va chart in www.ams.org/employment/2006Survey-FacSal.pdf

G. Faculty Collaborations

A network of research collaborations exists between faculty and students in Amath and other departments in natural sciences, engineering, medicine, and social sciences spanning at least three Colleges on the campus. These collaborations are listed and described in the Self Study. They are integral goals of Amath's Strategic Plan and its general philosophy on interdisciplinary research.

Several Amath faculty have cultivated extensive formal and informal research and educational collaborations within and outside of the U.W. Formal collaborations within the U.W. have generally been programmatic in nature. A major collaborative effort at the undergraduate level is the Applied and Computational Mathematical Sciences (ACMS) program that involves Amath, the Departments of Computer Science, Math, and Statistics, and Engineering. There is joint administrative operation of the Math Sciences Computing Center.

Loyce Adams initiated the NSF VIGRE Grant, which is collaborative with Mathematics and Statistics, and also is the PI on the U.W.-wide GK-12 Grant. In addition, there is a joint PhD Computational and Molecular Biology Program with other biologically oriented units on campus. Several Amath faculty have joint appointments with other departments, and participate regularly in co-teaching outside courses. Chris Bretherton is the Director of the Interdisciplinary Graduate Program on Climate Change ("PCC"). Mark Kot will be the Acting Director of the Quantitative Ecology & Resource Management ("QERM"). K.K. Tung has a joint grant, "Collaborative Research in Mathematics and Geophysics" with faculty in the Department of Atmospheric Sciences.

In addition, there are informal research collaborations with Amath faculty co-advising non-Amath PhD students, and collaborating with their own students on projects with outside faculty as well as with researchers outside of the U.W.

These collaborations are one of the great strengths of Amath, not to mention U.W. The Panel is deeply pleased by the entrepreneurial activity of Amath.

H. Faculty Leadership and Leadership Training

For the past 13 years, K.K. Tung, as the Chair of Amath, has provided leadership and has been a stable force guiding Amath to its present day configuration. He has been extremely successful in keeping the fabric of Amath together under difficult circumstances, such as marginal funding and the threat of a merger, and has been able to smooth the transition to the next generation of faculty leadership in Amath. *The Panel thanks him for his frequent and generous help in providing the research for this report, and wishes him success and happiness as he returns to his scientific activities full time.*

Much of this success has been the enormously collegial style of management that has characterized its outgoing Chair. The report of the previous Review Panel stated: "It was the universal feeling of students and faculty that the future and the continued visibility and smooth operations of Amath depend on the unusual and excellent leadership of K.K. Tung. He is seen as balanced and measured, as very fair, able to talk honestly to anyone on the faculty, and he is also seen as a superb mentor by students.... He also has the necessary vision and sophistication to bring this department along a distinguished path."

The present Panel hopes that the future Chair will take special measures to preserve the coherence, enthusiasm, and momentum of the entire Department as Amath endeavors to streamline and widen its scope of academic activities. It is essential to sustain the network of open channels of internal communication that forms the backbone of Amath's camaraderie and cohesiveness.

The panel report continues: “We strongly urge that the Dean [of Arts & Sciences] assist the Chair in this role, providing a few necessary resources that make his administrative tasks less burdensome, and helping the Department accomplish the small amount of growth that we see as so vital. Tung ... needs to lead a department with the necessary resources that encourage and [sic] expanding scientific vision, rather than a demoralizing acceptance of constraint. We think that this is both possible and practical for this Dean to accomplish.” Fortunately, Amath vigorously pursued the vision despite the fact that the Panel’s wish for necessary resources to reach these goals is still unrealized.

I. Amath’s Graduate Program

No department with the stature of Amath can thrive without a vigorous graduate program. The strength of the graduate program is determined in large part by the quality and quantity of the students and faculty, their morale, teamwork, funding, and administrative support. Accordingly, the Panel investigated issues of recruitment, retention, opportunity, and the general morale of the graduate students in the PhD and MSc programs.

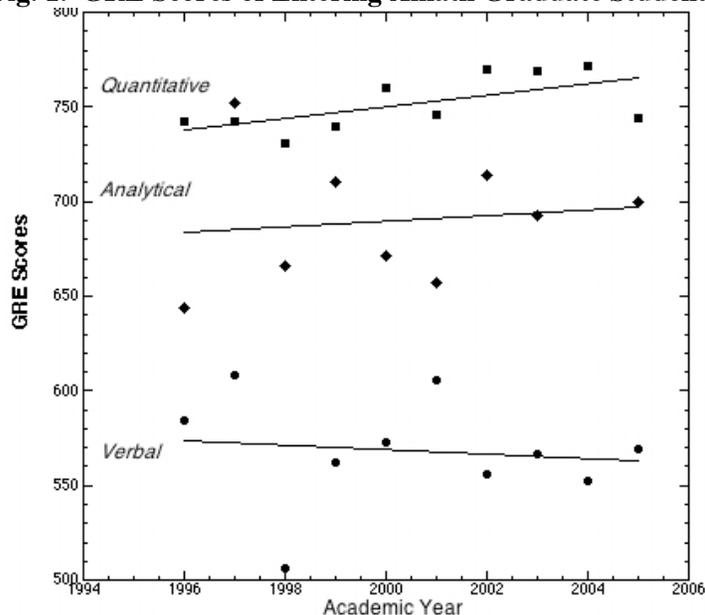
We present an overview of Amath’s entire graduate program in this section. The traditional MSc-PhD-oriented program (hereafter “PhD program” since nearly all students who enter it aspire to a PhD degree) and the newer one-year PMP are discussed separately later. Our analysis of the program is based on statistical data contained in the Self Study supplemented by additional data supplied by the Department and the Graduate School at our request, comments from the Graduate Adviser, Bob O’Malley, and other faculty during our interviews, the revised Self Study report, the statements of graduate students (of whom we interviewed nearly half *in camera*), and a summary of anonymous comments from graduate students supplied to us by the Graduate & Professional Student Senate after the Panel’s interviews were complete¹¹. *We were particularly impressed by the unanimity and candor of the graduate students that we interviewed on most of the topics addressed in the summaries.*

Reflecting its interdisciplinary interests in the development of many aspects of applied mathematics, Amath educates both graduate and undergraduate students in mathematics that has been discovered or exploited in the context of many research applications. In the last 10 years, Amath has seen considerable diversification in its educational efforts, strengthening of its PhD program, development and implementation of the PMP, and extension of the reach of the PMP statewide through an upcoming distance-learning curriculum. Total graduate enrollment has climbed from the low 30s a decade ago to the low 50s today. It is important to note that all of these changes have come without additional financial or staff resources from U.W.

The main reason given by incoming students for choosing the Amath program was the focus on applications of mathematics. Other reasons given by students included coming from a non-academic environment with an interest in something broader than a classical mathematics education. Others saw the inclusion of the connection between math and applications as added value to their research or career goals.

¹¹ We consider only the June Addendum of the GPSS survey in which the comments of 27 students (about 50%) were compiled. The views are undoubtedly more representative of student opinions than the May report when only two responses were submitted to the GPSS. The June comments were in close agreement with the testimony that we received during *in camera* interviews of the graduate students in April.

Fig. 1. GRE Scores of Entering Amath Graduate Students



The graph above shows the GRE scores of entering graduate students (about 20 per year). The scores of all entering students are included in the figure above. Trends in the data are small but statistically significant. GRE scores are normally taken as the premier standard of student quality. Note that the introduction of the PMP in 1998 had no obvious long-term impact on the average GRE scores of all entering students. (It is possible that the GRE scores of PhD students rose since the average scores of entering master’s students are typically lower.) We do not know how these results compare to Amath’s peer departments.

Table 4. Gender Statistics of the PhD and MSc Programs for the Past 5 Years
(Male Female)

| UW Amath Department | Combined "PhD" and Prof. Masters Programs | | | | |
|-----------------------------------|---|--------|--------|--------|--------|
| | 2002-3 | 2003-4 | 2004-5 | 2005-6 | 2006-7 |
| Applications | 51 43 | 64 41 | 62 35 | 59 29 | 69 36 |
| Offers | 14 14 | 24 20 | 39 15 | 34 14 | 39 21 |
| New Enrollees | 6 4 | 10 15 | 15 1 | 13 3 | 12 7 |
| Total Number of Enrolled Students | - - | - - | - - | - - | - - |
| Numbers of degrees | | | | | |
| PhD | 0 1 | 3 2 | 5 3 | 3 0 | 3 1 |
| Masters | 9 3 | 6 5 | 8 5 | 15 4 | 8 7 |

Over the last 10 years, an average of 27% women and 8.5% underrepresented groups were enrolled. Gender data for graduate students over the past 5 academic years are shown in Table 4. There have been about 100 applications per year of which about 30% are from women. The male-female ratio persists through the granting of degrees, so the graduation success rate is not a function of gender. That is, there is no sign of gender bias in the progress of graduate students through the programs (and we had no anecdotal reports of gender bias in our interviews). Even though the number of applications is small, the Department admits a slightly larger fraction of “minority” applicants than Caucasian and Asian American applicants. However, the numbers of matriculating minorities is so small that no statistical analysis of bias is possible. (We note that the shortage of women and minorities is prevalent in math and science programs throughout the nation.)

A deeper look into the program uncovered no serious problems other than those related to mentoring and expanding the array of graduate courses and some difficulties in the first-year experience discussed elsewhere. PhD students said that the core of the graduate program was in great shape, and that the Chair and faculty were attentive and responsive to student needs. Students in the PMP were somewhat less satisfied. The range of course offerings is good. Many students wanted more elective courses; however, they recognized that there aren't sufficient numbers of faculty to teach them.

The PhD students said that the courses were carefully taught (though some felt that the best teachers were too busy with undergraduate courses) and that the Department took their needs seriously and responded thoughtfully by allowing certain exceptions, clarifying the procedures and expectations (though there was still room for improvement), etc. Newer students, including those in the PMP, also said that a few of the faculty members are difficult to meet and know in the large first-year classes. PhD students felt that their large-scale research computing needs are met, and that maintenance of their computers and software is excellent. They also appreciated the level of engagement and empowerment offered to them by the Department during graduate and faculty recruiting efforts. However, a majority of students expressed frustration about the services from the permanent administrative staff.

The vast majority (but not all) of the students who we interviewed, or who submitted anonymous comments through GPSS interviews, felt that the courses taught by Amath faculty are good, and the student course evaluations are in agreement. However, the need for additional courses was expressed at every level. PhD students felt that there were not enough elective courses that would prepare them for the rapidly growing range of professional opportunities in the field. Students in the PMP felt similarly, though they don't have the time to avail themselves of more than two elective courses. The need for service courses at the 300- and 400-levels for students in other disciplines was brought to our attention from many members of the Amath faculty. In short, one measure of the inadequate numbers of faculty is in the courses that are not taught.

We discussed the quality of mentoring by the Department for the incoming students. All students praised the Graduate Adviser, Bob O'Malley for his devotion, openness, and quality of help. Beyond this, students in different programs and stages of advancement had somewhat differing opinions of the quality and quantity of mentoring that they receive. Advanced PhD students had no complaints. The newer PhD students were concerned that certain particularly active members of the faculty were not very accessible. Some of the students in the PMP felt that their appointed advisers did not serve them well, but that other faculty members were very responsive to requests to provide informal advising.

Some students will graduate with a PhD or MSc and leave academia to teach in K-12 schools or to work in industry. *We are very happy to see that Math offers courses to prepare them for a career in the K-12 classroom.* However, there is no parallel curriculum or structure to prepare students for a career in finance or other valuable commercial careers. This is not unusual in academic departments where almost all faculty have taken the straightest possible track to their present positions, bypassing the non-academic world. *It is probably incumbent on industry to provide summer or work-study experience for students with these interests.*

Overall, the committee was very pleased with the expressions of excellent training, supportive atmosphere, and overall satisfaction in the graduate program from students and faculty alike. It is clear that the faculty are exceptionally committed to training students from different backgrounds and with different goals. They are constantly crafting flexible approaches to the students' advantage without sacrificing programmatic quality. While certain frustrations were expressed by students in the PMP, the students that we interviewed agreed that their views were heard and treated respectfully and expeditiously, and that the Department was trying to take corrective action. All students praised K.K. Tung for his eagerness to communicate with them.

For example, in response to perceptions of problems with the Qualifying Exam, Amath recently replaced it with a six-hour written Preliminary Exam given in the first year to students in the PhD program. When the bugs are worked out, the Chair of Amath believes that the new exam policy will speed up the time to the PhD by a year, concomitantly reducing the load on financial support and other scarce resources without impacting the quality of the PhD program.

J. General Grad Student Issues

Appendix A of the Self-Study (the original 2006 version) provides statistical information about annual offers, acceptances, and enrollments of graduate students. However, it combined the numbers for the PMP and the standard PhD programs into one table. The Chair of Amath subsequently supplied us with useful sets of data for each program at our request. These data for each program appear in Tables 5 and 6 below.

J.1. Recruitment. Ambitious recruitment of new graduate students can only improve the productivity and vitality of any research department. It is also a vital step to improving its prestige and pursuing new grant support. However, the recruitment of new graduate students is particularly awkward in applied mathematics since few U.S. institutions have undergraduate programs in this field. Trying harder and more creatively is the obvious rejoinder.

Any successful recruitment of new students requires thoughtful, strategic efforts to reach recruits from a variety of majors, not just mathematics. It's possible that the Amath program might not be on the radar screen of some major math departments and their advisers. In response to a question from the Panel about recruitment strategy (submitted after the Panel met), K.K. Tung replied that the Department solicits referrals for PhD students by colleagues and former students in academia, who can identify students of talent who are heavily recruited by Amath. This has been fairly fruitful in identifying students whose strengths are not revealed by GRE scores and GPA averages. The Department also tried advertising in Peterson's Guide, but budget cuts now preclude this. Recruiting for the PMP is by word of mouth and the web site. This strategy should become increasingly productive as the number of graduates from Amath grows. The distance-learning version of the PMP will receive very broad distribution from the U.W. Extension Catalog with a local circulation of hundreds of thousands.

We find that the Department has recruited graduate students energetically but not particularly aggressively. Recruitment is an area ripe for improvement—provided the administrative support to make it work is available. (This was also the sentiment of the previous Review Panel.) Two Amath faculty noted that more visits to Seattle, more meetings with members of the faculty, and some of the many tactics used by other departments at U.W. should be studied and implemented by Amath. These are excellent tactical suggestions. Best practices in other departments that must recruit outside of their fields, such as Astronomy and Speech and Hearing Sciences, should also be considered. However, we also believe that nothing serves the goals of recruitment of students and faculty alike better than a strong international reputation for excellence in research, teaching, and mentoring. Given the other demands on faculty time, additional faculty engagement in recruiting will require more faculty or some difficult choices.

J.2. Retention. Overall, the vast majority of students finish their programs in a timely manner. The high *esprit de corps* in Amath certainly plays a role in student retention. About one student drops out of Amath's graduate programs per year. The reasons are diverse, and often they are not academic. *No trends or systematic causes that point to Departmental failings were identified.* In general, attrition rates are manageable.

J.3. Group Cohesiveness. A sure sign of trouble in a graduate program is when graduate students don't form a cohesive group. In our interviews with PhD and MSc students, *we found that there is a high regard for one another and for the faculty and Chair.* Bob O'Malley received the highest praise for his commitment and his helpful and cheerful counseling. The periodic lunches held by the Chair with the grad students also help to maintain open channels of communication about a variety of important departmental issues and to build enthusiasm.

Students also need administrative assistance, especially where the complex rules of the U.W. and Amath come into epistemological play. Administrative advising should be readily available from trained staff. *A few students felt that assistance from the administrative staff had been less than optimal. If this is indeed the case, then we urge an expeditious remedy.*

J.4. Mentoring. *To judge solely from its attitude, Amath is committed to the highest quality career and research monitoring of its graduate students. However, problems with mentoring—especially the quantity—will be discussed in subsequent sections of this report. We find that Amath is keenly aware of this situation, but has yet to fully cope with it.*

K. PhD Program

The PhD program comprises the core of a research-oriented department, such as Amath, which couldn't survive without it. Over two-thirds of the graduate students are enrolled in the PhD program. PhD students do much of the “heavy lifting” in research during their stay at U.W. They also continue to enhance the Department after their graduation by continued collaborations and the referral of new students to the program. For all of these reasons, the Department must focus on the successful recruitment and mentoring of talented, motivated, and imaginative PhD students. High morale is critical; communication is essential; forging career opportunities is mandatory, and teamwork is indispensable. We investigated these aspects of the PhD program carefully. *We are pleased to report that on the whole, the program is vigorous and very productive.*

Table 5. Statistics of the PhD Program for the Past Five Years

| Amath, standard graduate program | 2002-3 | 2003-4 | 2004-5 | 2005-6 | 2006-7 |
|---|---------------|---------------|---------------|---------------|---------------|
| Applications | N/A | N/A | N/A | 49 | 82 |
| Offers | 16 | 29 | 24 | 14 | 28 |
| New Enrollees | 6 | 9 | 6 | 4 | 9 |
| Total Number of Enrolled Students, fall qtr | 29 | 38 | 41 | 36 | 37 |
| Number of Degrees Awarded | 5 | 1 | 8 | 3 | 4 |
| Average Time to Complete PhD Degree | 6.0 | 6.7 | 5.8 | 6.8 | 6.2 |

K.1. Flow of Students. Amath's PhD program has been in routine operation for more than two decades. About 5 PhDs have been awarded annually over the past decade. At the present time (spring 2007), 34 students are in some stage of this program. Annual statistics on applications, acceptances, new enrollments, total enrollments, PhD degrees awarded, and time to PhD completion are compiled in Table 5. No clear upward or downward trends are evident in the numbers in the table or the graph of GRE scores. We do not know how these results compare to those of peer institutions.

The typical time from entry to graduation has been about 6 years; however, this time may drop as new exam procedures are implemented. The quantitative and analytical GRE scores of graduate applicants have remained almost constant at good values. *The statistics are those of a strong and stable graduate program.*

K.2. Program Quality. Rating the quality of a PhD program is complicated. Many measures of quality can be used. One of the more important ones is student satisfaction. This was reviewed in §I. *We find a very impressive and widespread enthusiasm for all aspects of the PhD program, including the quality of the teaching and mentoring, participation of graduate students in recruiting new faculty and students, open communication networks, strong esprit de corps, and encouragement (and adequate financial support) for attending meetings, publishing papers, and establishing careers.*

However, the most revealing measures of success are based on outcomes, *to wit*, student publication rates in refereed journals and post-PhD job placements. The rate of student publication in refereed scientific journals probes the engagement and success of PhD students in the research program. Excellence in this field requires strong core classes, quality mentoring, and good writing skills. Mark Kot compiled a detailed list of such publications for the past five years. Kot's complete list appears in Appendix F of the revised Self Study (version 23 April 2007). He reports that 22 PhD students are among the authors of 70 significant papers published in highly reputable and refereed journals. *The results are impressive. Students are gaining strong recognition through their publications before they enter the job market.*

Another outcome-based measure of program quality is the quality of job placement. The past current jobs of 60 post-PhD students for the period 1994-2006 are tabulated in Appendix E of the revised Self Study. The majority of these post-doctoral students, as with such students at many other research universities, took short-term postdoctoral, visiting, or entry-level tenure-track positions in academia upon graduation. A few went directly into industry. Many of these post-PhD students have ended up in well-known and reputable institutions. *Overall, the record of job placement is typical of successful (peer) Amath programs.*

We find that the quality of the PhD program is evident from all key measures. The strongest record is in student publications. The weakest link is the very high ratio of PhD students to faculty who are actively engaged in research—a sign that Amath faculty have limited time to perform all of their duties. Despite our concerns, and as we noted earlier, PhD students have nearly uniform praise for mentoring and the quality of the classes (cf. the GPSS Addendum).

K.3. Student Support. All of the students in this program are supported on RAs, TAs, and Fellowships. The number of supported positions for PhD students jumped with the award of the first VIGRE grant. There are about five annual VIGRE Fellowships (some of which are offered as recruitment enticements). These are awarded for two quarters during the academic year. Another seven fellowships provide summer support. The number of grant-supported RAs has remained fixed, and TA support from the College, which was steady at about 21 one-academic-quarter positions since 2002-3, dropped to 17 this past year. *We observe that present levels of support positions for students in the PhD program seem to be adequate. However, the VIGRE program will be coming to an end soon, and there will be a drop in the number of supported PhD students unless other sources of support are found.*

Planning for the termination of the VIGRE program is underway. As noted earlier, Amath has recognized the importance of fellowship support and has already begun to explore the prospects for a Research Training Grant under the NSF after the VIGRE award expires. Bernard Deconinck will lead the effort to develop a proposal for a “Research Training Grant” (NSF).

PhD students told us that the Department has been able to support their travel to meetings and workshops that help them in their research and provide them with national exposure. Such support is critical for building the foundation of a successful research career. *This is welcome. We hope and expect that the support for these career-building activities can be continued.*

We note that students in the PhD program have access to training as TAs through a program in Math. They also have the opportunity for contact with K-12 outreach. That is, the PhD program introduces students to an alternate career path of community service in local K-12 schools, and in doing so, it supports the curricular needs of the community extremely well.

K.4. Attention Areas. *We find that the PhD program is in very good shape.* However, part of our charge is to identify parts of the program, which can be improved. Foremost amongst these is the student-faculty ratio (Table 3). We have already addressed (or will address) several issues that are relevant in this section: the need for faculty to cover the strategic and fundamental areas of modern research; limitations on mentoring imposed by the small size of the faculty relative to the large numbers of graduate students, the vital need to attract top PhD students through a variety of nationally visible research programs, and limited support from the Department's administration. In addition, we noted the disruption to some PhD students caused by faculty leaves—especially those that cannot be planned—in a small department. *We emphasize the importance of all of these issues, all of which are elaborated elsewhere.*

Incoming PhD students have very diverse training prior to their arrival at U.W. There was some discussion that the first-year courses were somewhat repetitive for those incoming students with strong math background. Amath has begun a comprehensive review of its first-year courses, perhaps raising the level of their difficulty while requiring students of limited backgrounds to take appropriate 400 level courses to fill gaps before proceeding to the grad level courses. Of course, flexibility in the curriculum will almost certainly have impacts on the scheduling of Prelim Exams, at least for some students. Second-year graduate courses were recently reviewed and revised. *This initiative is certainly commendable—provided that graduation standards and career opportunities will not be jeopardized.*

The Prelim Exam was noted as a point of controversy among a few PhD students. The comments made to us are various and largely symptomatic. We were unable to diagnose the underlying problems. Scheduling and the attendant stress, more than the difficulty of the exam, seemed to be the point of primary concern. The Department is studying the scheduling issues and is about to try some changes. *We believe that the Department understands the issues and can find the optimum solution without our recommendations.*

In order to offer the broadest spectrum of research options to its students, the Department has also adopted the practice of co-supervision and sole supervision of Amath grad students by outside faculty from engineering, medical-biological, and forestry units, as well as other departments in the College of Arts and Sciences. Amath is also involved in a joint PhD program, Computational and Molecular Biology. *We see many advantages to such interdisciplinary opportunities for graduate students; nonetheless, a very vigilant eye must be kept on the progress of students whose primary supervision is from outside of the Department.*

The first-year experience was noted as a problem, primarily by PMP students. First-year PhD students who intend to pursue a research career (typically five per year) find themselves in classes with PMP students (typically ten per year) with a short-term outlook of their program and mixed career aspirations. The same courses are taken as service courses by students from other disciplines. *We speculate that this complicates the mentoring for all students in the first year, perhaps because faculty are not likely to become well acquainted with the mix of incoming students during 10-week courses. Also, it is possible that the first-year students find it difficult to “congeal” in this very mixed environment. Bob O'Malley might want to look at the first-year experience for all Amath's graduate students in order to determine whether there are serious problems that can be addressed outside of the class setting.*

L. Professional Masters Program (“PMP”)

Table 6. Statistics of the One-Year Professional Masters Program for the Past 5 Years

| Amath, Professional Masters Program | 2002-3 | 2003-4 | 2004-5 | 2005-6 | 2006-7 |
|--|---------------|---------------|---------------|---------------|---------------|
| Applications to the PMP* | N/A | N/A | N/A | 29 | 21 |
| Offers* | 12 | 15 | 30 | 34 | 32 |
| New Enrollees* | 4 | 6 | 10 | 12 | 10 |
| Total Number of Enrolled Students, fall qtr* | 20 | 11 | 11 | 17 | 10 |
| Number of Degrees Awarded | 11 | 12 | 13 | 19 | 15 |
| Average Time to Complete MSc Degree | 2.35† | 1.92† | 1.75† | 1.16 | 1.0 |

* Some of the numbers in the table may look unusual. For example, the number of offers in the past two years exceeds the number of applicants. That is because some applicants to the PhD program are redirected to the PMP each year. Also, the total number of new enrollees should equal the total enrollment in a 1-year program. Differences also arise because the numbers of Masters degrees awarded includes students in the PhD program who elect to get an MSc degree. A few students from other U.W. departments qualify to receive an MSc from Amath.

† The Preliminary Exam was implemented in 2001. It took a couple years for the students under the old Qualifying Exam to clear out of the system. This partially accounts for the longer than one-year time to degree for the Masters degree in 2002-2003. There were also a few part-time Masters degree students. Although few in number, they took 3-4 years to finish, thus affecting the time to complete a degree.

L.1. Background. The PMP was initially a suggestion by the then-Acting Dean of the Graduate School, Dale Johnson, who perceived a state need for professional training in Applied Math. The program was strongly endorsed by the previous Decadal Review Committee in 1996. This was prescient: a report of the Sloan Foundation shows that the top national need for a professional degree is applied mathematics, ahead of bioengineering.

In response, and without any promise of new financial resources for development and operations, Amath developed the program using resources redirected from elsewhere. Students who complete the PMP are awarded an MSc in Applied Math. The program went into full swing in 1998 and has been running at capacity ever since. It is built upon courses that were already in place. There are required “core” courses (22 credit hours) and flexible electives (at least two courses) and/or a thesis that allows students to pursue their own interests.¹² The students in the PMP are expected to attend seminars and journal clubs like all graduate students, which is thought to be a generally effective mechanism to engage faculty and students. (However, this may be more effective for PhD students with research experience.) Graduation does not require any sort of comprehensive examination.

Students in the PMP do not receive financial support from Amath. A few have outside jobs, and so they may attend the program only on a part-time basis. Amath offers extensions to the one-year limit in these cases.

L.2. Enrollment. Table 6 shows that there are 10 students presently enrolled in the PMP, which is typical.¹³ There are 20-30 applicants annually. The number of program graduates has increased by about 50% since 2002-3 (Table 6). A distance-learning version of the program is in the early implementation stages. Enrollment in the PMP will increase significantly when full implementation occurs.

¹² See <http://www.amath.washington.edu/admissions/Professional.html> for details of the requirements and expectations.

¹³ The Self Study Report, which was written earlier, shows 17 enrollees in the PMP in 2005--6.

L.3. Quality. The PMP has obviously grown to capacity; however, popularity measures quantity, not quality. The students that we interviewed are positive about the program, though less so than the PhD students. They expressed some legitimate concerns about limited access to dedicated mentors and research opportunities and complaints about the clarity of program expectations. Overall, they seemed less engaged in the program than the PhD students, which is natural given the one-year duration and the emphasis on coursework in the program. (We cover these concerns in Section L.4 below.) We were told that these complaints have been clearly communicated to the Chair, and that appropriate responses are forthcoming. *On the other hand, complaints like these seem to be symptomatic of a need for leadership, or at least a clear line of communication to a member of the Amath faculty who serves in a role such as a Program Director.*

Student satisfaction is just one measure of success. Grades in classes are another relevant measure for this program. (GPA data were not provided to us.) However, our preference is for an outcome-based measure of program success. We searched in vain for such measures. All of this raises the question of how the Department knows if the PMP is thriving. Are class grades a sufficient measure? Are there other authoritative standards of success that can be used, such as a standardized exit examination?¹⁴ Recalling the initial motivation for the program, can the value of the PMP to the State of Washington be ascertained?

Therefore, we do not have the means to judge the quality of the Professional Masters Program other than its popularity. That is, the success of the program will have to be reviewed by others who are more capable of expert judgment. We caution that without both standards and vigilance —i.e., an evaluation system that measures the quality of the PMP—it could possibly evolve to become an easy shortcut to a U.W. degree.

L.4. Attention Areas. Our interviews showed a high degree of student satisfaction, but without the same level of enthusiasm that characterizes students in the PhD program. Frustration with mentoring is foremost. Some of the students asserted that faculty are less accessible than they are for the longer-term PhD students. Some faculty concurred, including instructors in some of the classes taken by PMP students. *One plausible explanation is that the students are in and out of the program in just a year or two, much like postdoctoral fellows. Hence, it can be difficult for very busy faculty to make the commitment to get to know or perhaps even recognize a PMP student. So, although we note the complaints of inadequate mentoring, we can't clearly diagnose the disease. This is an area for the Department Chair and Graduate Advisor to explore further with PMP students.*

Another comment that arose widely in the interviews is that the students were confused about the expectations of the PMP. Some students expressed the need for better clarity about how to continue for a PhD, especially since the Preliminary Exam is no longer available to PMP students starting next year. The Department recognizes that there was insufficient clarity in the way their expectations were communicated to new PMP students. They are planning remedial steps for the future.

One student also expressed expectations for possible cooperative options with faculty or PhD students, such as research opportunities. However, we note that PMP students are not usually prepared with skills and tools for research prior to arrival. (Even if they were, their brief stay at U.W. will not allow them to contribute significantly while taking a heavy load of courses.) *In any event, Amath should clarify not just their expectations for PMP students, but also describe their extra-curricular options and potential pathways into the PhD program.*

¹⁴ We note that most students in the PMP will no longer be allowed to take the Preliminary Exam.

We heard a few complaints from individuals in the PMP who wanted to bypass those core courses that some of them had taken earlier elsewhere. Given the diversity in student ages, employment status, and career expectations, it seems futile to expect that the PMP can accommodate everyone optimally. *To its credit, Amath has responded to problems such as this one through flexible one-on-one responses rather than rigid curricular policy and changes. It might help to explain to students in the PMP that research opportunities and highly tailored curricula cannot all be honored.*¹⁵ Again, this points to a need for an ongoing dialogue between students and some sort of a faculty-level program advisor so that students develop realistic expectations of their stay in the PMP program.

In short, the PMP is up and running fairly smoothly. Meshing it with the PhD program will continue to be challenging since PMP and PhD students do not share the same backgrounds, program expectations, or career ambitions. We are particularly concerned that measurable standards for evaluating the success of the PMP have not been defined or implemented. The PMP program must develop a feedback path that can be used to establish and enhance its success. Outcome-based measures are highly preferred.

Many of the same comments about standards and measures apply with added emphasis to the electronic, or on-line, version of the PMP. Appropriate steps to monitor the quality of the program must be taken before the number of distance-learning students increases.

However, the most significant finding in this section of our report is not based on specific evidence obtained through documents and interviews. Rather it is simply a shared uneasy feeling. *The Panel senses that the PMP, while presumably valuable, is extracting a toll on faculty time and resources of Amath. While we applaud the Department for enhancing access to the PMP via a distance-learning extension, such expansion cannot be at the expense of the quality of the PhD or ACMS programs.* Unfortunately, we did not have the time to collect data or to make specific recommendations.

We can state that as a guiding principle, the full cost of the human capital, computers, software, and other monetary resources necessary to develop and maintain the quality of the PMP must be assured without deleterious impact on other valuable Departmental programs and functions. This statement goes beyond money to embrace faculty time and energy—resources that are already in very limited supply.

The distance-learning version of the PMP should continue in a limited “trial” mode until a mechanism for program evaluation and improvement is in place and necessary resources have been secured without placing stress on Amath’s core duties of research and on-campus education. Faculty-level leadership for the distance-learning program is mandatory.

M. ACMS and Undergraduate Education

M.I. ACMS.¹⁶ Amath has no undergraduate major of its own. Undergraduate teaching and mentoring were identified as substantial issues in Amath’s Strategic Plan and the report of the previous Amath decadal review panel. Amath moved ahead forthrightly in the late 1990s to coordinate the ACMS program with Math, CS&E, and Statistics to develop an extremely rich blend of integrated undergraduate courses. *This combined set of courses, and the many degree tracks available within it, is a national model for its uniqueness and the range of courses open to undergraduates. The breadth of the training received by the undergraduates makes many of them ready for gainful employment upon graduation.*

¹⁵ Research opportunities afforded to students in the PMP must not limit or take preference over Amath’s efforts to provide interesting research opportunities for its undergraduates.

¹⁶ “ACMS” stands for Applied and Computational Mathematical Sciences

The curriculum options shown on the ACMS web page are “Biological & Life Sciences”, “Discrete Math and Algorithms”, “Engineering & Physical Science”, “Mathematical Economics”, “Operations Research”, “Scientific Computing”, “Social & Behavioral Sciences”, and “Statistics”. The field of applied mathematics spans several of these descriptors, so the Panel was unable to identify a “track” or “program option” within ACMS that unambiguously coincides with applied mathematics. *We find the absence of an identifiable option labeled “Applied Mathematics” to be curious. If we are confused, students will be even more perplexed. We feel that the curriculum path for an ACMS student who is planning a career or future graduate program in applied mathematics must be as obvious as it is for statistics. ACMS advisers need to be fully trained to advise undergraduates accordingly.*

ACMS is the primary point of contact between Amath and U.W. undergraduates interested in the field of applied mathematics. We did not have the time or the charge to investigate the efficacy of ACMS and how well it satisfies the needs of applications-oriented undergraduates who wish to specialize in applied mathematics or how undergraduates and graduates in other disciplines can learn some of the methodologies and application skills that Amath can teach.

Only one ACMS student (a very senior one who had already worked in industry) was present for the interviews. He told us that the ACMS advisers told him only which courses are needed to graduate, not how to tailor a sequence of courses that takes a student’s interests and career needs into account. (A subsequent interview of ACMS advisers by BB and VG confirmed this allegation.) The student felt there is nowhere to turn for career counseling.

Among the faculty, no strong concern was expressed during the interviews about the quality of the existing ACMS curriculum in applied mathematics. However, we heard a variety of concerns about broader issues related to the structure and administration of ACMS. Most faculty who addressed undergraduate issues in the interviews felt that new ACMS students are not adequately exposed to applied mathematics within their first two years, and that some introduction to applied mathematics is needed early in the curriculum. Several faculty told us that they are frustrated about several facets of ACMS’ limited advising procedures, particularly their inability to recognize when students should be directed to Amath for career advising. Amath faculty sense that advisors do not understand the nature of applied mathematics and how the discipline differs from some of the others that are represented in the ACMS program. Several faculty felt that Amath was unable to influence major curricular designs and decisions in ACMS; for example, the implementation of Math 300, “Logic and Proof”, a foundation course and prerequisite for more advanced ACMS courses.

These and other frustrations with ACMS have led two senior members of the faculty to suggest that a new Amath major (parallel to undergraduate majors in the other participating departments) should be considered by the Department, even if it means stretching faculty resources still further. All of the necessary courses are already in place. Nonetheless, the numbers of Amath faculty, the level of TA support, and a system of Amath advisers will require substantial support from the College if a new degree program is to be implemented.

From afar, we suspect that many of the negative perceptions of the ACMS program are the result of poor communications. As an example, interviews with some of the ACMS advisors in May revealed that their formal job responsibilities and Amath’s expectations are inconsistent. As a matter of policy, advisors are told to leave all career advising up to individual departments in the ACMS program. Consequently, the advisors feel that Amath must find its own way to provide career advice directly to students throughout their participation in the ACMS program. *The issue of career advising is important, and other participating departments in ACMS seem to have been able to provide career advice to their students. This points to an advising deficiency that only Amath can remedy.*

Insofar as a new Amath undergraduate major is concerned, we find the concept to be suitable only as a means of last resort. The level of effort to design the program, have it sanctioned by the U.W. Administration, to plan the courses as well as the curriculum are formidable and unrealistic. We do not believe that Amath is ready to undertake such an effort. It's the wrong plan at the wrong time.

The complexity of the full set of concerns regarding the administration of the ACMS program raised in our interviews strongly suggests that better communications with ACMS management and a clarification of mutual expectations would serve Amath well. We urge them to appoint a faculty leader to initiate a full study of how ACMS can improve its curriculum for students interested in applied mathematics, to determine how Amath can best serve the high-level advising needs of these students outside the framework of ACMS, and how to make the entire undergraduate experience in applied mathematics whole and comprehensible to everyone. We strongly suspect that this will turn out to be an ambitious effort, one, which is long overdue, and one that will take too much time to be left for a new Chair.

Additionally we suspect that the ACMS program could benefit from a comprehensive ten-year review of its own. Based on what we have heard, we can only leave a legacy of questions for future discussion:

- Does the ACMS program provide students with a broad spectrum of experiences in applied math early in the curriculum?*
- Do students entering the ACMS program get an introduction to the full set of mentoring and research opportunities available in each of the participating departments?*
- How do ACMS and the participating departments assist students to make well-informed choices about curricular paths before they embark on them?*
- Has the ACMS program maintained a good sense of balance in its offerings?*
- Do the participating departments understand and address their responsibilities for meeting the needs of ACMS undergraduates in their disciplines?*
- Do the ACMS Advisory Committee and the Director maintain broadband communications with the participating departments?*

M.2. Undergraduate Outcomes. Whatever its difficulties, ACMS is successful in serving the needs of undergraduates in applied mathematics. Fifteen undergraduates have gone on to graduate studies in applied mathematics at some of the very best graduate programs in the country including the Courant Institute, Harvard University, Princeton University, Stanford University (three students), and Cornell University. The students have also been awarded a large number of prestigious awards: the U.W. Freshman Medal, U.W. President's Scholar, U.W. Advanced Undergraduate Research Award, McNair Presidential Fellowship, and eight Mary Gates Fellowships. Most impressive is the 20 peer-reviewed scientific and mathematical journal articles by faculty that have been co-authored with undergraduates. Without exception, the collection of peer-reviewed works have appeared in the leading research journals in optics, photonics, fluid dynamics, wave phenomena, and atomic physics. Undergraduates have given ten presentations at leading international research conferences.

A major U.W.-wide priority of the Provost has been the undergraduate research experience. The undergraduate research program has grown over the years into one (with its own Associate Dean) that permeates almost every department on campus. Amath, with its array of faculty-led research programs, is a natural fit. Many faculty (Criminale, Deconinck, LeVeque, Kutz, Qian) have responded with a variety of undergraduate research opportunities in the past two years.

We find that these outcomes speak very well of the quality of the teaching and to the dedication of opening research opportunities for undergraduate students. This is made more impressive when one considers that Amath has no undergraduate majors program of its own that it can use as a conduit for identifying talented students. Yet somehow it works!

M.3. Service Teaching. Undergraduates in many majors need to learn skills used in applied mathematics; for example, MATLAB, MATHEMATICA, MAPLE, and certain coding methods for building mathematical models and simulations of fluids. Amath engages in a variety of service teaching activities. Students in departments across campus, from engineering to the QERM program, take Amath's advanced undergraduate courses. Pressure has grown to add more courses as the utility of methodologies of applied mathematics spreads through more disciplines.

We were told that there is likely to be increasing demand for 400-level service courses across at least two different colleges. Amath is redesigning some of their 400-level courses in response to marketplace pressures so that graduate students outside of Amath can take them for credit. This illustrates the increasing importance of applied mathematics in modern education and research and the response of Amath to these market forces. *We commend the efforts by Amath to address the ever-increasing needs of students in many fields who share interests in sophisticated methodologies and the tools that exploit them.*

The need to expand Amath 301, "Beginning Scientific Computing", emerged as an issue during the interviews in the context of future resource allocations to Amath. The Panel was told during the interviews that ultimately 800-1000 students from many departments (primarily in the College of Engineering) would want to take Amath 301.¹⁷ *Obviously Amath cannot accommodate that level of demand without significant additional resources from the College of Arts & Sciences. We urge serious long-term resource planning if Amath 301 is to satisfy the needs of U.W.'s students for service courses. Obviously this adds pressure for more Amath faculty and TA positions.*

In summary, ACMS is the vehicle used by Amath for the academic preparation of undergraduate students in applied mathematics. While the outcomes clearly point to tremendous success, several problems and challenges lie ahead for both Amath and ACMS. One of these is how both groups can best serve ACMS students by sharing the responsibility for preparing and mentoring undergraduates with ACMS advising staff and insuring that the program provides comprehensive advice to undergraduate students about their courses and careers. Amath faculty are rightly concerned that ACMS students need to be exposed to applied mathematics earlier in the ACMS curriculum so that the students can make fully informed choices about their curriculum choices as early as possible, which may require changes in the Amath curriculum. Finally, new resources will be needed if larger numbers of students are to be accommodated in revised 300- and 400-level courses. Long-term strategic planning is needed towards this end. Most of all, high-level leadership is mandatory.

Finally, we speculate that undergraduate students who want to pursue a career in applied mathematics would be vastly better served if Amath maintains its separation from Math and each learns to develop good working relations with the other. As noted in §II.A.3, Amath would not be successfully assimilated, and if nothing else, key faculty may elect to leave U.W. For a deeper discussion, see the report of the previous Review Panel. Amath's record of advising its graduate students leads us to believe that they can and will do a far superior job at launching successful careers once they develop an advising system of their own that works.

¹⁷ Upon post-interview investigation, we learned that curricular changes in that college will increase enrollment from 150 in 2006-7 to 350 in 2007-8. The ultimate value of 800-1000 students is an estimate based on an expectation that students presently learning similar skills in other courses will move into Amath 301 over the next few years.

N. Administrative Support

N.1. Administrative or “Front Office” Staff. The administrative staff of Amath is normally 3 FTEs, a Department Administrator, a Fiscal Specialist, and a Receptionist/Secretary. At the present time, the College has reduced funding for the last position to 1/3 time.

The Panel did not meet with the Administrator or the Fiscal Specialist during the interviews, nor did it receive letters or other input from either of them. The Chair explained that both have been with the Department for many years. They have a deep sense of its history and practices. He feels that each person is competent at the technical aspects of their jobs. The paperwork generally flows smoothly through the office, including the preparation of new grants and their budgets. The staff has received day-to-day supervision by the Chair. Even so, keeping up with the full scope of administrative duties that assist the Chair is extremely difficult. Thus the transition to the reign of the new Chair must be watched carefully.

The Receptionist/Secretary, Crystal Peterson, was a temporary hire who is leaving the position in August. She talked with us about her frustrations trying to provide services of various sorts to the Department on a 1/3-time basis and, without suitable training by her supervisor. However, as we found later, Peterson’s job did not include such responsibilities. *This begs the issue of how such important services are being delivered to the faculty and students,*

Administrative support provided to the Chair, faculty, and students of Amath is essential for a smoothly operating department, especially when the faculty are already under severe stress to maintain the key elements of the program. A fully functional and professionally trained staff is essential if a lithe, research-oriented Department is to be successful and its students are to receive timely administrative advice and support. We are not capable of diagnosing the problems; however, we can express our hope that any problems will be addressed aggressively as a new Chair steps into the position. This is a major finding of the present report.

N.2. Technical Support. The computer infrastructure of a department affects every function of the department, including research, teaching, mentoring, and service. Email is just one example. A variety of research tools must be supported, such as MATLAB, MATHEMATICA, MAPLE, and IDL. The computer operating systems and networks simply must be up and running 99% of the time. Thus the computer infrastructure of a department such as Amath is every bit as important as administrative staff.

The system is maintained officially by Chris Whip who will occasionally pool his expertise and a few of the responsibilities with other technical people in nearby departments, especially when vacations and professional trips arise. Whip receives training on new systems and their features informally and, at times, formally through U.W. channels. He felt that the system runs very smoothly. Everyone else whom we asked was effusive in their praise of the maintenance of Amath’s computer systems. *We congratulate Amath for its outstanding support of its computer and software systems, both of which are key elements of a research department’s infrastructure.*

In the world of computing, long-term planning is important, especially as software becomes much more sophisticated and hardware capacity, power, and cooling needs grow. *We find that Whip’s daily responsibilities and budget leave little time for planning and developing a high-performance system. However, we have no solid evidence on which to predict future problems.*

O. Fundraising Efforts.

Departments increasingly need outside (private) support to fund faculty and student activities, such as travel to conferences and to invite outside speakers. They must also spend considerable amounts of money to attract new students through travel for visits and startup awards. Endowments to support professorships are essential for recruitment and retention. State funds never cover even a fraction of these many expenses. Fundraising to support the needs of the students and faculty is an ever-expanding activity in U.W. Science Departments.

We did not probe this aspect of the Department's activities in depth. Amath has held a Boeing Professorship for about a decade. The Department uses this selectively by appointing different faculty as the Boeing Professor for one- and two-year appointments. (Hong Qian is the present recipient.) It is possible to return to Boeing for further support. Present and former members of the Amath faculty have donated several Graduate Fellowship Endowments.

However, a broad array of fundraising activities is always needed. We understand that the current staffing limitations in Amath have hindered their ability to engage in fundraising. Amath, with many of its students entering industrial and commercial firms, needs to be planning initiatives in coordination with the development staff in the College of Arts & Sciences.

P. Amath's Need to Grow

Applied mathematics is in a golden age as methodologies become ever more sophisticated and the range of their applications expands rapidly. Amath knows that it can't stay where it is—it must at least keep pace with its much larger peers in this expanding cosmology or it will wither. Amath must be able to energetically pursue new research opportunities, develop its newer academic programs (as we outlined earlier), enhance its national prestige and funding, and keep moving forward with its strategic initiatives.

This can happen only through faculty leadership. This was clearly recognized by the previous Review Panel. In their words, "The [Panel] recommends that in the short term and in a resource constrained environment the [D]epartment be maintained at 12 faculty FTEs. In the future, further expansion into emerging interdisciplinary areas is desirable" (page 2). They also recommended "that one additional faculty member be hired in the area of Scientific Computing" (page 9). By this they meant filling the vacancy left by the departure of Fred Wan in order to add to the strengths represented by three other faculty, Adams, LeVeque, and Schmid. Today only Adams and LeVeque remain in this strategically valuable field, and Adams' attention is migrating to program administration. *So the sub-discipline of Scientific Computing in Amath is now on the verge of imploding, at a time when buildup of Scientific Computing is most needed at the undergraduate level for ACMS students and for non-applied mathematics undergraduate and graduate students.*

In the decade since the last review, the faculty size of Amath has remained fixed¹⁸, the number of graduate students has risen, grant responsibilities have expanded, funding from the College for administrative services has been curtailed, and Amath has developed two new, substantive, and ambitious academic programs, ACMS and PMP. Meanwhile the field has charged ahead with research in exciting new frontiers in areas from biology to engineering. Therefore, we find it easy to imagine that change

¹⁸ This is not to say that Amath has been treated anomalously by the College or U.W. We compiled faculty size statistics for each of the science departments in the College for 1996-98 (from the U.W. General Catalogue of 1996-98) and fall 2006 (from "Fact Sheets" on the College's web site). The total number of FTEs in science departments has not changed in the past decade. During this interval the number of FTEs in Amath and Math were constant. The only department with a substantial increase in FTEs is Statistics, which went from 13 to 21 FTEs (+62%).

within Amath is inevitable. Not to put too fine a point on it, the quality and quantity of the faculty and the Department (with support from the College, of course) will determine whether Amath's future will be the purposeful outcome of intelligent planning or the vagaries of Darwinian evolution.

From the material presented in various sections of this report, we now stress and consolidate our most significant conclusion: Amath's faculty must grow in order for this outstanding Department to reach its full potential in serving the vital core mission of the University of Washington. Our relevant findings:

(1) The previous Review Panel as well as this one have both emphasized the quality of Amath's faculty and its critical role in research, teaching, mentoring, and contributions to a broad range of interdisciplinary enterprises. In the past decade, the faculty have led ambitious new programs for undergraduates and PMP students, both of which are still in a state of active review and optimization. At the same time the research horizons of applied mathematics have swept forward. Half of the faculty from the previous decade have been replaced, and the nature of the department's research has been transformed as a result. Yet gaps remain in research coverage. Investment at the faculty level is the key to assure the strength and national reputation of Amath for the next decade.

(2) Unlike a decade ago, there is now a very broad range of accumulated needs that demand more faculty involvement:

- Expand the scope and balance of research, as described (§II.A), and fill the gap in Numerical Analysis/Scientific Computing*
- Expand the breadth of elective course offerings at the graduate level (§II.I)*
- Reduce the research mentoring load per faculty member to reasonable levels (§II.E.1)*
- Enhance the national reputation and the competition for top students and new faculty (§II.C, F,I)*
- Increase grant support, especially for future Department-wide grants similar to VIGRE (§II.D.2)*
- Provide faculty-level leadership of the PMP (§II.L)*
- Provide faculty-level leadership and student mentoring within the ACMS program (§II.M)*
- Provide additional research opportunities for undergraduate students (§II.M)*
- Provide more and larger service courses at the 300 and 400 levels (§II.M.3)*
- Provide more faculty muscle for the recruitment of top graduate students (§II.J.1)*
- To use a baseball analogy, provide a "bench" that can keep the team whole during the leaves and other professional absences that are essential to sustain the network of programs in interdisciplinary research.*

In addition, it is conceivable that the increasing administrative complexity of Amath, with its many academic programs and interdisciplinary collaborations, may soon require an Associate Chair. Under present circumstances this would not be advisable without an additional faculty member.

(3) Experience shows that present staff levels are not sufficient to maintain the vitality of present programs for the long term or to implement the new strategic objectives aimed at benefiting students listed above. Much like horses on an overweight stagecoach, continued stress on the faculty will lead to exhaustion. Any additional expansion of Departmental activities that can address the many needs listed above simply cannot be absorbed without more faculty. We find that 12 FTEs is an absolute minimum in order to lighten the load and to cover the present gap in Scientific Computing, but probably not enough to insure that its strategic initiatives will be successful.

(4) The increase in faculty should be planned strategically and implemented steadily over the next decade. The obvious first step is to begin the search for a successor to Peter Schmid immediately. His absence leaves a huge hole in Scientific Computing. The path beyond can be gleaned from Section 11 of the Amath Self-Study document. Quoting from the second and third paragraphs of that section:

“We envision a department of 13 FTE [sic] to allow us to expand our courses and the teaching of applied mathematics from 300- and 400- level courses to the 100-level while maintaining strength at the graduate level and introducing more scientific computing throughout the curriculum. Of our research specialties within applied mathematics, 13 FTEs are probably just about critical mass.... With 13 FTEs, we can provide the needed continuity of graduate programs and create more synergy among different research areas, while allowing our faculty to devote more energy to undergraduate teaching and toward achieving a coherent undergraduate program for both the non-majors and the ACMS majors.”

We wholeheartedly concur with the sense of their plan. We find that it serves as a thoughtful outline for attaining the set of objectives in Amath’s Strategic Plan of 2000. However, our recommendations (§III.B) add even more pressure for additional faculty. Therefore, we will not endorse any specific number of new FTEs. Rather, we urge that Amath review their Strategic Plan in the light of our recommendations, develop its strategic priorities in collaboration with the College, and build a realistic implementation plan that will secure the requisite resources needed to reach their most vital goals.

It is easy to speculate that one of the contributing factors to the persistence of the inadequate FTE numbers is simply that the issue of a merger of Amath with Math remains unresolved. Even the smallest doubts about the future of Amath makes it likely that other more secure departments will be the first to reap precious long-term investments in faculty as funds become available. Leveling the playing field is one among many reasons (§II.A.3 and elsewhere) to clear the air about the merger.

Any effort to add additional faculty will precipitate a problem with office space. New space must be added in a manner that preserves the coherence of the Department, one of its major sources of strength.

Part III. Conclusions and Recommendations

In this section, we use our findings and observations in the previous section to generate conclusions and to make specific and, we trust, sensible recommendations for change. Context for our recommendations is provided in §III.A. Detailed recommendations follow in §III.B.

Summary of the Panel's Recommendations

Must-do-now recommendations

1. Plan for strategic success. Update, justify, and prioritize the elements of the Strategic Plan, including consideration of the recommendations by the Panel. Seek College endorsement for the Plan and collaborate with the College to develop a realistic implementation plan and schedule.
2. Invest in human capital. Obtain the resources in order to implement the Strategic Plan over the next decade in close collaboration with the College. Expedite the replacements of Peter Schmid and upcoming retirements. Enhance research strength in Scientific Computing.
3. Serve the full range of needs of undergraduates who wish to pursue a career in applied mathematics. Reach such students early in the ACMS program through Amath-taught courses and informal professional counseling, and actively connect undergraduates to research opportunities and career mentoring offered by Amath. Appoint an undergraduate leader and advocate at the faculty-level
4. Provide leadership and management for the Professional Masters Program (“PMP”). Appoint a faculty-level director who serves as a communications node and advisor, set outcome-based performance standards for the PMP, and assure that the PMP will complement rather than compete with the core PhD program, ACMS, and enhanced service courses for scarce resources.
5. Clear the air about a future merger with Math. Obtain a policy statement from the U.W. Administration that allays doubts about a merger in order to focus everyone’s energy on the long-term efforts that really matter: strategic planning, curriculum development, teaching and mentoring, faculty recruitment, interdisciplinary research, and collaboration with Math.

Additional recommendations

6. Revitalize the administrative support unit, or “front office”. A full range of administrative support for the Chair, faculty, and graduate students must be provided if the Department’s missions in research, teaching, mentoring, and service are to thrive, top students and faculty are to be recruited, and its strategic plan is to be implemented.
7. Implement more service and graduate courses. Planning for the expansion of 300- and 400-level service courses should be pursued vigorously. Broaden the array of graduate courses to cover the spectrum of modern research. New faculty FTEs and TA positions should be added as needed.
8. Seek faculty diversity and age balance. Aggressively pursue equality in gender and minority representation and maintain the current age demographics.
9. Pursue graduate recruitment more aggressively. Develop a range of more proactive recruitment strategies to reach and recruit the best graduate applicants.

A. Context

The Department of Applied Mathematics (“Amath”) is an outstanding example at U.W. of a department that works. Amath has secured a place in the top ten departments of applied mathematics in the U.S., and it intends to remain there. It serves as a model for departmental achievements, creativity, coherence, commitment, cooperation, and forward thinking. There is ample evidence presented in this report—much of it from in-camera testimony and the various versions of Amath’s Self Study—to demonstrate that Amath has been an active, if not exemplary, participant in implementing U.W.’s mission of learning, research, and service. Its grant support is exceptional among math-oriented science departments and comparable to much larger science departments with large on-campus labs. We are deeply impressed with the evidence of Amath’s initiative and accomplishments, its confidence in its future, and the happy team spirit that bind all of the faculty and the graduate students that comprise it.

Amath has lived through a decade of remarkable change under the capable leadership of K.K. Tung. Major programs and large grants have changed its character, expanded its focus, and enhanced its national prestige. Among these are the highly prestigious VIGRE and GK-12 grants, the new Professional Masters Program, and participation in the new ACMS program for undergraduates. All of these major changes have occurred during a decade of faculty rejuvenation. New fields of specialization have been established, some of which have led to a variety of productive interdisciplinary programs. At the same time, the number of College-supported TA positions and support for its administrative staff have declined. Moreover, Tung is retiring as Chair, and the leadership of Amath is passing to the next faculty generation. The turbulence left in the wakes of all of these changes and the pending change in leadership motivates most of our recommendations.

So, although Amath may be thriving, it needs help to consolidate its gains, excel in new areas, build the careers of its junior faculty, and to sustain and expand its collaborations with other rapidly growing scientific and mathematical communities at U.W., many of which wish to exploit the power and versatility of modern methodologies in applied mathematics.

Despite our very strong confidence in the future of Amath, we are obliged to spotlight one quite conspicuous 800-pound gorilla: limited human resources. We highlighted a varied set of problematic symptoms that largely point to a single problem: *the faculty are stretched too thinly to meet some key responsibilities to students both inside and outside the class curriculum*. Readers should refer to §II.P for our comprehensive review of this issue.

Manifestations of an overloaded faculty appeared in almost every interview that we conducted. The faculty have already recognized precisely the same set of problems (Self-Study, §11), and they feel increasingly frustrated that their attention is being channeled to “firefighting” rather than towards the pursuit of longer-term strategic objectives. Our recommendations are aimed at securing a minimal but secure footing from which the strength of the department and its international reputation will be able to keep up with (1) the national needs for growth in applied mathematics and (2) the expanding spectrum of needs of the undergraduate and graduate students—especially those who intend to pursue applied mathematics as the focus of their careers.

We recognize that adding faculty positions won’t be easy, and that careful justification and planning are essential if progress is to follow. So be it. Time is precious: The present state of frustration within the faculty ranks, while still largely incipient, must be remedied before weariness spreads and top people are tempted to leave U.W. for greener pastures—as was the case this year for Peter Schmid. How best to proceed is too important a topic to be left to a panel of outside reviewers.

B. Recommendations

The Panel is very pleased to be able to recommend improvements that will support and nurture Amath at a critical time in its history. These recommendations range from strategic planning, faculty staffing, graduate and undergraduate education, and administrative services. They are offered more in the spirit of important tune-ups than major repairs.

The Panel has selected five “must-do-now” recommendations for their large and immediate impact on the functions and orderly enhancement of the Department. We also offer additional important recommendations of lower immediacy.

If so, this is because it is not within our purview to craft solutions to messy problems that are difficult to diagnose in a few days of interviews, a few hours of panel discussion, and a few weeks of writing reports in our separate offices. In those cases, we will be careful to identify the problem rather than to propose a possibly meaningless recommendation.

Recommendation #1: Plan for strategic success. Update, justify, and prioritize the elements of the Strategic Plan, including consideration of the recommendations by the Panel. Seek College endorsement for the Plan and collaborate with the College to develop a realistic implementation plan and schedule.

As described in §II.A, the Department’s Strategic Plan was developed in the 1990s and reaffirmed several times since. The Panel concurs that this plan is forward looking and that it builds from Amath’s strengths to support critical areas of research and its teaching functions. It nicely describes what the endpoint of the planning process should be.

Almost all science departments face faculty shortages, or at least the perception of such. New positions will go to those who make the most compelling strategic case. Thus, strategic planning is essential. However, every strategic “what” needs a “why”. We feel that the key elements of the Strategic Plan, almost all of which add pressure for new FTEs for permanent faculty, need much more concrete justification, and we urge that the Plan be modified accordingly. Demonstrate how many faculty are required (10? 12.5? 15?) to serve the full spectrum of essential department functions, including those listed in §II.P.

The second step in the realization of the Strategic Plan is its endorsement by the College. This assures that the changes proposed for Amath are nicely aligned with the institutional missions of U.W. So far, the College has been silent on endorsing the existing Strategic Plan and assuring that Amath’s goals are supported and reached. Reaching accord is necessary for a commitment of resources over the next decade. We recommend that the Dean of the College of Arts & Sciences play a more active role in working with Amath to help set funding priorities among their strategic goals.

Strategic plans generally consist of goals and a vague compilation of expectations. The Amath plan is no exception. The next step in realizing the plan is an analysis of the “how”, the “who”, and the “when”. We recommend that Amath prepare an implementation plan with a roadmap that outlines how the Strategic Plan should be realized within the next decade. This includes a full set of resources that will be needed (e.g., space, clerical support), a management plan, and a timetable that can be used to plan for the allocation of resources and to judge ongoing progress. We recommend that this implementation plan should be assembled in time for the arrival of the next Dean of the College in summer 2008.

Recommendation #2: Invest in human capital. Obtain the resources in order to implement the Strategic Plan over the next decade in close collaboration with the College. Expedite the replacements of Peter Schmid and upcoming retirements. Enhance research strength in Scientific Computing.

Faculty staffing is by far the most important issue for the long-term health and reputation of Amath. Any increments—especially with a positive sign, must be very thoroughly justified in the Department’s Strategic Plan. In §II.P, we noted a broad spectrum of serious symptoms all of which point to a dangerously low level of faculty number to address the suite of essential functions that Amath must support well.

Let us be more specific. There has been a significant expansion of activities within Amath since the last 10 year review, e.g., VIGRE, GK-12, the ACMS Program, the Professional Masters Program, increased teaching of special upper division courses for graduate students in other departments, increased collaboration in interdisciplinary research, and the assimilation of 5 new faculty members, to name a few. We noted in II.P that the stress imposed on the faculty to manage these programs, to provide all necessary support for undergraduates, and to maintain strength in core research programs had reached dangerous levels. Any further loss of faculty could create a vacuum and trigger frustrations.

The fields of Scientific Computing and Numerical Analysis stand out as key areas in which one or two faculty hires are needed immediately. The expertise of Schmid, who covered these areas, needs to be replaced, Adams is turning to administration, and LeVeque is carrying too large a load. Also, Wan was never replaced by someone in these areas. Therefore, it is easy for the Panel to recommend that, as a first step, the vacant faculty position created by Peter Schmid’s resignation should be filled immediately without the customary waiting period. This will avert an immediate crisis in research coverage, but it will not provide the human capital needed to fully address many of the other problems listed in §II.P.

The Panel unanimously and emphatically supports the concept of growth of the Amath Department. Increasing the faculty number immediately is the key to the future success of the Department in research, teaching, mentoring, internal leadership, and fundraising.

Recommendation #3: Serve the full range of needs of undergraduates who wish to pursue a career in applied mathematics. Reach such students early in the ACMS program through Amath-taught courses and informal professional counseling, and actively connect undergraduates to research opportunities and career mentoring offered by Amath. Appoint an undergraduate leader and advocate at the faculty-level.

Judging from the success of its students, undergraduate education in applied mathematics has blossomed in the past decade. Ten years ago, there were plans, and now there is the ACMS program. So why then did undergraduate teaching and ACMS appear as a source of contention in our interviews?

Serving the needs of U.W. undergraduates is a serious business since it lies at the core of U.W.’s mission. Amath is in a particularly awkward position since (as far as we know) it has no established conduit to students except through 300- and 400-level courses. All ACMS students, especially the new students within the ACMS program, potentially suffer. We find that that there are several problems, some of which reach beyond ACMS and into Amath, that require urgent attention by responsible faculty.

Regarding ACMS itself, the scope of its present classes is the dominant problem seen by students. Students with the appropriate aptitude and interest to enjoy and succeed in a career in applied mathe-

matics are not exposed to the discipline early in the curriculum. They remain largely unexposed to the patterns of thought and the focus on applications that separate applied from pure mathematics. Therefore, topics or courses in applied mathematics must find their way into the ACMS curriculum at the introductory level. (Much the same can be said for all participating departments, of course.)

Undergraduates who might ultimately find applied mathematics to be an engaging career possibility require faculty-level professional mentoring to help them to chart their way into graduate programs or professional careers. However, ACMS advising staff do not and cannot competently provide this advice. Therefore, only the most industrious students are presently able to find such assistance from Amath faculty. So our second recommendation in this area is for Amath to provide and aggressively promote a highly visible path for students to find career advice.

Thirdly, we feel that strong advocacy for students with interests in applied mathematics must be provided continuously within the ACMS program as it continues to evolve. The necessary influence mandates high-level involvement.

One of the major U.W. initiatives of the past decade has been an emphasis on research opportunities for undergraduates at U.W. Amath has a strong record of success in this effort. However, the present advising system fails to provide any obvious way for a student in ACMS to make a connection to a research program that might be available in Amath unless this opportunity is mentioned by faculty member in Amath who happens to be teaching a 300- or 400-level course. Amath must find a more systematic way to open the door to research programs to all ACMS students.

Recommendation #4: Provide leadership and management for the Professional Masters Program (“PMP”). Appoint a faculty-level director who serves as a communications node and advisor, set outcome-based performance standards for the PMP, and ensure that the PMP will complement rather than compete with the core PhD program, ACMS, and enhanced service courses for scarce resources.

The PMP is seemingly an experiment that worked, at least to judge by its popularity. However, the PMP must now move towards maturity. It needs permanent leadership, its students, who enter the program with very diverse backgrounds, need a permanent advisor and mentor, and above all, it needs objective standards by which its value and success can be monitored. Moreover, the lack of clarity of expectations expressed by several PMP students must be addressed. So to be clear, we are not recommending changes in the structure of the program, but rather that a means be found to assess the value and success of the program, and that a central node of communication be established to promote dialog and feedback to PMP students and the Amath faculty.

Some elaboration is useful. Leadership is critical if the program is to address the many issues (none of them life threatening) that arose during our interviews (see §II.L). Above all is the perception on the part of several PMP students that they have second-class citizenship in Amath. (The Panel knows that such a status is not intended, and that there are plausible explanations for this unfortunate impression.) We concluded that the perception is almost certainly the result of an inadequate level of ongoing communication despite the efforts of K.K. Tung to meet periodically with PMP students. We feel that a mentor-leader at the faculty level is needed immediately to advise the PMP students on campus, to evaluate the quality of their experience in the PMP, and to guide the expansion of the program into the far less personal realm of distance learning.

The Panel found that it could not judge the success of PMP against objective standards other than the size of enrollment. We could not determine if PMP students have consistently met any of the usual qualifications for the Master's degree, and how PMP students compared to other students who receive the MSc degree from Amath. Course grades would have provided limited useful information. But the measure of a program's success should be judged by outcomes, such as a standardized exam or job placement.¹⁹ We urge the development of such standards, such as reinstating the Preliminary Exam as a requirement for graduation. The Prelim grades of PMP students can be monitored from one year to another and compared to those of students in the PhD program. (As a suggestion, a threshold grade, called a "Masters Pass" might be considered for all masters-level students.)

The Panel is particularly concerned about the imposition of standards for the distance-learning version of the PMP. Good feedback from students can be especially difficult to obtain in such courses. Without it, the notion of success will be lost. We urge that the distance-learning PMP program remain in a tentative trial mode for three years, and that it be carefully evaluated against objective standards in 2009. If possible, the standards used to assess achievement should be the same as those applied to the on-campus PMP.

The PMP is just one of many exciting new programs within Amath. However, it is not as central to the core mission of Amath as, say, the PhD and ACMS programs. The necessary resources and leadership needed to administer the PMP must not be allowed to compromise these or other programs of higher priority. PMP students must have lower priority for engaging in research programs than other students.

At the very least, unless precluded by State or University tuition policies, we recommend that all of the direct and indirect costs of the program should be borne by fees paid by the participating students. In addition, it is quite possible, if not likely, that an additional faculty position should be allocated to Amath for support of the PMP if it is to meet clear objectives and before any commitment is made to a permanent distance-learning component.

Recommendation #5: Clear the air about a future merger with Math. Obtain a policy statement from the U.W. Administration that allays doubts about a merger in order to focus everyone's energy on the long-term efforts that really matter: strategic planning, curriculum development, teaching and mentoring, faculty recruitment, interdisciplinary research, and collaboration with Math.

The Department of Applied Mathematics at the U.W. is widely recognized throughout North America as one of the top ten outstanding departments in applied mathematics. Through its funding, the U.W. administration ultimately is responsible for Amath's long-term excellence. It is difficult for the Panel members to reconcile the high regard with which Amath is held outside the U.W. and the limited support that Amath has received at the U.W. from the point of view of finances, human resources, and moral support in the past decade as the range of its activities grew at a torrid pace.

Frankly, of all the issues that were raised during our deliberations, the issue of a possible merger with Math was the most baffling. The issue of a possible merger arose in nearly every interview, and it was uniformly described to us as a threat rather than a collegial decision in which the faculty of Amath could exert due influence. The previous Review Panel considered, and strongly rejected, as does this Panel, the notion that Amath should be dissolved or absorbed (see §I.B and II.A.3).

¹⁹ Publications are not relevant since PMP students do not have a uniform opportunity to engage in research.

What possible productive purpose is served by a merger? We see no practical benefits whatsoever. As emphasized by the previous Review Panel, Amath does not need amalgamation with Math to provide academic or administrative strength, and the ensuing culture clash would be tempestuous. This still rings true today. Amath has continued to thrive for the past decade despite hardships over its operating budget and TA support, the launch of major new programs, and the replacement of half of its faculty. The Panel searched in vain for any other significant benefit. Optimistically, we imagine that a merger might produce enhanced cross-department collaboration between Amath and Math. However, that outcome is more probable as a result of co-location rather than co-administration, as the Astronomy and Physics departments illustrate. (On the other hand, co-location is no panacea, e.g., Amath's relationship with Aero & Astro, with whom it shares a building and a common ancestry, is not particularly symbiotic.)

Therefore, we highly recommend and vehemently urge that Amath obtain a statement from the Provost and the Dean of the College of Arts & Sciences to remove the ambiguity of silence that has relegated it to a seat in purgatory for a decade. This would enhance Amath's position in recruiting and developing liaison with departments with whom it shares many research and educational interests.

Recommendation #6: Revitalize the administrative support unit, or "front office". A full range of administrative support for the Chair, faculty, and graduate students must be provided if the Department's missions in research, teaching, mentoring, and service are to thrive, top students and faculty are to be recruited, and its strategic plan is to be implemented.

The front office of any department enables a broad range of critical administrative functions. As we pointed out in §II.N, we heard several anecdotal accounts that Amath's front office is not fully functional. Some areas work (e.g., fiscal) much better than others (clerical). Of greatest concern to us is the role that the front office normally plays in connecting students with authoritative sources of advice and help. An additional concern is the central role of the front office in the annual recruitment of new graduate students, including visits by top applicants to campus. Also, the Administrator is vital to a new Chair for tactical planning and execution, budget preparation and monitoring, policy research, departmental history and records, and running the front office.

Because of the need to respect the privacy of specific employees, because the Administrator and the Fiscal Specialist both declined to be interviewed, and because the administrative functions of the Department are only a peripheral part of our charge, we cannot and will not analyze the problems in sufficient detail to make concrete recommendations. We can and will, however, emphasize—with the greatest urgency—that the problem be addressed, and quickly, as the new Chair takes office. We will further suggest that the Chair justify more salary support for clerical staff, perhaps to create a new full-time position of Program Coordinator to spread the load of routine functions of the department and to provide a little extra capacity for holidays, recruiting, and special projects.

Recommendation #7: Implement more service and graduate courses. Planning for the expansion of 300- and 400-level service courses should be pursued vigorously. Broaden the array of graduate courses to cover the spectrum of modern research. New faculty FTEs and TA positions must be added as needed.

The need to expand service courses at the 300- and 400-level was explored in §II.M.3. Our Panel cannot assess the "customer base" for them. On the other hand, meeting the wishes of Amath's graduate students for more elective courses (§II.I) is easy to recommend, but only if the faculty time can be spared from other pressing activities, including the optimization of the PMP and undergraduate programs.

Obviously Amath will need substantially more faculty and TA positions. Properly instrumented classrooms will need to be assigned. Stakeholders with disparate expectations will have to be engaged to design the courses and monitor their success, so it is easy to predict the need for a governing committee analogous to ACMS. Therefore, we suspect that the effort to offer larger service courses will turn out to require a great deal of Departmental leadership.

Amath has many interesting challenges on its plate in addition to new service courses. A realistic management plan with prioritized objectives needs to be established within the framework of a coherent strategic plan and a practical implementation roadmap. Teaching more graduate-level courses is the easy part. Service courses will require vastly more time and a higher level of commitment. Although the Panel is supportive of new courses, we do not assign this recommendation a high degree of urgency. We leave that decision on resource allocation for Amath and the U.W. Administration.

Recommendation #8: Seek faculty diversity and age balance. Aggressively pursue equality in gender and minority representation and maintain the current age demographics.

This recommendation, which arises from the discussion in §II.E.3, almost seems like standard boilerplate in 2007. Nonetheless, diversity must receive ongoing attention and sustained priority. So far as we have observed, Amath is making a commendable effort. Our recommendation is simply to remain committed, collaborate with the College to the extent possible, stay vigilant for opportunities, and keep up the generally good work.

Recommendation #9: Pursue graduate recruitment more aggressively. Develop a range of more proactive recruitment strategies to reach and recruit the best graduate applicants.

Graduate students are the energy that enable outstanding research and enhance the reputation of the Department. Top schools and departments compete ruthlessly to recruit the top students. Issues of graduate recruitment were presented in §II.J.1. Discussions with some of the faculty revealed that the recruitment of graduate students has not gone much beyond the “usual”, and that more effort could be attempted to lure students with visits and better interviews. We recommend that the Department develop some proactive recruitment strategies to exert a full-court press for outstanding students. They could usefully share best practices with similar departments, such as Astronomy, who must recruit from universities without parallel departments.

Signature Page

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