Mathematics & Statistics
Strategic Planning Phase III, Part I
Departmental Scan & Enhancements to the Undergraduate Experience
Version of January 2015

Part A. Investment of Choice: Intellectual Mission and Scholarly Recognition

1. Overview. The Department of Mathematics and Statistics is a community of scholars committed to excellence in research and instruction. We offer a comprehensive set of curricula in our disciplines, from introductory-level general education courses to doctoral dissertation direction and postdoctoral mentoring. Undergraduate majors enjoy a broad array of options through which they can earn the bachelor's degree, and can also apply to participate in summer research activities. The Department's Ph.D. program appears among the top public graduate programs in the recent National Research Council rankings. The M.S. programs in both Applied Mathematics and Statistics contribute to an important pipeline of professionally trained students who enter the high-technology industrial sector.

2. Research Profile. Mathematics has long been recognized as a fundamental language for the formulation, exploration, and analysis of scientific ideas. Partially as a result of technological breakthroughs, not only the natural and physical sciences, but increasingly the social sciences, have come to rely on mathematical and statistical methods for formulating hypotheses and results, and for analysis and evaluation of claims based on observations. It is clear that tomorrow's scientists will need to maintain a constant dialogue with progress in the mathematical sciences, and that mathematicians and statisticians will be called on for ever deeper interdisciplinary engagement with colleagues from an ever widening span of intellectual disciplines. We are therefore at an exciting time where we simultaneously continue to deepen our disciplinary knowledge at a rapid pace, but also look to engage with our colleagues across the campus in educational as well as scholarly activities.

The Department's research profile spans a wide spectrum of pure mathematics, applied mathematics, and statistics. In that regard, it provides a comprehensive set of opportunities for BS, MS, and PhD students, and constitutes an important resource for fellow researchers and collaborators in closely related disciplines such as physics, astronomy, chemistry, biology, engineering, and even economics and sociology. At many institutions, Mathematical Sciences are spread over multiple departments. Housing Pure & Applied Mathematics as well as Statistics in one Department allows us to capitalize on synergies and efficiencies. It is not uncommon to find pure mathematicians drawn into applied problems proposed by colleagues in the Department, for example. The potential for collaboration among the applied mathematicians and statisticians is particularly strong. Indeed, the boundaries between all of these fields are becoming more nebulous, and the theme of *computational techniques,* which is gaining ever greater prominence, unites us as well. The

department's current research strengths are in

Pure Mathematics: *Algebra, Algebraic Geometry, Analysis, Differential Geometry, Number Theory, Probability, Representation Theory, Topology*.

Applied Mathematics: *Fluid dynamics, Mathematical Biology, Mathematical Physics, Nonlinear Partial Differential Equations, Numerical Analysis, Scientific Computing, Stochastic Modeling, and Statistical Mechanics*.

Statistics: *Bayesian Statistics, Bioinformatics and Biostatistics, Finite Mixture Models, Measurement Error Models, Machine Learning, Mixed Models and Smoothing, Network Analysis and Sampling, Quantitative Ecology, Social Science Statistics.*

Areas in which the Department does *not* provide specialized expertise include: *Mathematical Logic, Information Theory, Coding Theory, Combinatorics, Graph Theory, Cryptography, Mathematics Education, Algebraic Topology, Actuarial Mathematics, Mathematics of Finance*. In all cases, a number of faculty have secondary or interdisciplinary interests in these fields. At most peer institutions that have combined Mathematics & Statistics departments, the size of the faculty is significantly larger. For a comprehensive department of our size, we have remarkably good coverage of the most important fields. However, an increase in size would allows us to offer greater expertise in many of the areas above, and present an opportunity to create more connections between the existing groups. It would also significantly increase our potential for interdisciplinary collaboration outside the department and expand our value to the Commonwealth on educational as well as scholarly levels.

The Department is active and successful in seeking outside funding. The level of external funding for research in the department has remained roughly constant in recent years, thanks to the combined success of our established faculty and the infusion of new faculty. The preponderance of grants comes from the NSF, and to a lesser extent, the NSA. These rarely provide for funding for postdocs, but the department has been able to secure funding that supports postdocs. Unlike some departments, our research support is not dominated by a few large grants. Typical NSF grants for a single researcher are in the range of $100,000–150,000 for a 3-year period. The Department has had extraordinary success in the NSF CAREER program (each providing approximately $500,000 over a 5-year period) with three in the last decade (Kevrekidis, Zhang, and Oblomkov). It should be noted that in mathematics, very few NSF CAREER awards are given, about 15 each year nationwide. The Department also has two Sloan Fellows (Tevelev and Oblomkov). Some other recent highlights include an AFOSR grant for Panos Kevrekidis, a multimillion dollar DOE grant for Markos Katsoulakis and Luc Rey-Bellet, and a large NSF individual grant for Bruce Turkington; the latter three include funds for research postdocs, which is highly unusual in mathematical sciences. The Department has an excellent group in Algebraic Geometry which has secured funding from NSF for *AGNES*, Algebraic Geometry in New England Symposium, a conference that meets twice a year and rotates among MIT, UMass Amherst, UConn, UPenn, Stony Brook, Boston College, Brown and Yale. Several members of the Statistics

faculty have been active in collaborating on federal projects with colleagues in Food Science, Computer Science, and Kinesiology on multi-million dollar projects funded by NIH and NASA. Gile, an Assistant Professor in Statistics who was a cluster hire, is an active member of the Computational Social Science Institute; the department has pledged financial support to the Institute (as it did previously for the Initiative). The department itself supports some research activities through expenditures from its Research Trust Fund account, which draws 10% of indirect costs from grants held by department members. In particular, these funds support startup funds, costs associated with visitors to our weekly seminars, travel by faculty, and computer equipment for which external grant funds are not available. In addition, the Department Head utilizes these funds for partial matching costs on grant proposals, when necessary.

The Department runs a number of weekly seminars, which draw regular participation from other departments in CNS, Public Health, SBS, and Engineering, as well as from other local colleges. Two of them, the Valley Geometry Seminar and the Five College Number Theory Seminar are partially funded by Five Colleges, Inc. The Department's graduate courses and seminars enhance the preparation of students at the liberal arts colleges in the area, many of whom register for upper division and first-year graduate classes we offer, and some of whom do a senior thesis or REUs under the direction of our faculty. The Department also runs a *Statistical Consulting Center* (http://www.math.umass.edu/research/statistics) which is an important resource for the campus, as well as being a vertically integrated outfit where graduate students and faculty work side by side. A focus for the joint activities of our applied mathematicians is the *Center for Applied and Computational Mathematics* which sponsors a weekly seminar, oversees the MS Program in Applied Mathematics (chapter 5) and serves as a point of contact for interdisciplinary interactions with the College of Natural Sciences and the College of Engineering. The *Center for Applied and Computational Mathematics* is also a focus of our engagement in activities related to the *Massachusetts Green High Performance Computing Center*, the first of its kind in the nation.

3. Faculty, By the Numbers. The faculty currently consists of 41 tenure-stream faculty (including the Department Head), 6 Visiting Assistant Professors (non-tenure-track, usually appointed to three-year terms), 9 permanent lecturers, and a small number (1-3) of temporary lecturers. The tenure-stream faculty consist of 6 at the rank of Assistant Professor (8 if we include two positions being searched this year), 10 at the rank of Associate Professor, and 23 Professors. There are 2 Lecturers, 6 Senior Lecturers, 1 Senior Lecturer II, and 3 temporary 1-year lecturers. In addition, in recent years, two retired faculty members have taught two courses each per year.

4. Shifts in Departmental Profile, 1994-2014. For the past two decades, the Department of Mathematics and Statistics has systematically worked toward its overarching goal of becoming one of the top 10 departments of mathematical sciences among public research universities. At least two sets of budget cuts have presented obstacles, but thanks to a sustained focus on excellence and a remarkable record of faculty hiring since 1994, we have already made great strides and stand poised to achieve that goal in the near future. In 2004, concurrent with a restructuring necessitated by a wave of

retirements, the Department adjusted the teaching load from the former standard of four courses per year to three courses per year for faculty active in research and service. This move, which was consistent with those made by a number of our peer departments and was strongly endorsed by the 2004 AQAD report, enhanced our competitive position as a research department, from which we anticipated and did in fact experience enhanced scholarly productivity, external funding and faculty recruitment. In the 2004-2005 AQAD report, the external visiting committee wrote: *"Regarding excellence, it cannot be too heavily stressed that the department has done a superb job of recruiting strong young mathematicians and statisticians. Their excellence is a tribute to the leadership of the department. If this strong group of young faculty can be maintained and further developed, the department indeed is in a position to move up a level."* Seven years later, the next AQAD report and the University's Doctoral Program Review noted the measurable gain in the NRC rankings, in which we moved from the upper 50s in 1995 to the mid 30s among all mathematics departments nationwide, public as well as private.

The success of the strategy for hiring young faculty with great research potential can also be partially measured by three NSF CAREER awards (Kevrekidis, Zhang, Oblomkov), and two Sloan Fellowships (Tevelev, Oblomkov). The Department's research activity also rose during this period as a result of a strategy developed to cope with the retirement of a dozen faculty members in 2001/2, namely a sharp increase in the number of Visiting Assistant Professors (VAPs) to 12. These young PhDs make significant contributions to the research and teaching missions of the Department: they collaborate in research with faculty who mentor them, participate in mentoring the graduate students, bolster the ranks of calculus teachers, and have proven to be successful teachers of upper division courses as well. The number of VAPs was significantly reduced (from 14 in 2001 to 6 today), which has made us a bit out of step with our peer departments. An increase in the number of VAPs, as well as the eventual institution of a few (at least 3) enhanced positions (with more money for research and a smaller teaching load) form part of the Department's vision for the future.

The vision that continues to lead us forward is of a unified department encompassing the most vital contemporary research areas in pure and applied mathematics and statistics, and providing the highest quality instruction in a curriculum ranging from elementary service courses to doctoral studies. Within our department we bring together faculty whose expertise spans the full range of the mathematical sciences, and we foster an intellectual atmosphere that is collegial and cooperative. In this way we not only ensure a unity of purpose, but we also reap the benefits of the cross-fertilization between fields that drives much of today's research and teaching agendas.

A unified department is also an efficient department. Our instructional responsibilities are very large indeed — we teach over 7,000 students each semester, more than any other single department at the University. Our vast and complex teaching burden is divided into lower-division undergraduate, upper-division undergraduate, and graduate courses. To deliver a multi-faceted curriculum of this magnitude and to do so with uniformly high quality requires that we organize our teaching activities optimally. Before describing the components of this mission, and how they have changed over the

last two decades, we must recall some demographic history of the department.

The ten-year period from 1994 to 2004 was one of dramatic demographic change for our Department. Starting from 53 tenure-stream faculty in 1995/6, there were a total of 31 retirements, over 60% of the faculty. The retirees, and a few faculty who left for other reasons, were replaced with only 23 new hires, so in 2004/5 the tenure-track faculty numbered 40, a drop of about 25%. In the 2004-2014 period, a further number of faculty retired and a number of Assistant Professors were hired, but the total number of tenure stream faculty held steady at 40, even as enrollment boomed. The combination of a decrease in faculty and increase in students and the effect it had on the Department's instructional program will be discussed in the destination of choice sections below. Throughout this period, the Department hiring strategy prioritized building viable research groups over providing comprehensive coverage of areas across the mathematical sciences. In particular, when the size of the Statistics group declined to a handful around 2005, the Department prioritized Statistics, including adding a faculty member at the rank of Professor. Especially during 2002-2010, the tenure-track faculty had a large concentration of young Assistant Professors, who inaugurated a period of vibrant research even as they pitched in for heavy service assignments the retiring senior faculty had vacated.

The loss of faculty combined with a steadily growing student body has meant that we have had to make compromises. We took as a given that we must honor our obligations to UMass Amherst students from all disciplines whose mathematical training is a major necessity toward the completion of their degrees. Thus, in selecting what courses to offer, we have always prioritized lower-division service courses over courses for our own majors. We have chosen to increase class sizes at the lower division and to severely cut back on the number and variety of courses we offer at the upper division and graduate levels.

At the lower-division level, we have successfully met the challenge of teaching a growing number of students, as a result of restructuring, and through the addition of a large number of Lecturers who almost exclusively teach large-enrollment courses at the lower-division. We have incrementally increased many class sizes and consolidated some courses, thereby reducing the total number of course sections offered but still meeting student demand. Great care has been taken in this consolidation process to maintain high teaching standards and to ensure a uniform experience by students in large-enrollment classes. This has been achieved through institution of common homework and common exams across all sections of courses such as Precalculus and Calculus (MATH 101-233) and Elementary Statistics (STAT 111 & 240). We also maintain tight control over the curriculum via the Undergraduate Affairs Committee, as implemented by Course Chairs. Our course delivery is now essentially optimal given our resources.

In 2004, when UMass introduced the *Amherst 250 Plan* to expand the faculty by 250 over the subsequent three to five years, the mood in the department was optimistic, and we expected to rebuild the tenure-track faculty back to around 50. But reality did not meet expectations and we remained a tenure-stream faculty of about 40 even while the

tenure-stream faculty at UMass Amherst as a whole increased about 8%, from 917 to 993. Meanwhile, our non-tenure system faculty, Lecturers and Visiting Assistant Professors, decreased from about 16 to 12 while the total at UMass Amherst increased from 183 to 232, our administrative staff decreased from 9 to 7, and the number of full-time equivalent students we teach increased significantly. To accommodate the increased student/faculty ratio, most courses below Math 131, Calculus I, are now taught by lecturers in class sizes of up to about 250–300 and we have pared our upper-division and graduate offerings to a point that is just barely acceptable.

The 2004 and 2011 AQAD reports both document the severe negative impact of the downsizing of the tenure-stream faculty on the upper division and graduate offerings. Courses such as MATH 513 Combinatorics, MATH 475 History of Mathematics, MATH 503 Technology Tools for Secondary Teaching (the latter two of which were in fact required for pre-service secondary mathematics teachers) were summarily dropped, and the graduate program special topics courses were reduced to a bare minimum. Moreover, course releases given to the Chief Undergraduate Advisor, Undergraduate Program Director and Graduate Program Director were all eliminated, which placed a severe burden on the (often young) faculty who were filling those roles. Many of the Department's deficiencies in effective advising can be directly traced to these pressures and the choices the Department made in prioritizing the thousands of undergraduate majors and graduate students from other departments over the hundreds of students housed in our own Department.

Part B. Destination of Choice: Graduate Education

1. Overview. The Department offers three graduate programs: MS in Applied Mathematics, MS in Statistics, PhD in Mathematics. The latter includes students who study statistics. Nearly all of the students teach for the Department, thereby contributing to our teaching mission; on the one hand, this is a fairly cost-effective means of teaching some of our calculus offerings, and on the other hand, it represents a very important component of the graduate students' training. The students we graduate are finding good positions in industry, R&D, finance, and increasingly at strong academic institutions.

2. Doctoral Program Review. The Department's graduate programs received a favorable evaluation during the Doctoral Program Review recently conducted by the University. The Mathematics program was rated as "Aspirant" and the Statistics Program was deemed "Good." This agrees with our own self-assessment and the AQAD visiting committee, although in the case of Statistics, the comparison group consisted of nearly all stand-alone Departments of Statistics, which we believe skewed the results somewhat. The doctoral program is rapidly improving, and we have plans that we believe will make us competitive with many of the top programs. We are gratified that the DPR report concurred with our main findings: that the mathematics PhD program should become larger, and that we need to be able to offer more courses. We also agree that student (and faculty) diversity and the completion rate are serious

issues where the department needs to improve.

a. Size of the program. Our goal is to increase the number of mathematics PhD students from around 34 to around 48, which would bring us close to a 1.5 to 1 ratio of students to faculty. This would require some combination of increasing the number of TA positions and moving some students from TA support to RAs or fellowships for at least part of their career. We hope to obtain external funding for at least part of this increase. We have been actively pursuing such grants: in 2011 and 2012 some applied math faculty submitted proposals for an NSF IGERT grant, and we have submitted three proposals for an NSF RTG (research training grant), in 2007, 2012 and 2013. We note that one area where the reviewers were critical of these proposals was the lack of matching commitments from UMass: for instance, one review of the 2012 RTG wrote that "[i]nvestment in this department seems timely, advisable and potentially very rewarding. On the other hand, it seems that while the department has committed funds to match the RTG grant, the university has not really stepped-in, e.g. by committing post-grant funds (as other competing institutions have)." If we are to succeed in obtaining these kinds of large training grants, and if they are to have a lasting impact on the department beyond the duration of funding, support from the College and University will be essential. We are gratified that Dean Goodwin has approved our requests for post-grant support on the most recent RTG proposal.

Another avenue we are pursuing which potentially could support an extra graduate student is a *Five College Graduate Teaching Fellowship*; it has become routine that our more experienced teaching assistants have been asked to fill in teaching shortfalls at one of the other colleges. Since this is a valuable experience to include on their CV, we allow this. The FCGTF regularizes and formalizes that relationship. It is reserved for students with the strongest teaching credentials, and would give them a valuable introduction to teaching in a liberal-arts setting, where many of our students obtain employment. This is now in place for one student, but we would like to expand the program through negotiations arranged through Five Colleges, Inc.

b. Recruitment. To increase number of students and still maintain quality, we need to improve our recruiting. Although we have a large applicant pool and thus can be quite selective in making offers, we are not yet competitive with the strongest schools, and our yields among the best and most prepared students are still relatively poor. Recent feedback from some of our applicants have convinced us that our low stipends are a significant problem for recruitment. In particular, in many recent years, the IPO's cost of living adjustment put their minimum financial requirement for international students above our stipend, forcing students to provide a personal financial statement in order to get a visa. This is very embarrassing for the department; we need to make certain that it does not happen in the future. After studying the stipends offered by some of the peer departments we compete with, we feel it is urgent to raise stipends. We plan to do this through the Department's CEI revenue stream, and appreciate matching funds being provided by the Dean, but making a commitment prior to knowing the details of changes to the resource allocation model appears risky. It would also greatly help our recruiting to offer more fellowship support as inducements to the very best applicants. It was an eye-opener to see during this review the much larger fellowship programs

that some of our peers have. We are exploring using department funds and possibly funds collected from alumni donations to give "top-up" awards to increase stipends for strong students. More expensive awards which give periods with no teaching duties will require outside funding from grants and/or the College. We strongly support the committee's finding that the University should increase the size of the graduate fellowship program. It has also been extremely helpful to have a few fellowships which are controlled at the department level and can be reassigned if an applicant withdraws. Finally, another potential source of graduate funding is the NSF graduate fellowships. In the past we have not had many students apply for these, but going forward we plan to be more active in encouraging eligible students to apply and guiding them through the process. Obtaining an NSF fellowship will be a tremendous boost for the student, it will allow the department to fund another student, and the prestige of the award will be a useful tool in recruiting.

c. Diversity. Increasing the diversity of our student body is a serious concern for the department. In the last several years we have seen a significant drop in the percentage of female applicants, and we have struggled to enroll enough qualified female students. The worst year was the class of 2010, in which only one of ten new PhD students was a woman. Since then the percentage of women matriculating has stabilized at 25-30%, which is still too low. As a small step to help increase the number of qualified female applicants, we began a policy of waiving the application fee for female applicants from the Five Colleges. We also organized meetings last year with current female students to learn what we can do to make the department more welcoming to women. We received very useful feedback on issues ranging from nighttime safety in Lederle to a lack of transparency in assigning graduate student service roles. We are working to address these and other issues, and hope that by making our current female students happier, they will help us to recruit the next generation of students. We had an especially successful year in AY2013-2014, when we graduated 7 students, 4 of whom were female. Hiring more female faculty continues to be a high priority for us.

d. Graduate courses. The most important structural improvement we can make to the PhD program is to offer more graduate courses. Under current conditions too much of our graduate instruction beyond the first year is done via independent studies taught by faculty as an overload. While that does allow for more individualized instruction, it is very inefficient, and doesn't foster connections between students within the research areas. To bring us up to the low end of our peers we would need to offer 24 courses per year, **an increase of 6 from the current number.** We refer to the document "Report on Departmental Instructional Needs" which we produced for the Dean in 2012 for a broader picture of the department's interrelated teaching needs at the graduate and undergraduate levels.

For the most part, offering more graduate courses would require increasing the tenure-stream faculty, although a limited benefit could also come from hiring additional temporary Visiting Assistant Professors (postdoc), since VAPs can teach some upper-level undergraduate courses which would release faculty to teach graduate courses. With all other demands remaining static, the goal of adding 6 graduate courses per year can be achieved by adding 1.5 new VAP positions. We have committed departmental

funds (through CEI) for hiring one additional VAP, but unfortunately the new VAP is being used mostly to help cover undergraduate classes due to growing enrollments. Since a VAP is only a 3-year commitment, we felt it was a safe and wise investment.

Besides enabling us to offer more regular classes, these extra teaching resources will allow us to implement curricular innovations which would greatly enhance the quality of our program. One example is a proposed one-semester "introduction to applied mathematics" course which would provide first-year applied students with a broad introduction to applied methods and problems, giving them a broad foundation before they move to more focused and specialized work. Another proposal is to form graduate reading seminars in each major research area which students could take for credit. Students would gain experience reading papers and giving talks. Seminars of this general type have been given in algebraic geometry, representation theory, number theory, and applied mathematics, and the statistics group is planning to create one. In order to ensure that enough faculty are willing to devote the time to run them on a regular basis, we would like to offer a fractional teaching reduction, so that running one for two semesters would give a one-semester teaching reduction in a later semester.

e. Completion rate / time to degree. The time to degree and especially the completion rate of our students has lagged behind our peers; if we are to join the ranks of the top programs they must be improved. To some extent this is already happening, thanks to a revitalized faculty and greater success recruiting strong students. The classes which entered in 2007, 2008, and 2009 have achieved greater than 50% graduation rate, with 2008 and 2009 reaching more than 70%. The time to degree is also improving, with more recent students finishing in five years. Most of the changes discussed earlier in this report should help improve the completion rate and time to degree. We have also made some small adjustments to the qualifying exams to help students progress through them more quickly, and we are considering a more comprehensive overhaul of the exams. We would like to improve the advising and oversight our students get, by moving the primary responsibility for advising students who have not yet chosen an adviser from the GPD to groups of faculty in the various research areas. We have also set up a departmental fund to supplement the graduate school travel grants, helping our students to attend conferences, disseminate their work, liaise with their peers and senior researchers and access the job market. Finally, we plan to start a regular seminar or brown-bag lunch series for our students on professional development. Some possible topics are:

- Tools for finding and organizing mathematical literature in the digital age
- Strategies for writing longer papers (this is particularly important since some of our students in pure math don't write anything longer than a few pages before their thesis)
- How to prepare a talk; matching the presentation and format to the audience
- Doing research with undergraduates
- Different kinds of academic and nonacademic careers, and what kinds of preparation are necessary for each of them.

Part C. Destination of Choice: Undergraduate Education

1. Overview. One of the largest teaching units as measured by student credit hours, the Department provides instruction for approximately 14,000 students per academic year. Some 85% of the Department's student credit hours are generated by non-mathematics majors. Yet the Department is also one of the larger units on campus as measured by the number of majors. We offer a comprehensive set of undergraduate programs in pure and applied mathematics, as well as in statistics, distributed over seven concentrations. As of December 2014, these programs currently serve nearly 550 majors.

The greatest strength of the Department is the range, depth, breadth, and diversity of the expertise represented in its faculty. Its biggest weakness is that the very heavy "service" obligations at the lower division have had an undesirable effect on our ability to offer the appropriate number and variety of courses at the upper division and graduate levels.

The *American Mathematical Society* and the *American Statistics Association* have begun a dialogue with Departments of Mathematics & Statistics across the country regarding undergraduate education, particularly in the first two years -- some of the impetus for these efforts has been catalyzed by the Report of the President's Council of Advisors on Science and Technology) available from

http://www.whitehouse.gov/administration/eop/ostp/pcast/docsreports.

The steps outlined below as improvements to the undergraduate program align well with this national conversation. In particular, the *AMS* and *ASA* recommend a move toward inclusion of more opportunities for students to interact with each other during class; the proposals outlined here take into account these recommendations.

As is typical of mathematics departments, and distinct from most other departments in the university, in addition to serving our majors (which now number nearly 550), a large fraction of our teaching is to non-majors who enroll in everything from 100-level General Education courses to upper-level courses designed for our majors. Approximately 90% of undergraduate students enrolled in MATH/STAT course are not math majors; and 40% of graduate students enrolled in MATH/STAT classes are from another department. Our undergraduate curriculum is taught by a mix of graduate TAs, VAPs, Lecturers and tenure-stream faculty. The general rule, with a few exceptions, is that lower-level classes are taught predominately by Lecturers and TAs while higher-level classes are taught by VAPs and tenure-track faculty. Ideally, we would like to teach all classes in small sizes and offer a rich upper-level curriculum with many choices for majors. But in practice we are limited by the size of our staff. In response to increased enrollments over the past few years we have increased class sizes, where possible, at the lower-level up through MATH 127/8, Calculus for Life and Social Sciences. Classes above that level are taught in smaller sections, including MATH 131/2, Calculus I/II, which is typically taught in sections of 30 in the case of graduate student instructors, and 60 for other instructors. At the same time, we feel our offerings for undergraduate majors are just barely adequate. Thus, if additional major efficiencies must be found,

MATH 131/2 is a place to look. Meanwhile, the university is steadily increasing the number of undergraduates, and therefore the number of undergraduates who take mathematics. Several thousand students have been added in recent years and the goal is to add several thousand more. Thus, we will need additional staff just to remain in place.

2. Classes for Non-Math-Majors. The Department offers far more sections of General Education classes than any other unit on campus. In 2011, we had ten MATH Gen Ed classes reviewed and approved through the Quinquennial Review process at the Gen Ed Council. Four STAT courses as well as the Junior Year Writing Class will undergo that process in 2014-2015. Our pre-calculus (MATH 100–104) and other elementary courses (MATH 121 and STAT 111) are standard courses such as those found in many state universities. They are taught in large lectures of over 100 students, supplemented by either recitation sections or a drop-in center with undergraduate teaching assistants. These courses are taught mostly by Lecturers and use web-based homework systems in lieu of recitations. Recently, total enrollment in these courses has been about 2300 students per year. We have noted a drop in the need for the more elementary 101-102 two-semester sequence which covers the same material as MATH 104 does in one semester. We have proposed ideas to work with client disciplines (particularly with Biology and Chemistry in the case of MATH 101-104) to bring in examples from the sciences into these courses, and have followed up with participation in grant proposals to the HHMI, for example, and to the NSF IUSE program. We plan to increase our commitment to this line of collaboration and coordination.

The department teaches Math for Elementary Teachers I/II (Math 113/114). Each course runs once per semester with an enrollment approximately in the range of 40–60. The Department has instituted some changes to these courses to to reflect adoption of the Common Core State Standards by nearly all States, including Massachusetts.

Calculus for the life and social sciences (Math 127/8) differs from standard calculus by concentrating more on big ideas and less on technical details. It is taught in large classes almost entirely by Lecturers, uses web-based homework systems and the Calculus Tutoring Center. The per-section size of these courses has grown recently and now stands at 200–400, constrained by the available lecture halls. Recent total enrollment in these courses has been over 3000 students per year.

Our core introductory sequence (MATH 131/132/233/235/331, i.e., Calculus I/II/III and Introduction to Linear Algebra followed by Differential Equations) for physical scientists and engineers is taught mostly in sections of about 60 students, with a few sections of about 30. The number of larger sections is constrained by the available classrooms. Tenure-track faculty serve as course chairs, coordinating the curriculum and logistics of the many other sections taught mainly by VAPs, Lecturers, and experienced TAs. These courses use a web based homework system (WebAssign or WebWork) and students can seek support at the Calculus Tutoring Center. Enrollment in these courses is growing. The total went from 3392 in 2009/10 to 4585 in 2013-2014, **representing an average increase of 300 students per year, or 35% in a 4-year period**. To say that the growing enrollment in these lower-division courses strains our resources is an

understatement. We have to ask the administration each year for money to hire additional temporary help to teach these courses. The continuing addition of lecturers is not sustainable. Continuing to add students at this rate will mean that under a decentralized resource allocation model, the Department may be able to hire more faculty members to staff these courses and we feel that is the appropriate, and sustainable, path to pursue. Short of adding positions, the Department would soon have to grapple with the choice to teach these courses in sections of 120 or 250 (assuming the rooms are available), which would mirror the arrangement at many of our peer institutions. We would prefer to maintain the smaller class sizes, which we believe are beneficial to students.

We should note that that especially after the move to permanent 13-week semesters, MATH 233 and 235 do not give adequate coverage to all the material desired by other departments whose students take these courses, including our own majors. In consultation with client departments, we have determined that increasing 233 and 235 from 3 credits to 4, through the use of recitations, would significantly improve student learning in these courses. Making the change would require an additional 5-6 TAs, which is in line with the goals outlined in the previous section on graduate education. If the funds become available, we would also opt for a 4-credit version of MATH 331, with a 4th hour recitation.

3. Student Support Services. The department operates three tutoring centers, one for calculus, one for pre-calculus, and one for elementary statistics. Each of these centers is located in a room exclusively reserved for the purpose. The pre-calculus tutoring center is staffed by the undergraduate teaching assistants (UGTAs) who work in Math 101–104, the pre-calculus courses. The Calculus Tutoring Center is open 10am–3pm for students in 131/2 and 233 (added about six years ago) and 3pm–8pm for students in 127/8 (longstanding). During the first block of time, the CTC is staffed by TAs and instructors from 131/2 and 233. Because each of these courses is coordinated by a course chair, all sections are covering the same material at the same time, so TAs and instructors are prepared to help students from any sections. During the second block of time, the CTC is staffed by UGTAs. The UGTAs in both tutoring centers have been selected for their knowledge of mathematics and their ability to help struggling students.

4. The Mathematics Major. General facts about the major are available on the web at http://www.math.umass.edu/~advise/ and a brochure is available at http://www.math.umass.edu/~advise/brochure.pdf. Over the last dozen years, the number of majors in our Department has more than doubled from about 220 to about 550. The major program is divided into seven concentrations. Every undergraduate mathematics major must enroll in one of the seven. Due to changes in student demand, the concentrations were revised about 5 years ago. They are now 1. Actuarial; 2. Applied; 3. Computational; 4. Pure Mathematics; 5. Statistics; 6. Teaching; 7. Individual. Most are self-explanatory. The teaching concentration prepares students to teach in grades 8–12 in Massachusetts. The individual concentration permits students to design their own programs in consultation with their advisors and with the approval of the Chief Undergraduate Advisor.

The actuarial concentration is new, and was added subsequent to the AQUAD in 2004/5. It is the fastest growing concentration in the department. We have also instituted an Actuarial Club (separate from the Math Club). To supplement the concentration, the department holds an annual actuarial career fair, in which representatives from multiple insurance firms come to the department to meet students, answer their questions about actuarial careers, and solicit resumes for internships and job openings. The fair is co-sponsored by the Five Colleges, an arrangement we hope to continue. We have also continued to strengthen ties with alumni currently working in the industry. The original plan for our students to satisfy two of the so-called VEE requirements (Validation by Educational Experience, instituted by the Society of Actuaries) was not workable due to very few seats (if any) in courses given by the School of Management being allocated to our students. We have had to re-organize the VEE requirements, and we need to offer our own course on Applied Statistical Methods including Time Series. Many comparable institutions, including U Connecticut, U New Hampshire, U Vermont, UMass Dartmouth and UMass Boston offer such a course — but our current staffing levels are insufficient for us to do so. Given the strong interest from our majors in pursuing this concentration, the department feels the investment of more resources to support an expansion of offerings in the actuarial sciences would enhance our standing as a destination of choice.

5. Advising for majors. We have approximately 550 majors, up from 220 twelve years ago, and the number is growing! They are advised throughout the year mainly by a Chief Undergraduate Advisor, and the Assistant to the Undergraduate Program. The Chief Undergraduate Advisor is appointed by the Head and is one of the major service jobs in the department. In addition, each mathematics major is required to meet with a faculty advisor once per semester for standard advising about courses, tracks, and so on. Advisors are volunteers; each handles about 15 students, though the number varies. More than half the faculty serve as advisors. The Senior Survey makes it very clear that students are broadly dissatisfied with academic and career advising in our Department. The Department has recently taken steps to help its majors transition from college to career. The web page for Career Advising has been extensively revised and is scheduled to be updated in February 2015; also, the department arranges each semester to have at least one presentation by a representative from the University's Career Services and from a mathematician or statistician in industry; and specific programs, such as the Actuarial Program, organize focused career events on a regular basis. We believe we need to take further steps to improve advising and are currently considering putting RAC holds on student accounts each semester if students do not show up for an advising appointment. More details on plans for improvement are contained in Section 12 below.

6. International Programs. There is a specialized and well-known program of Study Abroad for Mathematics Majors: The Budapest Semesters in Hungary. We encourage students who want to participate in this as well as more generic study abroad programs. The Budapest Program has recently added a new program for math majors who are in the teaching concentration. We also routinely have about 3-5 students from abroad (England and Germany are the most common) spending a semester or a year in our

Department as exchange students.

7. Diversity. The Department is very pleased that about half of its majors in the most recent class are women; we have been less successful in attracting students from underrepresented minorities this year (%US reporting ALANA is 16%). These numbers have fluctuated quite a bit since Fall 2005, but their means are 41.2% and 24.2%, which, although not as high as we would like, are not discouraging. In Fall 2014, the entering class of declared Mathematics Majors had 21% first-generation college students and 25% Pell Grant recipients, which are not very different from the corresponding numbers for CNS and the campus as a whole. These numbers were a bit higher in each of 2013 and 2012. We recognize the need for hiring more Mathematics & Statistics faculty members who are female and/or come from underrepresented groups.

8. Student Progress / Time To Degree. The 4- and 6-year graduation rates for our majors fluctuate from year to year, but generally mirror the CNS mean statistics in the early years of the data, and significantly outpace it in later years. We should point out a serious issue to contend with, namely the skewing of the data that could occur when students declare a major for admission reasons which do not correspond to their plans once matriculated. Many students anecdotally related to us at the first advising meeting that they in fact had no interest in studying mathematics, but had heard from friends that their chances of admission to UMass were increased if they indicated interest in majoring in math. I have corroborated that such a bias does in fact exist in admissions. This is consistent with the 2003 data showing that for the Fall 2004 cohort math majors, only 16% graduated within 4 years in the math major, and 24% graduated within 4 years in a different major. The six-year graduation rates were only slightly higher (21% and 29%). For the same cohort the 4-year rates were 25% and 23%, climbing to 32% and 35% for 6-year rates within the College and outside the College respectively. By contrast, for the Fall 2009 cohort, the 4-year graduation rate within the major is much higher, at 43% (vs. 32% for CNS) and 21% in another major. Thus, we have shown significant improvement in that time period; we aren't sure what the breakdown of the causes are but we suspect students' better preparation probably plays the most important role. There is another statistic which in our experience would be important to consider but appears to be unavailable in the OIR databases we searched. Namely we believe many students who do not succeed in engineering and particularly computer science switch to being math majors in sophomore, junior, and even senior year -- mostly because they've already taken many of our courses. Indeed, Computer Science turns away hundreds of students and explicitly advises them to major in Mathematics instead. Many of these students struggle to complete their degree, and our department helps them do so. The Department has structured the math major courses in such a way that such students can successfully complete a Bachelor's degree in a desirable field within a reasonable span of time, which certainly helps the campus' overall graduation rate. But we are not sure how to try to capture this aspect of the Department's positive contribution to robustness of the 4- and 6-year graduation rates into hard evidence given the structure of the data provided.

9. Faculty Contact and Student Engagement. The Senior Survey Data is a clear indicator that the Department needs to step up its efforts in these categories. The

Department has a lounge dedicated for math majors which is underutilized, and generally has fallen short in its efforts to create a vibrant community for the undergraduate majors. One bright spot is a two-decades long program to mentor undergraduates during the summer in Department-funded and NSF-funded REUs. Since we can only afford to include a dozen or so students in such programs each year, we do not reach a majority of students this way. We have an active Math Club that meets every week and is mentored by graduate students, but again the students who take advantage of this great opportunity are very few. It would be facile to chalk up our low scores to student apathy, but we need to redouble our efforts to engage with the students outside the classroom, to talk with them more to find out the root causes of the student body dis-satisfaction in all of the categories surveyed. Since the survey results do not reflect the largely satisfactory Student Response to Instruction administered at the end of each course, we must seek answers beyond the classroom and look into how to bring students into office hours more often, and how to organize high-attendance social and educational events for math majors throughout the year. For Calendar Years 2011-2013, the senior survey indicated that our Department was at the very bottom of rankings among all units on campus. In almost every category, senior survey scores for our Department are more than one standard deviation below the mean. Clearly, we have much to investigate to understand the root causes and to develop plans for creating a more positive experience for our majors. We will conduct a survey of grades within the difference classes in our major and try to compare them to mean grades for other departments. We do not have a sense of whether our grading policies are generally in line with those of the rest of the campus or not.

10. Teaching Effectiveness. The Senior survey indicates students in the major are largely unsatisfied with the instruction in Math Major classes. It is difficult to match these findings with our knowledge over many years of the results of SRTI in math major classes, which generally provide very positive feedback to our faculty. As described above, the huge burdens we experience in meeting our heavy service teaching demands have had a negative impact on class sizes and numbers as well as variety of courses we can offer for math majors. We are sure that this is part of the explanation for these low scores, but there must be more to it. We will have to dig deeper to understand these results better and make plans accordingly. One fact which must be kept in mind is that the lower division obligations we face do not create an opportunity to take classes as a homogeneous group until junior year. We need to be more pro-active in finding ways to build community among math majors starting in freshman year.

11. Student Outcomes. In the data on what students do after graduation from UMass Amherst, the Department is in the middle of the pack among CNS departments in most categories. We are an outlier in one category, namely 40% of the students going on to graduate study report being enrolled in a PhD or Ed.D. degree which is at least twice the rate for any other department. On the survey of learning and high impact practices, the Department is largely at or slightly above the mean in the many categories, but we do fall one standard deviation below the mean in the category of providing opportunities for internships. We plan to work on a plan to increase such opportunities for students, especially those in the actuarial track.

12. Enhancements.

In this subsection, we recap a number of ideas for short-term and longer-term plans in Mathematics & Statistics to improve the experience of UMass Amherst undergraduates Our driving question is how our Department can contribute to our campus being a more desirable destination of choice.

A. Recitation Section Reforms.

(I) Within the lower-division, one of our top priorities for improving the undergraduate experience is to overhaul the way recitations for MATH 131 and MATH 132 (Calculus I and II for Scientists and Engineers) are conducted. Specifically, we propose to incorporate team-based learning activities in these recitation sections. Currently, recitation sections, which are taught by graduate student teaching assistants, are largely un-structured; that is to say, the TA answers questions about the homework, aims to clarify the lectures, and provides solutions of more examples than are covered during lectures. We would like to experiment with a more structured format centered around worksheets we provide for the TAs, who then organize the students into groups who work on the worksheets. This would perhaps take up 30 of the 50 minutes of the session. The implementation has the one-time cost of creating worksheets, which we hope to do in collaboration with faculty in the School of Engineering as well as those in CNS (Physics, Biology, Chemistry, etc.). But the long-term budgetary impact is minimal. We believe the new format for recitations would enhance student learning and engagement, as well as promote greater skill in using mathematics to set up and solve modeling problems.

(II) The second of our top priorities for improving undergraduate experience is to enhance MATH 233 (Vector Calculus) and MATH 235 (Linear Algebra). Both courses currently carry 3-credits and thus have no recitations. The material covered in these courses are critical for the success of not only math majors, but also of majors in engineering, physics, chemistry, economics etc. The proposal to convert them to 4-credit courses first made about five years ago garnered strong support from the UPDs of the Engineering College and other CNS departments. The situation is even more critical following the 13-week per semester calendar adoption. This proposal requires a significant increase in funding, as it would require the addition of 5 or 6 teaching assistants to the Dept. We would stagger this, and prioritize M235 going to 4 credits first. We would set up the recitations as in Item (I) above (with worksheets and group work) from the start.

(III) In Spring 2015, the Department will participate in an experiment of ExSEL, an idea based on the program PILOT at Johns Hopkins University. The course chosen for this implementation is MATH 127 Calculus for Life and Social Sciences, our largest single course. Peer tutors will lead discussion of worksheets with small groups (10 or so students). We are currently working on creating the worksheets which will parallel the curriculum. A large-scale implementation will require a significant investment. Creating the worksheets is a highly non-trivial task. We are hoping that we can learn lessons here for the implementation of similar ideas in (I) and (II).

B. Collaboration/Coordination within CNS and beyond.

Math/Stat has a history of collaborating with the other departments whose students populate the lower division courses. About seven years ago, the Engineering College had concerns about the teaching of MATH 132 and MATH 235 in particular; in the case of the latter, a suggestion about the ordering of the material in 235 was implemented and has been deemed to result in improved understanding both by our Dept and by our colleagues in Engineering. We have an especially good relationship with ECE.

We propose to renew an offer made in previous semester to work together on developing problem sets and examples in lectures which originate from our client disciplines. In the case of M131, M132, M233, that would include Physics, Chemistry, Engineering. In the case of M127, M128, that would include Economics, the Isenberg School, and the Biological Sciences. For MATH 104, we collaborated on an unsuccessful HHMI proposal whose key principles we would like to implement, namely vis a vis injecting examples from CHEM 111/112 and BIO 151/152 into MATH 104. These efforts would also be especially useful in the creation of worksheets for the recitation sections in M131, M132 and eventually M233, M235 and even M331.

Another possible area of collaboration is to create a course, let us call it MATH 234, which would be a cross between M233 and M331 with a mix of topics chosen in consultation with faculty from CHEM and CHEM-Engineering. The latter departments require MATH 233 but have expressed the desire to have a course with a more specialized curriculum instead. We believe enough students from these depts take MATH 233 that this could be a budget-neutral proposition: converting one section of MATH 233 to one section of MATH 234 (offered at a strategically chosen time slot agreed upon by all departments involved).

Another important course undergoing review this year is STAT 240. This is a large service course that we are proposing to convert to 4 credits. Currently STAT 240 already includes a weekly (non-credited) recitation, so this conversion is budget-neutral. Aside from letting students earn the appropriate number of credits for the work they put in, a key goal of this conversion is to update STAT 240 to provide a solid understanding of statistical theory, to buttress that understanding with useful knowledge of software tools, and to offer a wider variety of contexts for the use of these types of knowledge.

We hope many of these ideas will find their way into collaborative IUSE or WIDER proposal(s) to the NSF. The Department leadership is strongly committed to these efforts.

C. Student Support Services.

About 5 years ago, we created a MATH Help Center for MATH 131, 132, 233 on the first floor of Lederle. The staffing is budget-neutral: We ask instructors in those courses to hold one of their office hours in the center. We have also added a separate room for STAT 111 and STAT 240, and we have been running a smaller Help center with

Undergraduate TAs for MATH 101-104. The model we propose, which is fairly standard for our peer institutions, is to have one large, dedicated space, as a unified, one-stop Help Center for all lower division classes, including MATH 235 and MATH 331. Some of the space restructuring in Lederle being proposed as a result of the addition of PSB will make this possible. We also need better coordination between the department's instructional faculty and the peer mentors provided by the Library.

D. Math Writing: MATH 370.

In Spring 2015, our Junior Year Writing course MATH 370 is under review. We have used this opportunity to from a small study committee and are offering an experimental section of the course in a TBL classroom in ILC. The curriculum of this course in recent years has fluctuated from instructor to instructor. The new format and the review will bring with it some beefing up of the curriculum as well as support for students as they get ready to apply for jobs, look for research and internship opportunities, and learn to use the internet as a resource for finding information.

E. Teaching Philosophy.

Continuing with the philosophy of engaging students in the lectures discussed in item A above, we would like to use the creation of the new format for the recitations as an opportunity to invite faculty to incorporate group work in their lectures on a regular and structured basis. We cannot push this idea too far too quickly, since this calls for significant change to the culture and philosophy of teaching and so requires support and input from faculty.
But over a relatively short span, a departmental conversation and some spirit of experimentation guided by strong leadership may achieve significant results without a big price tag in terms of resources. This conversation was put forward by the Dept Head at a fall faculty meeting and will intensify in Spring 2015.

F. Advising.

Our Department's majors are generally unsatisfied with the Academic Advising they receive. Many of them in fact do not come in for advising on a regular basis. This is a twofold problem. First, we need to provide more training and support for advisers. Second, we need to make sure students do show up for advising sessions. We therefore propose to switch back to requiring students to come in for RAC numbers during advising week, but only after we have provided significant training for advisors. This will require providing a lot of support during the transition period. We also plan to create informational videos for describing the structure of the mathematics major. Another idea to be implemented in Spring 2015 is to hold two advising sessions in the evenings during advising week, where students can drop in for advising with expert advisors, not necessarily their own assigned advisor.

We have just switched to an upgraded website which will allow us to update our pages more efficiently and with greater ease. We will create and upload a number of new FAQs and Model Pathways for Advancing to Graduation on the new website over this

academic year and next. This will make a big difference for students and faculty.

Students also find the career advising offered by the Department unsatisfactory. We work with the Career Office, but need to step our own efforts in communicating with students about internships off-campus. The Department has created a thoroughly reworked and expanded section on career advising for our web page, which will go live in February 2015.

The fundamental issue is that we do not have the appropriate human resources in place to cope with the huge task of advising over 500 majors. A dozen years ago, when there were 200 majors, the Chief Undergraduate Advisor was usually a senior aculty member who carried a greater-than-average service load to compensate for a less active research program, and in fact was given a course release in addition. The drop in tenure-stream faculty numbers means that we have eliminated such courses releases for all roles, save the Associate Head. Advising is also more complex now and involves more components. We need to add a member of the department who is assigned the role of permanent Chief Undergraduate Advisor. Besides advising students, this employee would contribute to: training advisors, doing transfer and new student advising during the summer, hosting open houses and provide support for the math club, as well as maintain a database of internships and close contact with alumni who can be invited back to campus to provide practical career advice.

G. Performance tracking.

In Fall 2014, the Department has begun a comprehensive study of the performance of students served by our department. We will continue and expand the study of student success markers in the Spring. As for the math majors, currently each one belongs to one of seven concentrations, each with a specific set of courses geared toward specific career tracks. A key objective of our comprehensive study to analyze the graduation time and retention rate of each concentration, and to identify for each concentration one of two key courses most strongly correlated to students performance and revise the syllabus and/or course format as needed to improve on students' success rate.

H. The Undergraduate Curriculum.

The final item on our list is probably the single most important and also the most costly. It concerns the list of courses offered in the 300 and above range. Our curriculum needs a long-overdue modernization. In particular, we need to add a course on computation and place a heavier emphasis on computation throughout our courses. We would like to add such a course at the 300 level so that students are equipped to use software and more programming in all of their upper division classes. We need to offer a greater variety of courses such as: A course on Dimensional Analysis and Problem Solving, a course on Combinatorics, more courses in Data Science and Cyber-security, two areas in which we hope to make proposals for cluster hires, and a course on the History of Mathematics, which is required for prospective secondary mathematics teachers.