Self Study Academic Program Review, Spring 2017

Mathematics and Statistics Department
University of San Francisco

February 21, 2017

Contents

1 Introduction: Academic Program Review 2010–11

The current state and trajectory of the Department of Mathematics and Statistics can only be understood by considering its past. The last program review was conducted six years ago, in 2010/11, and the external reviewers were laudatory at that time: "[the Department] consists at its core of engaged, scholarly, productive faculty members. Their exceptional commitment to excellence in teaching is clearly aligned with the core mission of USF..." But they did not shy away from our challenges, either. Indeed, they zeroed in on three: "*the principal challenges to the department are to increase the numbers of majors, to increase the number of full-time faculty members, and to improve the department's physical space.*"

Here, in greater detail, are some of the reviewers' comments on these three issues:

- Students: "We find that the department faculty offers a sound mathematical experience for undergraduate majors, on par with many strong programs in the United States. It is unfortunate, therefore, that so few students at USF are partaking of this treasure." The reviewers nevertheless found student morale within the major to be extremely high.

- Faculty: The reviewers described the core faculty as "engaged, productive in scholarship, superlative in teaching, and strikingly collegial." However, as to our numbers, "For an institution of USF's size, and considering that this is a department that is meant to cover statistics in addition to mathematics, this is a small number [of faculty]. There are pre-eminent small colleges with a student body one-third the size of USF's with twice as many permanent faculty of mathematics and statistics."

- Space: As it was written six years ago, so is it now: "The department's Self Study underscored the lack of office space, both in quality and quantity. They were not exaggerating. ... While the concerned faculty members seem to be good sports about it, their tolerance of a small, windowless environment is bound to wane." Hope was expressed at the time that the new Center for Science and Innovation (aka CSI, aka LS, which was in the planning stages at the time) might ultimately provide the Department with at least a dedicated meeting space, if not new windowed faculty offices, but this did *not* come to pass. The CSI does contain two *classrooms* [LS 209/210] dedicated to our Department, but nothing more.

As we shall discuss in subsequent sections, the last six years have seen improvements in all three of the problem areas identified by the reviewers, but the progress has been uneven. The most notable improvement has been in the number of students. This number has almost *tripled*, thanks in large part to timely and successful new programs (linked to "Big Data") that were conceived of, initiated, and then fully implemented by our faculty, most notably by professors Uminsky, Hamrick[1], and Devlin.

[1] Now serving as a Vice Provost for Institutional Planning, Budget and Analytics, Dr. Jeff Hamrick is actually an Associate Professor of Finance, but he is considered a friend and honorary member of the Math-Stats Department!

In response to the success of these new programs and the influx of new students, the Administration has seen fit to increase the number of our faculty, but this increase has been commensurate *neither* with the overall growth of the demands placed upon the Department, *nor* with the major new revenue stream afforded the University by the creation of the new MS in Analytics program.

Lastly, the issue of Space has seen the least improvement, despite the rational optimism expressed by the reviewers six years ago: "The three principal challenges to the department are interlinked. If the department is successful in attracting more majors, this will justify and necessitate more faculty and it will demand with more urgency a solution to the department's space problems." Well, the increase in students has happened; a modest increase in the number of faculty members has happened; *but* we continue to have tenure-track faculty who are attempting to carry out their research (and office hours) in what an earlier program review referred to as "small, uncomfortable, windowless cubicles."

Furthermore, the social life and sense of identity of the Department has also been greatly repressed and depressed by the lack of appropriate, dedicated space in which to gather in groups. For 25 years now our Department has hosted a weekly, informal gathering of our faculty and students, called "Math Tea." As the 2010/11 reviewers remarked, "One activity in the department receiving kudos from all is the weekly Math Tea. This event is universally seen by both students and faculty as very successful and beneficial. It is even known by members of other departments and the administration, some of whom stop by on occasion. The benefits of this interaction are not merely social. This forum stimulates mathematical conversation, discussion, and collaboration."

At the time of the last review, the number of majors was still small enough that Math Tea could be held in the Department Office, but even then the space was not really fit for the purpose: boisterous, happy groups of students would frequently spill out into the hallway, inducing bewilderment in passers-by: how could the *Math* Department be the locus and focus of so much fun?!

Since then our student numbers have increased greatly, making the Department Office venue completely untenable. So, following the completion of the new Center for Science and Innovation (aka CSI, aka LS) we have relocated to a space that is nothing but an uncozy hallway in that building, right outside classrooms, with no couches or comfortable chairs. It is a space that cannot even be officially reserved for our weekly use, and which is therefore occasionally peppered with random non-math students, obstinately continuing to do their homework on laptops in the midst of our attempt at a social gathering! The fact that *any* people continue to show up to this weekly event, let alone the often large crowd that *does* gather, is a testament to our *esprit de corps* and *not* to the space itself!

The 2010/11 report applauded the character of the Department, but it also had a criticism: "The department has a distinctive friendly atmosphere that every student and faculty member is quick to mention. The department is a great place to work. It is rare to find a department in which there seems to be so little conflict. But this absence of conflict may also be interpreted as a sign of weakness.... There is a certain culture of complacency among the faculty who seem to be generally resigned to long-standing difficulties with space and with attracting students."

Goaded by this criticism, and after decades of mounting frustration, we are determined in *this* Self Study to be "complacent" and "resigned" no longer! Indeed, later in this document we shall propose a specific and realistic (though partial) solution[2] to the problem of the inadequate faculty offices. We shall also propose an equally concrete (though again only partial) solution to the lack of a social meeting space for Math Tea. If you, our reviewers, are persuaded by our arguments, we ask that you please exert whatever pressure you can (through your report) to urge the Administration to actually *implement* our proposed solutions, or else to (quickly) find and implement even better solutions. The long-standing, abysmal dearth of professional office space and of meeting space is simply untenable.

This brings us to the singular relationship between the Faculty and the Administration at USF. The unionized structure of USF's faculty is so unusual that external reviewers, coming from more traditional power structures, understandably tend to have their perceptions involuntarily and unconsciously slanted. For example, the 2010/11 report urged the Department Chair to exert himself in various ways that are simply *not possible* within the unionized USF framework. The underlying harsh reality—which must not be forgotten for an instant in the current tense times as the Faculty Association renegotiates its contract with the Administration—is that, day to day, *The Administration has ALL the power, and the Faculty (including Department Chairs) has NONE.*

To drive home this impotence, let us cite a few examples of the duties that are *required* of a Department Chair within the University of California system, but which are *forbidden* for a USF Chair, and are instead the sole prerogative of the Deans: 1) Hire faculty and staff; 2) Assign courses to individual faculty members; 3) Set the class schedule; 4) Assign non-teaching duties to faculty members; 5) Make appraisals and recommendations for promotion and tenure; 5) Maintain a departmental affirmative action program for faculty and staff personnel, etc., etc!

All that being true and said, the reality is actually far less bleak. Indeed, the relationship between *our* Department and the Administration has been cordial and productive for more than two decades. Dean Marcelo Camperi is a physicist with a soft spot for mathematicians, and he has bent over backwards to help us hire the very finest new faculty. And just this past summer our new Associate Dean for Sciences [Dr. Christina Tzagarakis-Foster] went out of her way to help us remedy some serious physical problems in two classrooms [LS 209/210] that are specifically designated for use by our Department. Furthermore, our current Chair, Professor Paul Zeitz, *does* in fact wield considerable influence within our Department, and he routinely succeeds in getting people to do jobs that are not fun but that are genuinely useful for the Department—as proof, *he* did not write this section! But this particular Chair's influence is derived *entirely* from the affection and respect in which he is held by his colleagues. He is contractually *forbidden* from issuing orders to us, while the Administration can and does.

People come and go, but the power *structure* lives on. By the time your report is submitted, Professor Zeitz will no longer be Chair. And even Deans have been known to come to their senses, returning to the faculty! Thus, regardless of the good will that exists today, on both sides of the fence, we would ask, and indeed *urge* you to be as explicit (and personality-independent) as possible in your recommendations to the Administration, in the hope of genuinely improving the lot of our Department.

[2]This plan was originally devised years ago by Dr. Brandon Brown, then Associate Dean for Sciences.

2 The Math Department, 2011–2016

2.1 The State of the Department

The past six years have afforded us the opportunity to transform the Department. The result has been explosive growth and change, and we anticipate more to come. A simplified explanation for this is that several mathematically-minded USF faculty recognized very early on the significance of the "Big Data" economy, especially in San Francisco, rising out of the ashes of the 2008–10 recession. Their response to this (assisted by nimble members of the Administration) was to create the MSAN program (MS in Analytics) and the BSDS (BS in Data Science) major.[3] Both programs were largely conceived of, and decisively carried forward by mathematics faculty. The MSAN program has produced an "updraft" effect that has increased demand for quantitative coursework, and the BSDS program—an interdisciplinary program overseen by our Department—has increased demand in a variety of mathematics courses, persuading the Administration of the need for our three new hires.

2.1.1 Growth and Change

We'll begin with a brief overview of this steady growth in faculty and students, and the changes to our curriculum. More details will be provided in later sections.

New faculty. In 2010, we had 12 full-time faculty, consisting of 1 term, 3 assistant, 2 associate, and 6 full professors. In reality, it was equivalent to 10 full-time professors, as one person (Stillwell) is at USF only for fall semesters, another (Pacheco) teaches many courses in CS, and one (Nel) has been in University upper administration for many years.

Since this time, we have grown impressively, with a net gain of 5 full-time faculty members (3 tenure-track and 2 term). Here is a brief chronology.

- Pete Wells retired in 2011.
- We hired Emille Lawrence (term; starting 2011).
- We hired David Uminsky (tenure-track; starting Fall 2012).
- We hired Mario Micheli (tenure-track; starting Fall 2014), to help with our new data science (BSDS) program. Unfortunately, Micheli was unhappy at USF, and left after the 2014-15 academic year.
- We hired Vince Matsko (term; starting Spring 2015).
- We hired Nathaniel Stevens and James Wilson (tenure-track; starting Fall 2015), our first faculty members with doctorates in statistics.

[3] See 2.2.1 and 2.2.2 below for more details.

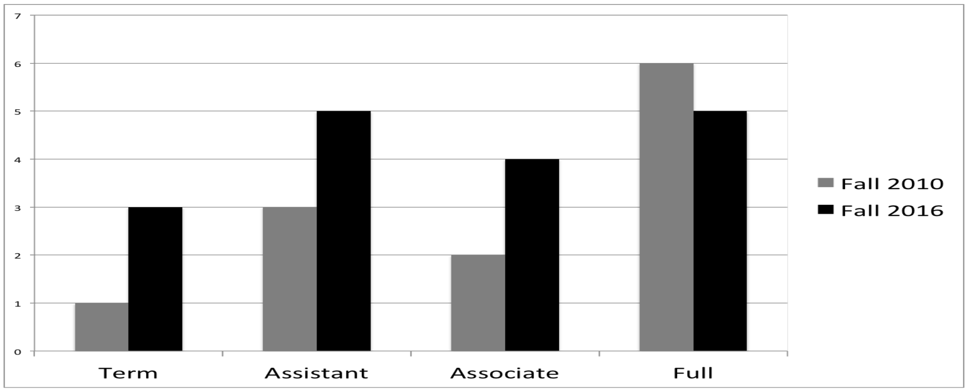

Figure 1: Faculty composition, 2010–16

- We hired Xuemei Chen (tenure-track; starting Fall 2016), filling the vacancy caused by Micheli's departure.

Although we have five more people on the books, this translates to less staffing support: Both Stevens and Wilson teach approximately half-time in the analytics masters (MSAN) program, and Uminsky has been detailed (we hope only temporarily) to administer this program since Fall 2014, reducing his teaching nearly 100%. No changes have occurred with Nel, Pacheco, or Stillwell, so our impressive-looking staff of 17 full-time professors really translates into only 13 full-timers. And Matsko's term appointment is non-permanent, possibly ending with this academic year.

That said, the faculty has improved in many ways. We are younger, more diverse, and more productive than ever, by traditional metrics of books, papers, and grants.

Students. From 1993–2010, the number of mathematics majors fluctuated from a low of 20 to a high of 46, but besides those two outliers, the number of majors stayed close to its mean of 33. Starting in 2011, the number of majors has averaged over 50. When we include Data Science majors, we now have over 100 students in both majors (as of this writing, there are 56 mathematics majors and 52 data science majors). In other words, we have approximately *tripled* the number of students who are seriously studying mathematics and statistics.

Changes to the curriculum and program. As the number of majors grew, we appeared to have the luxury to offer more advanced classes more frequently, helping to promote a more rigorous major. At the time of the last Self Study, we had begun moving in this direction, requiring all majors to take either Modern Algebra (Math 435) or Real Analysis (Math 453). We have been able to offer these courses yearly, with few exceptions.

The new Data Science major has also engendered growth and change. We changed our one-semester calculus-based probability and statistics course (Math 370) into a single-semester

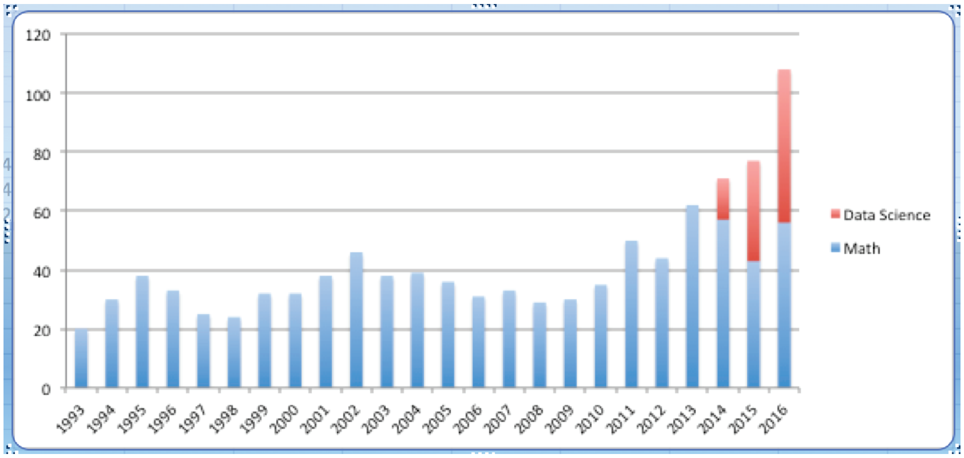

Figure 2: Majors, 1993–2016

probability course, coupled with a single-semester statistics sequel (Math 371), which has been offered every year since 2014–15.

The hiring of two dedicated statisticians (Stevens and Wilson) in Fall 2015 signaled a conscious expansion of the Department's ambitions. Correspondingly, we then changed the *name* of our Department to "Mathematics and Statistics." Two more statistics courses are set to debut in 2017–18 (Math 372: Linear Regression and Math 373: Statistical Learning), which we plan to offer every year. Data Science will debut a single section of an entry-level "Introduction to Data Science with R" course in spring 2017, which we hope will be a popular math core class for non-majors, as well as the entry course for Data Science majors.

These developments, along with parallel (and even more dramatic) growth in the Computer Science major has increased demand for linear algebra, calculus and our CS service courses, Discrete Math (Math 201) and Probability and Linear Algebra (Math 202). The synergy with Computer Science has come at a cost, in that our connections with Physics have diminished. We have fewer math-physics double majors or major-minors, and Differential Equations and Differential Geometry have struggled with enrollment. *charts?*

2.1.2 Questions and Concerns

In many ways the past six years have been good to our department. However, there are three important areas of concern, all connected with the opportunities and problems of managing growth.

The evolving relationships between three programs Our department is approaching a crossroads. Although, nominally, Math and Statistics and BSDS and MSAN are separate entities, in reality they are all Arts and Sciences programs, and are all led by and largely conceived by mathematics faculty. In the non-quantitative terms of "blood, sweat, and tears," perhaps 90%

of BSDS is and at least 50% of MSAN are math/stat. Given that these programs expend energy and resources of math/stat faculty, and their very existence provides the department with resources (new majors, new hires, new courses), we are faced with a number of questions.

- Will we continue to grow together, or should these three programs grow apart (perhaps with separate faculty and administration)?
- Is Data Science growth synergistic or parasitic in its relationship to Math and Statistics?
- What direction will the growth of our statistics program take? A separate department? A new major? Or just a new minor?
- How shall this growing Math/Data Science/Analytics entity interact with the rest of USF in terms of service courses and service to the research mission of the university?

Faculty The Department continues to place too much reliance on part-time faculty, although this has improved due to recent hiring. However, this fall (2016), part-time faculty taught 15 sections, with an average of 31 students. Full-time faculty taught 31 sections, with an average of 26 students. Thus part-time faculty taught one-third of the sections (part timers generally only teach 100-level courses) but nearly 40% of the students.

While some of our part-time faculty are excellent teachers, the Department and the University don't have the resources to routinely monitor their performance. Also, since the part-time faculty are paid so little, they must usually work elsewhere to make ends meet. Consequently, through no fault of their own, they simply cannot fully engage in Departmental activities.

Space The previous Self Study had high hopes that the new science building (CSI, aka LS) would help to resolve the Department's long-standing shortage of professional, usable space. Sadly, the CSI provided only modest gains, and our space remains wholly inadequate. In fact the *only* real benefit arising from new building has been two dedicated math classrooms [LS 209/210], but unfortunately even these are flawed: each seat only 25 students, and they were very poorly designed.[4]

Most seriously, we lack appropriately sized, windowed offices for our growing faculty: only nine full-time faculty members have offices with windows, and some of the windowless offices measure only 9ft by 11ft. Our contract specifies that office space is awarded on the basis of seniority (independent of department or school, although in practice, this is done at the departmental level). Currently, two full-time faculty members (Hubert and Wolf) have voluntarily relinquished their right to a good office, and the current chair (Zeitz) plans to do so starting in fall 2017. While such acts of office-space altruism are admirable, this is not a sustainable way to provide adequate space for our hard-working full-time faculty. Furthermore, there is no adequate dedicated space for such fundamental morale-builders as

[4] As previously mentioned, we are grateful to our new Associate Dean for Sciences, Dr. Christina Tzagarakis-Foster, for fixing some of the worst problem with these classrooms over this past summer.

group study, group discussion, and informal socializing. Our Math Tea, an institution that has survived for 25 years, has been relegated to an uninviting hallway close to our CSI math classrooms.

Proposed Partial Solutions to the Space Problems:

- WINDOWED OFFICES. A previous Associate Dean for Sciences, Dr. Brandon Brown, devised a plan to remodel two groups of mathematics offices on the second floor of Harney, thereby *creating two new windowed offices.* We explain the idea using the pair of offices HR218/219, currently occupied by Professors Needham and Van Cott. These two adjacent offices each have three windows on their long side. The idea would be to rewrite 2x3 as 3x2, i.e., to create three office with two windows each, a net gain of one new windowed office. This would necessitate assimilating the two windowless offices adjacent to HR218/219. The same plan would likewise be applied to the mirror-symmetric pair HR211/212 on the other side of Harney, creating a new windowed office there too. All this will be much easier to understand when we can physically show you the rooms involved in the plan.

  The construction could be done over one summer, during which time the affected faculty could work at home. Of course this construction project would involve a considerable financial commitment by the Administration. If they are unwilling or unable to follow through on Dean Brown's plan, we welcome hearing alternative ideas. But the current situation in which tenure-track faculty must work for years on end in tiny, windowless spaces, simply cannot be tolerated.

- MATH TEA. On the ground floor the CSI is the *J. Paul Getty Study*, a comfortable space with armchairs, tables, a gas fireplace, and a lovely view out over lawns of the magnificent St. Ignatius church, the physical heart of the University's Jesuit identity, as well as the venue for our graduation ceremonies. Although the lounge is open to all students throughout the day, it is possible to *reserve* this space for special occasions. Indeed our Department does reserve this space once a year when we meet with and orient the new crop of freshmen.

  The Getty Study would provide an infinitely better space in which to hold our weekly Math Tea than the current use of a vacant, uninviting hallway on the second floor of the same CSI building. The snag is that if one reserves a University space like this, then it is supposedly mandatory that it be catered by the University food service, called Bon Appétit. Their food is not appropriate for our informal gatherings, and it is shockingly expensive—there is no way the Department budget could sustain this, even if we ordered only a modest amount of food and drink each week. Thus the only way this could work is if the University could allow us some kind of waiver, allowing us to bring in our own home-made baked goods, sandwiches, etc., to provide to our students, rather than forcing us to use Bon Appétit. Since we cannot afford it, the only alternative to a waiver would be to use Bon Appétit, as currently required, but for the Administration to agree to fund this crucial part of the life of our Department.

2.2 The Rise of Data Science and Statistics

2.2.1 The Data Science major

Introduction The undergraduate data science program launched in the fall of 2013. The program was conceived of and started within the mathematics department as a response to several environmental factors. First is the remarkable rise of data science and analytics, both nationally and locally, but especially in the Bay Area. Data science now represents a core competency in just about every aspect of business and industry: small startups and non-profits, government and health care, high tech, sports and entertainment, and on. The widespread demand for data scientists represents an opportunity for our department to place well trained graduates in attractive, well compensated, and rewarding positions.

Of course, the educational philosophy of our University and department is by no means focused on vocational training alone. Here however, the field of data science itself–a hybrid of mathematics, statistics, and computer science–offers an exciting landscape in which to reimagine our curriculum in a particularly modern way without sacrificing intellectual honesty or rigor. This was the second environmental factor: At the time of the program's launch there were *very* few undergraduate programs in data science in the country. That number, while rising, is still relatively small and afforded us the opportunity to position the department as an early adopter, and destination, for undergraduate study in data science.

The final factor: We had the good fortune of a highly successful Masters program in Analytics (MSAN; another program that our department was instrumental in starting), to help serve as a model for the undergraduate program, and to provide a pathway for the most talented students to move seamlessly on to graduate study via an incentivized 4+1 program (see 2.2.2 for more information on the MSAN program and outcomes).

Growth The Data science program has seen strong growth over a relatively short period of time. Without any real outreach beyond simply putting the major on the books, the number of students has grown from an initial group of 6 at launch to 52 at the start of the fall 2016 semester. Interestingly, this is almost exactly the same size as the mathematics department. One of our initial fears upon launching the program was cannibalization of mathematics majors, but as of now this doesn't seem to have happened. The primary source of data science majors has been the computer science department. Students who find that they miss taking mathematics courses in the CS major often consider and declare data science in order to keep one foot in each of the computational and mathematical worlds. The computer science department has also seen dramatic growth recently, to the point of being oversubscribed, so the modest flow of students into data science hasn't been seen as unhealthy for any of the related departments. (See 2.5 for details.)

Curriculum The original curriculum reflected the hybrid nature of the program. Students took foundational courses including two semesters of calculus and programming (Python and Java), linear algebra, data structures and algorithms, probability and statistics. Students then chose a concentration from among three offered: Computation, Mathematics, or Economics. Depending on concentration, students then filled out their course of study taking appropriate electives such as Data Mining, Data Visualization, Econometrics, Mathematical Modeling, etc. The completion of the program required 68 total units– a fairly large, but not unreasonable major.

The program was launched primarily using existing courses in Math, Computer Science, and Economics. This was done partly out of necessity as the program also launched with only one new faculty member in support. The major curricular modification that involved data science at launch was the splitting of the existing one-semester probability and statistics course into a year-long sequence with a full semester of probability(Math 370) and a full semester of statistics (Math 371). It was understood that the new hire would, for the short term at least, own this particular sequence lying at the heart of the data science major. Other new courses included a Data Mining (CS 451) course to be developed and taught by CS faculty, and an upper-division Numerical Linear Algebra course to be developed and taught in the future.

Faculty There is no data science department, so in practice any and all faculty members in Mathematics or Computer Science might teach in service of Data Science students. That said, the following faculty are/were self-identified as principal players in data science:

1. Mario Micheli (fall 2014–spring 2015)
2. David Uminsky (BSDS director fall 2013–spring 2014 / MSAN director as of fall 2014)
3. Stephen Devlin (BSDS director as of fall 2014)
4. James Wilson (hired fall 2015–half MSAN)
5. Nathaniel Stevens (hired fall 2015–half MSAN)
6. Xuemei Chen (hired fall 2016)

There has been considerable change as one can see above. In particular, Mario Micheli—the original data science hire—left the University in spring 2015, and David Uminsky, the original BSDS program director, became MSAN director in fall 2014. The new hires of Wilson, Stevens, and Chen have brought much needed stability and perspective to the BSDS program. Still, the program relies very heavily on a relatively small number of faculty members. One example: Data Mining (CS451) was set launch in fall 2015, but the CS faculty member who created the course unexpectedly left the University before the summer. Devlin was able to take over the Data Mining course in this case, but these inevitable shake-ups seem especially daunting with a small number of faculty, especially since Wilson and Stevens have rigid schedules determined by their half-appointments in MSAN at the downtown campus, and Uminsky occupied primarily by the MSAN directorship.

Curriculum changes The original curriculum had several shortcomings which became evident over time and has resulted in proposed changes. The first was a lack of an introductory course, taken in the first year, and designed to introduce students to some of the foundational ideas and tools of data science. This course is now on the books and will run for the first time in the spring. The course, An Introduction to Data Science with R, will be taught by Wilson and will also serve as a core B1 course with minimal prerequisites. It will be taken by beginning data science majors, but also by students in other disciplines interested in learning more about data and the R environment. The second proposed change involves creating courses to better directly address the core skills required of someone presenting themselves as a data scientist. To that end, courses in Linear Regression and Statistical Learning have been created and added to the required courses in the major (see attached checklist). Other more peripheral courses have been scrapped from the required list and placed into an elective pool. Finally, the concentrations have been eliminated. The result is a slightly smaller major (56 units), with a more focused attention on data science, and with more free electives and more freedom for students to craft their own concentrations depending on their interests. While we expect many students to choose those electives from among the usual math/stats/cs courses, the possibility that a student might craft their own concentration in an area of interest (politics, social science, etc) is also appealing, and we see no reason to actively prevent this.

Another huge problem of the old curriculum was the unintended rigidity of the concentration model. Many of the upper division courses required of the computational and mathematical concentrations run once a year only. The courses also tend to be prerequisite heavy. This is inevitable, but still narrows the path by which students can advance toward graduation. For students who have transferred into the program or changed majors late in the process, this rigidity represents a serious financial burden if they cannot complete requirements on time. The proposed changes will add much needed flexibility to the program.

Technology The inclusion of technology in the data science program occurs through increasingly in-depth exposure in courses. The primary platforms used are Python and R, which have the two-fold advantage of being free and open source, and being the two languages most used in the Bay Area data science ecosystem. R is introduced in the new introductory data science course, and Python in CS110. Both platforms are then used in courses like statistics, regression, machine learning, data mining, and the applied math lab. Faculty have agreed to restrict software in future new or elective courses to R and Python (for now) so as to best serve students with respect to depth of learning and to present the most cohesive curriculum possible.

One challenge is managing the need for computers in class. Many data science courses are best taught with laptops present. Currently, only two of our classrooms, LS103 and LS303, have accessible laptop carts that could be used in the event that an enrolled student did not have a laptop. Moreover, these classrooms have limited capacity that the introductory data science course has already outgrown. In practice almost all students do have access to a laptop, but it seems worth considering a blanket policy, or a more practical loaner program to facilitate optimal teaching practices in BSDS courses moving forward.

Another technological challenge facing the data science program is data warehousing and computational resources. As of yet, the program has focused on small and medium sized data analysis. Realistically the program will need to grow to include big data techniques and problems in the curriculum. Doing so will require additional support and infrastructure. MSAN can offer some guidance along these lines, but it seems prudent to consider the programs needs, particularly in terms of hardware, access to resources like AWS and a dedicated data warehouse, and systems administration as it grows and develops.

Challenges The data science program has grown rapidly and is thriving. There is a healthy cohort of students, strong growth, and an increasing profile on campus. A new data science club has been developed with James Wilson serving as faculty advisor, and students and faculty are both engaged and optimistic about the program's future. Still, there are concerns and challenges.

First, the data science program grew extremely quickly, and in a manner of speaking, carved itself out of a mathematics department that until recently was a small, liberal arts department rooted in classical mathematics. That this transition from classical-liberal-arts to modern-mathematics-and-statistics happened as smoothly as it did is a testament to the collegiality of the department, and to the open-mindedness of its members. Still, growth like this is delicate and undoubtedly raises serious existential questions about the nature of the department, its goals and mission, and its future growth and development. An academic program review seems an ideal time for members to speak openly about their thoughts and concerns. One need not look far for examples where pure and applied mathematics are not always agreeable bedfellows.

Also, the data science program relies heavily on the computer science department. This dependence puts a large burden on a department that is already taxed to its near-limit with its own students. To date, the CS department has been an extremely good citizen dealing with BSDS students who have their own unique issues and needs, often very different from those of the CS students. Furthermore, the nature of the CS and math curricula have historically resulted in a relatively distant relationship between these departments. Data science is changing that, but is also creating new stresses and challenges. If the BSDS program continues to grow at its current rate, can CS handle the increased pressure on its notoriously difficult-to-staff introductory courses? While it seems appealing that data science and computer science students move freely between departments for elective courses, the nature of prerequisites makes this unfortunately difficult. BSDS students lack courses like software development often required in upper-division CS while CS students lack statistics and calculus courses required in upper-division data science courses. The databases course, CS 333, is a current (and future) requirement of BSDS students, but for (understandable) reasons having to do with staffing constraints, the course hasn't run recently and won't in the near future. Other stress points certainly exist, or will soon.

The first cohort of data science students is just beginning to approach graduation. To date, the bulk of our effort has involved growing the program, advising students (a nightmare due to the rigidity mentioned above), and staffing courses. But in order for our program to truly reach its potential, we should have a robust internship program, and dedicate considerable energy to interviewing preparation and employment outcomes of BSDS graduates. With a small number of faculty (mostly junior), properly developing these programs and relationships is a considerable challenge.

A host of other questions—the kind that arise in any new program—abound. Will the data science program continue to grow, and if so, what is a stable number of majors? Is the current level of staffing sufficient? Can the program handle Wilson and Stevens going on sabbatical (at the same time?)? Is there room for a data science minor (currently there is none and double majors with math or CS are not allowed due to the excessive number of overlapping courses)? Is there room for a statistics minor? What are the minimal prerequisites that these programs must require? These are all questions that have been deferred as the program launches, but need to be addressed.

2.2.2 The Analytics MS program

We include here a brief description our Analytics MS program (MSAN), although it is technically not part of the department, nor a focus of this academic program review (indeed, MSAN will have its own review in 2019). However, because of the close connections between the faculty in this program and the math-stat department, as well as the synergy that seems to create an "updraft" benefiting undergraduate math, statistics, and data science, it is important to understand this program.

Introduction USF's location in the heart of San Francisco is close to the largest concentration of technology companies in the United States. While traditional quantitative education and software and computer science is in a mature state, the exploding field of data science and analytics was quite new in 2012. USF took the innovative step of launching a one-year masters program in Analytics (MSAN), at the time one of only a half-dozen such graduate programs in the country.

The program was jointly developed and launched by the College of Arts and Sciences (CAS) and the School of Management (SOM)[5] and the first cohort graduated 12 students (with a total application pool of just over 30). Program applications and students have grown exponentially over the past few years: the fifth cohort (AY 2016-2017) has 61 current students out of nearly 600 applications. The current students are arguably the strongest academic students attending USF, coming from the prestigious institutions such as Brown University, NYU, Peking University, Rice University, Shanghai University of Finance and Economics, UC Berkeley, UCLA, UT Austin, University of Waterloo and IIT. Since the programs inception, 100% of graduates have been employed within three months of graduation at companies like Google, Microsoft, Facebook, Square, Amazon, LinkedIn, Underarmour, Uber, and Capital One Labs. Graduates become data scientists and

[5] SOM chose not cohost this degree program during the third year, so it is now solely run by CAS.

analysts working in areas such as finance, marketing, web analytics, logistics and supply-chain management. The median starting salary has grown from $85K a year for cohort one to $110K for cohort four.

The Mission of MSAN The mission of the MSAN program is to produce graduates who possess a theoretical and practical understanding of many classical and modern statistical modeling and machine-learning techniques; who use contemporary programming languages and technologies to scrape, clean, organize, query, summarize, visualize, and model large volumes and varieties of data; and who use their knowledge and skills to successfully solve real-world, data-driven business problems and to communicate those solutions effectively.

Core curricular program and Practicum The 35-unit program focuses on teaching students to apply mathematics, statistics, and computer science to solve real data-driven business problems. The curriculum is very technically focused and the programming languages and technologies reflect the Bay Area's focus on open-source languages, including R, Python, Spark, etc. One of the key innovative features of the program is the 9-month Practicum, which provide students with invaluable practical experiences and mentoring in a business setting, making them very desirable job candidates. The Practicum is a project sponsored by a company, allowing students to work with industry partners to gain analytics experience and reconcile mathematical theory with business practice. Student groups—supervised by an MSAN faculty member—work with the Practicum's company to identify, define, scope, and analyze a particular business problem. All groups are additionally supported and supervised by the MSAN Practicum director. Each cohort of MSAN students is engaged in Practicum projects from October through July of each academic year, in which they are expected to work 15 hours per week. Past and current partners include Google, AirBnb, Eventbrite, the San Francisco 49ers, PayPal, Uber, Williams-Sonoma, Flyr, Wells Fargo, GE Software, and the Houston Astros.

The Mathematics and Statistics Department (MSD) and MSAN The Mathematics and Statistics Department (MSD) plays a fundamental role in both leading and supporting the MSAN program. The role of the MSD in MSAN has increased dramatically in the past few years, and it is now the dominant department contributing to MSAN. About a third of the 35 units are core mathematics and statistics courses and up to half of the courses could be taught by members of the MSD. In addition, the high volume of practicum mentors required (35 separate projects in AY 2016-2017) are often drawn from MSD faculty, who receive overload pay. For the past two years, both the program director as well as the practicum director have been staffed by members of the MSD. This year, MSAN is supported by approximately 3.5 MSD FTEs for teaching, practicum supervision, and service. In contrast, the role of computer science department has diminished to approximately .75 FTE. The remainder of faculty staffing are 3 people currently designated as "core" analytics faculty, who have no departmental affiliation (one has a Ph.D. in applied mathematics, two have Ph.Ds in computer science).

The MSD has no formal graduate program, but MSAN has become a de factor graduate program that it supports. This has been a boon for recruiting new faculty to MSD (both Wilson and Stevens were explicitly hired to divide their time between the undergraduate programs in MSD and MSAN), and MSAN plans to continue to grow as long as demand supports such growth. In the next 3 academic years the program is to grow by 10 students a year, to reach 90 in 2019-20. These increases will further strain on the teaching load for the MSD. As we move forward it will be important to plan on how the MSD continue to support the teaching and service demands of MSAN. It will also be important to understand how can MSD and BSDS leverage the success of MSAN to support its other curricular areas.

2.2.3 The New Role of Statistics

Data is all around us. In recent years its importance has been recognized and emphasized in sectors such as business, science, healthcare, and public policy, to name a few. With the increased relevance of Big Data and data-driven decision making, it is extremely important that academic institutions provide future generations of students with the analytical skills and tools necessary to collect, organize, and analyze data. Recognizing this, in 2015 the Department of Mathematics hired two tenure-track Assistant Professors of Statistics, James Wilson and Nathaniel Stevens, thus becoming the Department and Mathematics and Statistics.

In the past two academic years, Wilson and Stevens both developed new courses for the Mathematics major and helped to modify the BSDS program to focus more on statistics and computation. In particular, they have developed three new courses.

- Math 372: Linear Regression
- Math 373: Statistical Learning
- BSDS 100: Intro to Data Science with R

These courses expand the current offerings for both BSDS and MATH majors and provide a more contemporary perspective on statistics. Under the new curriculum, students are well-prepared for a role in data science or analytics in the Bay Area.

In the future, we plan to incorporate statistics across other disciplines at USF, such as Economics, Politics, Psychology, and Sociology. We hope to provide a Statistics Minor for students in these disciplines so as to provide a quantitative foundation for students who wish to pursue graduate school or employment at a data-driven company. This expansion has coincided with the hiring of Prof. Xuemei Chen in 2016, who will aid in the teaching of these courses and other BSDS courses. However, to fully expand Statistics into a Minor or Major, we will need to hire additional faculty members.

2.3 The Faculty

During the past seven years (2010–2017), the Department of Mathematics and Statistics has been highly productive and has undergone substantial growth. We have been privileged to welcome six(!) new full-time faculty to our department, four of which hold tenure lines.

This section includes summary information about our department's collective achievements and interests, biographical sketches, and concludes with a discussion of some of the challenges we face. Curricula Vitae may be found in an addendum to this Review.

2.3.1 Faculty Demographics

We currently have 17 full-time faculty members on the books:

- Xuemei Chen (tenure-track assistant)
- Jennifer Chubb (approved for tenure by peer-review committees; pending dean's approval she is likely to be tenured associate by the time you read this)
- Stephen Devlin (tenured associate)
- Renée Hubert (term)
- Emille Lawrence (term)
- Vincent Matsko (term)
- Tristan Needham (tenured full)
- Stanley Nel (tenured full)
- Peter Pacheco (tenured full)
- Nathaniel Stevens (tenure-track assistant)
- John Stillwell (tenured full)
- David Uminsky (tenured associate)
- Cornelia Van Cott (tenured associate)
- James Wilson (tenure-track assistant)
- Robert Wolf (tenured assistant)
- Stephen Yeung (tenured associate)
- Paul Zeitz (tenured full)

The actual teaching strength, as pointed out above, translates to about 13 FTEs, since Nel has been in senior administration for decades, Uminsky is nearly out of the picture due to directing MSAN, Stillwell only works at USF during fall semesters, Wilson and Stevens both divide their time between math and statistics and MSAN, and Pacheco teaches many CS courses. Furthermore, Matsko's position is unstable and at the time of this writing it is not certain if there is funding for him next academic year (2017–18).

Of these 17 people, twelve are male, five are female; two are Asian; one is African-American; and one is Latino. Eight are in their 30s or younger; five in their 40s and 50s; four are older than 60.

Additionally, we currently are employing 8 adjunct faculty, with varied educational pedigrees.

- Spencer Bowen (MA in Math, SF State)
- Kenneth Harrington (chair of Math at Stuart Hall High School, graduate work at SFSU)
- Christopher Kaegi (MBA, Northwestern)
- Vera Klimkovskaia (MA in Math, SF State)
- Olivia Mah (Ph.D. in Financial Mathematics, Monash University)
- Mark Rinker (Ph.D. in Math, UC Berkeley)
- Bin Shao (Ph.D. in Math, UC Santa Cruz)
- Van Tran (MA in Math, UCLA)

2.3.2 Faculty Productivity and Awards

Selected faculty and departmental achievements are highlighted below, and are followed by a summary of our collective creative output, service to academics, and research interests.

- Cornelia Van Cott received a Post-Sabbatical Merit Award.
- Paul Zeitz received the Frank L. Beach Distinguished Service and Leadership Award.
- John Stillwell became a Fellow of the American Mathematical Society.
- David Uminsky was selected as a Kavli Frontiers of Science Fellow.
- USF Math Department hosted the *Workshop in Computability Theory, 2011*.
- New degree program: B.S. in Data Science
- New courses: Quantum Computing, Introduction to Regression, Introduction to Statistical Learning, Mathematics and Digital Art.

Of sixteen full-time faculty members, thirteen were active in pedagogical development, scientific research, and professional service in the last seven years. In that time, we've published 59 articles in peer-reviewed journals, 13 book chapters, and wrote, edited, revised, or translated 15 books. Invitations led to nearly 200 invited research/expository talks and short courses in the U.S. and abroad.

We have collectively been awarded over $200,000 in external grants. Besides the awards listed above, our newer faculty members won 13 awards while at their previous institutions. We've served on organizing or program committees for 23 conferences and 32 special sessions. The total number of society memberships reported is 34.

Faculty research interests include

- Algorithmic learning theory
- Assessment and comparison of measurement systems
- Braid groups
- Combinatorial group theory
- Combinatorics
- Computability theory
- Computable structure theory
- Digital art
- Dynamical systems theory
- Josephson junction arrays
- Sigma-delta data converters
- Equational logic
- Equity in educational opportunity
- Experimental design and A/B testing
- Fluid dynamics
- Foundations of mathematics
- Geometric topology
- Geometry
- History of mathematics
- Knot theory
- L-systems
- Logic
- Low-dimensional topology
- Machine learning
- Network analysis
- Parallel computing
- Partial differential equations
- Pedagogy of parallel computing
- Polytopes
- Problem solving
- Process monitoring and network surveillance
- Quantum computing
- Quantum information theory
- Quantum logic
- Reliability analysis
- Scientific computing
- Spatial graphs
- Temporal network analysis
- Theory of random graphs
- Variation reduction
- Visual differential geometry

2.3.3 Biographical Sketches of Faculty

All faculty are tenure-track, with degrees in mathematics, unless otherwise indicated.

Xuemei Chen (2016–, Ph.D., Vanderbilt University, 2012, Assistant Professor) is the newest member of the department, an analyst that works in the field of applied and computational harmonic analysis. She is interested in the theory, as well as its application to data science. Her current research focuses on applied harmonic analysis and mathematical aspects of signal processing, especially compressed sensing, frame theory, and fast linear solvers for high dimensional data.

Jennifer Chubb (2009–, Ph.D., George Washington University, 2009, Assistant Professor) studies logic and recursion (or computability) theory, and she has a particular interest in computable structure theory. She holds a B.S. in Physics and Applied Mathematics, and an M.S. in Applied Mathematics from George Mason University. While pursuing those degrees, she worked in experimental physics and studied chaos and nonlinear dynamics.

Renée Brunelle Hubert (1997–, MA, UCSD, 1997, Assistant Professor, term) received a BS in mathematics from the University of San Francisco in 1994 and an MA in pure mathematics with emphases in algebra and complex analysis from the University of California, San Diego in 1997 where she was a recipient of the Cota Robles Fellowship. During her nineteen years of term faculty appointments at USF, she has specialized in teaching the Department's service courses. As one of the few full-time faculty members who regularly teaches these courses, she has been involved in curricular planning, integrating the use of technology, and mentoring adjunct faculty.

Stephen Devlin (2004–, Ph.D., University of Maryland, 2001, Associate Professor) grew up in New York and graduated from Manhattan College. He wrote a dissertation on representation theory, and was a C.L.E. Moore Instructor at MIT before joining the faculty at USF. His recent interests include complex networks and game theory.

Emille Lawrence (2011–, Ph.D., University of Georgia, 2007, Assistant Professor, term) is a low-dimensional topologist. Her mathematical interests include braid groups, geometric group theory, and spatial graphs. She is also an advocate for broadening participation in the mathematical sciences through outreach and mentoring.

Vincent J. Matsko (2015–, DA, Carnegie Mellon, 1993, Assistant Professor, term) earned B.S., M.S., and D.A. degrees from Carnegie Mellon. His research interests include classical polyhedral geometry and the combinatorics of permutation polytopes. He is also interested in digital art, and is currently teaching a Mathematics and Digital Art course designed for USF's First-Year Seminar program.

Tristan Needham (1989–, D. Phil, Oxford, Professor), son of the distinguished social anthropologist Rodney Needham, grew up in Oxford, England, where he attended the Dragon School (with Stephen Wolfram and Hugh Laurie). He studied physics at Merton College, Oxford, before moving to the Mathematical Institute, where he enjoyed the great privilege of studying black holes under the supervision of Sir Roger Penrose. His current focus is Differential Geometry, but Complex Analysis, General Relativity, and the history of science are abiding loves. His continuing mission is to seek out new intuitive forms of understanding, and new visualizations.

His book *Visual Complex Analysis* won first prize in the National Jesuit Book Award Competition. An earlier paper received the Mathematical Association of America's Carl B. Allendoerfer Award. He is currently writing a new book, *Visual Differential Geometry*.

Stanley D. Nel (1983–,Professor) grew up in South Africa, and studied Cosmology under George Ellis at the University of Cape Town, where he earned a Ph.D. in Applied Mathematics. As a Rhodes Scholar at Balliol College, Oxford, he performed research as a member of Roger Penrose's Relativity Group at the Mathematical Institute. His papers have focused on the observational foundations of cosmology, and on techniques for obtaining solutions of Einstein's field equations in General Relativity. After teaching in the mathematics department, he moved to administration, and served as Dean of the College of Arts and Sciences 1990–2003. He is currently the Vice President for International Relations at the University of San Francisco, working from Bangkok and Beijing.

Peter Pacheco (1989–, PhD., Florida State University, 1983, Professor) was originally trained in topology, but currently his main research interest is parallel computing. He's been involved in the development of the MPI Standard for message-passing. His book *Parallel Programming with MPI* is an elementary introduction to programming parallel systems that use the MPI 1 library of extensions to C and Fortran. His book *An Introduction to Parallel Programming* is designed to teach inexperienced programmers how to program both shared- and distributed-memory parallel systems.

Nathaniel Stevens (2015–, Ph.D., Statistics, University of Waterloo, 2015, Assistant Professor) teaches jointly in the Math and Statistics Department and MSAN program. During his academic career he has also worked as a research assistant and consultant with the Business and Industrial Statistics Research Group (BISRG) on various statistical projects resulting in collaborations with several industrial and healthcare organizations.

In general, Nathaniel is interested in using data to make decisions, solve problems, and improve processes. Specifically, his research interests lie at the intersection of data science and industrial statistics. He is interested in experimental design and $A|B$ testing, process monitoring and network surveillance, the assessment and comparison of measurement systems, reliability analysis, and variation reduction.

John Stillwell (2002–, Ph.D., MIT, 1970, Professor) was born in Melbourne, Australia, and taught at Monash University from 1970 until 2001, before moving to USF in 2002. He was an invited speaker at the International Congress of Mathematicians in 1994, and his mathematical writing has been honored with the Chauvenet Prize of the Mathematical Association of America in 2005 and the book award of the Association of Jesuit Colleges and Universities in 2009. He was made a Fellow of the American Mathematical Society in 2012. Among his best-known books are *Mathematics and Its History* (3rd edition, 2010) and *Yearning for the Impossible* (winner of the AJCU book award in 2009).

David Uminsky (2012–, Ph.D., Boston University, 2009, Associate Professor) received a B.S. in Mathematics from Harvey Mudd College. He is currently the director of the MSAN program and was the founding director of the BSDS program. His research interests are in applied mathematics; specifically, unsupervised machine learning, data clustering, algebraic signal processing, as well as pattern formation, dynamical systems and fluids. David was selected in 2015 by the National Academy of Sciences (NAS) as a Kavli Frontiers of Science Fellow. Each year, 100 researchers under the age of 45 are selected by the academy, and the 20% of the current NAS were previous Kavli Fellows. Before joining USF, he was a combined National Science Foundation and UC President's Fellow at UCLA, where he was awarded the Chancellor's Award for post-doctoral research. This award is given to approximately top 20 postdocs out of over a thousand who qualify for consideration.

Cornelia Van Cott (2008–, Ph.D., Indiana University, 2008, Assistant Professor) received her undergraduate degree from Wheaton College (Wheaton, Illinois), where she majored in mathematics and minored in music. She did her graduate studies in math at Indiana University, getting a Ph.D. in 2008. She joined USF in the fall of 2008. Her research is in geometric topology with a focus on knot theory. She founded the USF Math Department Colloquium Series together with Steve Devlin in 2009, and she is active as the faculty advisor for the USF Women in Science Club. Outside of USF, she enjoys speaking at math circles for children and undergraduate math colloquia both in the Bay Area and around the country.

James Wilson (2015–, Ph.D. ,Statistics and Operations Research, University of North Carolina, 2015, Assistant Professor) received an M.S. in Mathematical Sciences from Clemson University (2010). His dissertation work was entitled "Statistical Analysis of Relational Data: Mining and Modeling Complex Networks." Through his research, James brings together techniques from machine learning, statistical inference, and random graph theory to model, analyze, and explore relational (network) data structures. His interdisciplinary work has led to collaborations with researchers from genetics, infectious disease, political science, and managerial science. Currently in San Francisco, James also works with data science teams such as researchers from the AT &T Big Data team, as well as from Airbnb, to solve exciting statistical and network analysis problems. His hope is to understand and motivate the interplay between statistics and application.

Robert Alan Wolf (1968–, Ph.D., UC Berkeley, 1968, Assistant Professor) graduated from the Massachusetts Institute of Technology in 1962 with an SB degree in mathematics and received a master's degree in 1964 from the University of California at Berkeley. He received an MS degree in physics from San Francisco State University in 1990. He is interested in the mathematical and physical sciences.

Stephen Yeung (2006–, Associate Professor) received his B.Sc. from the Chinese University of Hong Kong and his Ph.D. from Cornell University. He has diverse research interests, having worked on dynamical systems theory including coupled oscillators, Josephson junction arrays, injection lasers, and sigma-delta data converters, on which he is a co-inventor on two patents. He has also developed algorithms to analyze microarray data to reconstruct gene regulatory networks efficiently.

Paul Zeitz (1992–, Ph.D, UC Berkeley, 1992, Professor) majored in History at Harvard and studied ergodic theory in graduate school. Between college and graduate school, he taught high school mathematics in San Francisco and Colorado Springs for six years.

One of his greatest interests is mathematical problem solving. He won the USA Mathematical Olympiad (USAMO) and was a member of the first American team to participate in the International Mathematical Olympiad (IMO) in 1974. Since 1985, he has composed and edited problems for several national math contests, including the USAMO. He has helped train several American IMO teams, most notably the 1994 team which, for the first—and only—time in in history, achieved a perfect score. This work, and his experiences teaching at USF led him to write *The Art and Craft of Problem Solving* (Wiley, 1999, currently in its third edition). He has also been very active in local events for high school students. He founded the Bay Area Math Meet in 1994 and co-founded the Bay Area Mathematical Olympiad in 1999. In 2016, he received the College of Arts and Sciences Frank L. Beach Distinguished Service & Leadership Award.

He has focused on two different projects: expanding mathematical enrichment to underrepresented populations, and promulgating Eastern European "math circles" culture. With regards to the former, he founded the San Francisco Math Circle in 2005, under the auspices of the Mathematical Sciences Research Institute and with generous funding from the Moody's Foundation and Bechtel Foundation. This project serves over a hundred students and a dozen teachers in several locations around the city. Also, he created a service-learning class, Mathematical Circles, which helps to train students to teach in this program. With regards to the latter, he has worked extensively in teacher-training programs around the country, and serves on several editorial boards, and in 2010 edited and helped to translate the American edition of a celebrated Russian work, *Malyshi i Matematika* ("Kids and Math"), by Alexander Zvonkin.

Most recently, he was a co-founder of an independent secondary school, Proof School, for children with passion for mathematics in grades 6–12. Proof School opened in September 2015. He is currently serving as the chairman of the board of trustees of Proof School. He also is starting a math circle for local teachers, to be held at Proof School, beginning December 2016. This project is sponsored partly by the American Institute of Mathematics, and Cornelia Van Cott will be part of the leadership team.

2.3.4 Problems Faced by Faculty

The most significant issue facing our faculty is office space. The department has grown substantially since the last Program Review, and we are feeling the crunch. One faculty member who works primarily with the MSAN program has no office space on the Main Campus, and must work wherever he can find space.

This is not only an issue for full-time faculty. Adjunct faculty are sometimes five to an office, and they must plan their work on campus so as not to interfere with colleagues.

With the MSAN and BSDS programs growing, coupled with the fact that the Computer Science major (a large major on campus) now requires Calculus I for their degree program, this problem will not disappear, but will be exacerbated.

2.4 The Curriculum

2.4.1 Service curriculum

All USF students are required to take four units in math or a quantitative science as part of the Core Curriculum. Courses satisfying this requirement comprise the majority of courses taught by the math department, and we list them below. Highlights in the service curriculum include the two first-year seminars which are described in more detail.

- **Math 100 Great Ideas in Mathematics**

  This course is an overview of some of the seminal achievements in mathematics from ancient to modern times. Topics include properties of real numbers, number theory, set theory, infinity, geometry, topology, probability, and statistics.

- **Math 101 Elementary Statistics**

  This standard course is required for nursing and sociology majors.

- **Math 102 Biostatistics**

  This standard course is required for biology majors; it is not much different from Math 101.

- **Math 104 Algebra for Business & Science**

  This 2-unit course is a prerequisite for students whose test scores upon entering USF are not high enough to take other required math courses.

- **Math 105 Mathematics for Educators**

  All students in the Dual Degree in Teaching Preparation Program at USF are encouraged to take this course to fulfill their Core Curriculum math requirement.

- **Math 106 Business Statistics**

  This course is required for all students in the USF Business School. In Fall of 2014, we renamed the course from Quantitative Methods in Business to Business Statistics.

- **Math 107 Calculus for Liberal Arts**

  This one-semester introduction to calculus is designed for non-science majors. Students majoring in architecture and community design and students minoring in architectural engineering are required to take either this course or Math 109 Calculus and Analytic Geometry I.

- **Math 108 Precalculus**

  Topics include polynomial functions; factor and remainder theorems; complex roots; exponential, logarithmic, and trigonometric functions; and coordinate geometry.

- **Math 195 First-Year Seminar**

  First year seminars are designed and taught by faculty who have a special passion for the topic. The following first year seminars have been offered over the past seven years.

  Professor John Stillwell has consistently taught a first-year seminar known as *Math and the Impossible*. This course is a novel introduction to mathematics and its history. It tackles some of the most difficult ideas in math head on: the seemingly impossible concepts of irrational and imaginary numbers, the fourth dimension, curved space, and infinity. By focusing reason and imagination on several apparent impossibilities, the course aims to show interesting math to students whose major may be in another field, and to widen horizons of math students whose other courses are necessarily rather narrowly focused.

  In the spring of 2013, Visiting Professor Thomas Banchoff led a first-year seminar titled *Exploring the Fourth Dimension*. In this first year seminar students spent at least half of the time exploring ways writers and teachers have used the notion of dimension as a metaphor and also as more than a metaphor for something beyond our familiar experience. Topics included art and music; psychology and literature; physical, biological, and social science; and philosophy and theology. The other side of these explorations investigated patterns in geometry and arithmetic that gave new meaning to all the math which students had already seen and also gave insights into the new kinds of math being invented and discovered in the modern world.

  In the fall of 2016, Vincent Matsko started a freshman seminar titled *Math and Digital Arts*. It focuses on making digital arts with mathematics. The students learn how to create their own digital images and movies in a laboratory style classroom. There is also an emphasis on using the computer to create various types of fractal images. The course focuses on the Sage and Python environment and teaches students to use Processing, as well.

- **Math 201 Discrete Mathematics**

This course, required for computer science majors, is a standard treatment of truth tables, proof methods, counting, graph theory, algorithms, etc.

- **Math 202 Linear Algebra & Probability**

  This course is required for computer science majors. It is a combination of matrix algebra, geometric applications of linear algebra, and topics in probability.

2.4.2 Curriculum for Math Majors

2.4.2.1 Courses The complete list of courses taught for math majors is as follows:

- Lower division courses
  - Math 109 Calculus & Analytic Geometry I
  - Math 110 Calculus & Analytic Geometry II
  - Math 201 Discrete Mathematics
  - Math 211 Calculus & Analytic Geometry III
  - Math 230 Elementary Linear Algebra (course number changed from 130 to 230 in Fall of 2013)
  - Math 235 Introduction to Formal Methods
- Applied mathematics courses
  - Math 340 Differential Equations
  - Math 345 Mathematical Modeling
  - Math 370 Probability with Applications
  - Math 371 Statistics with Applications
  - Math 422 Combinatorics
- Classical mathematics courses
  - Math 310 History of Mathematics
  - Math 314 Mathematical Circles (Problem Solving)
  - Math 350 Math Colloquium
  - Math 355 Complex Analysis
  - Math 367 Number Theory
  - Math 380 Foundations of Geometry
  - Math 395 Special Topics in Mathematics

- Math 435 Modern Algebra
- Math 453 Real Analysis
- Math 482 Differential Geometry
- Math 485 Topology

One of the biggest changes to the curriculum was to split the original Probability and Statistics class into two new classes on Probability (Math 370) and Statistics (Math 371) respectively to meet the needs of the Data Science major, as discussed in 2.2.1.

One course on the above list which is unique to USF is Math 314 Mathematical Circles. This course is taught by Paul Zeitz and Cornelia Van Cott using Zeitz's book *The Art and Craft of Problem Solving*. Students in the course spend the semester exploring problem solving methods up to the Putnam level. In addition, they volunteer outside of class time with junior high and high school students in the San Francisco Math Circles program. This course meets the Service Learning Requirement from the Core Curriculum.

The courses are offered at differing intervals. Calculus I and Calculus II are offered every semester. Calculus III, Linear Algebra, and Formal Methods are offered once a year. All upper division courses are offered *every two years* to keep enrollments up. The infrequency of class offerings (and the occasional canceling of a course due to low enrollment) can be problematic for students who need particular classes for graduation or as prerequisites. As a result, students often ask faculty members to teach independent studies on the needed topics, which can be found in Section 2.4.3.

2.4.2.2 Requirements Math majors are required to take three semesters of calculus, linear algebra, and a proof-writing course. Beyond this, students must take six upper division math courses. One of these six courses must be either modern algebra or real analysis. A second course must be in applied mathematics, and a third must be in classical mathematics. In addition to these math courses, majors are required to take one computational course, such as CS 110 Introduction to Computer Science and two units of Math Colloquium. This is a one-unit course in which students are required to attend biweekly math talks given by invited math professionals.

Altogether, the major requires 48 units of coursework, not including the colloquium classes.

The department offers an honors major, as well. To complete the honors major, students must satisfy all the requirements for a math major and additionally take two semesters of calculus-based physics and three more upper division math courses, including at least one 400-level course. Although we have an honors major, we do not have a uniform "capstone" requirement.

2.4.3 Beyond the Requirements

At times, students request independent studies that cover deeper mathematical topics not in the standard curriculum. Below are recent topics along with its instructor.

Math 398: Independent Study

- Linear Systems, Jennifer Chubb, Spring 2011
- Introduction to R Programming, Steve Devlin, Spring 2012 and Fall 2013
- Introduction to Knot Theory, Emille Lawrence, Spring 2013
- Analytic Number Theory, Paul Zeitz, Fall 2013
- Algebraic Topology, Cornelia Van Cott, Fall 2013
- Advanced Topics in Modeling, David Uminsky, Spring 2014
- Galois Theory, Paul Zeitz, Fall 2014
- Reverse Mathematics, Jennifer Chubb, Fall 2014
- Numerical Analysis, Peter Pacheco, Fall 2014
- Advanced Linear Algebra, Steve Devlin, Spring 2015
- Statistical network analysis, James Wilson, Fall 2015 and Spring 2016
- Representation theory, Steve Devlin, Spring 2016
- Algebraic Number Theory, Paul Zeitz, Spring 2016
- Dynamical systems, David Uminsky, Fall 2016
- Linear regression, Nathaniel Stevens, Fall 2016
- Advanced Number Theory, John Stillwell, Fall 2016

Occasionally, the interest level in special topics is high enough to create a special topics course, listed as Math 395 Special Topics in Mathematics. In the spring of 2011 and in the fall of 2015, Professor Jennifer Chubb offered a Quantum Computing special topics course.

Another area of activity for the department has been undergraduate research. The following is a list of recent projects:

- [Name Redacted] (2013-2014, advised by Steve Devlin)
  Project: A network based algorithm for ranking NBA players
  Result: [Name Redacted] gave a talk at the 2014 Joint Mathematics Meetings in Baltimore, MD.
  Abstract: We introduce a network based algorithm for ranking NBA players, which shares ancestry with other network based ranking methods like Google's PageRank, and the methods of Keener and Colley. Two players are connected by an edge when they have played against each other for a (non-trivial) period of time during a regular season game (or games). Each edge is then weighted by a score that measures the success of one player against the

other, and is computed from readily available play-by-play data. Once the edge weights are specified, we formulate a graph diffusion problem on the network. The player ranking arises as a solution to the diffusion problem, and is given by an eigenvector corresponding to the Perron-Frobenius eigenvalue of the associated matrix. As the solution to a diffusion problem, one can argue that the ranking arises organically from the data in a way that coefficient ranking methods like PER and Wins Produced do not, and is more intuitive and less suspect in its interpretation than multiple regression models like APM. Regardless, the method here provides a useful point of comparison that can help evaluate strengths and vulnerabilities of existing ranking methodologies.

- [Name Redacted] (2015-2016, advised by Jennifer Chubb)
  Project: Detecting algebraic properties from finite descriptions of groups
  Result: [Name Redact has admitted by the Ph.D program at the University of Washington in Fall 2016, and the collaboration is ongoing.

  Abstract: Given a finite description of a group in the form of a finite presentation, or a finite algorithm to enumerate a recursive presentation, it can be very hard to determine whether or not the group exhibits a specific property. When it is possible to effectively detect a property from a description, we say that the property is recursively recognizable within that class of descriptions. When it is not, we can describe how difficult it is in terms of Kleene's arithmetical hierarchy of sets. For example, one of our early results was that detection of non-trivial partial orderability is Σ_2^0 complete in the class of recursively presented groups, in particular, this is not a decidable property.

- [Name Redacted] (advised by Paul Zeitz)
  Project: Computing fixed fields for 7th-degree polynomials

- [Name Redacted] (advised by David Uminsky)

  Project: Project: On pattern formation in a non-isotropic setting

  Contribution to the Project:[Name Redact was a senior USF mathematics major who I was fortunate enough to mentor this past year in research related to this project. I first got her up to speed on the most recent progress on this project. She first re-derived many of the difficult stability calculations in the isotropic case and has also written matlab code to simulate many of the interesting pattern formations that occur in these systems. She is extending her code to the more challenging anisotropic setting. She is now attending NCST for her Ph.D. in mathematics

- [Name Redacted] , [Name Redacted] , [Name Redacted] (advised by Peter Pacheco and David Uminsky)

  Project: Rezoning Strategy for Arbitrary Lagrangian-Eulerian (ALE) Methods

  Contribution to the Project: Co-mentored by myself and Peter Pacheco (USF) on the project in collaboration with LLNL. Specifically[Name Redacted] worked with undergraduates [Name Redacted] and [Name Redacted] on a Reference Jacobian Rezoning Strategy for Arbitrary Lagrangian-Eulerian (ALE) Methods. They spent significant portions of time working with the LLNL code and planning out new rezoning strategies. [Name Redacted] graduated the MS in Analytics in 2016 and is now a data scientist at Eventbrite. [Name Redacted] is now attending a Ph.D. program in Nuclear Engineering at University of Florida.

- [Name Redacted] (advised by David Uminsky)

  Project: Studying how information propagates on a non local network model

  Results: She developed the numerical simulations of this model and characterized several important relationships between the attractiveness of the information and the decay rates of that information.

- [Name Redacted] (advised by David Uminsky)

  Project: Collaborative filtering for course recommendation and grade prediction

  Results: This work was co-mentored during a research program at UCLA. She is now attending UIUC for a Ph.D. in CS.

- [Name Redacted] (advised by David Uminsky)

  Project: A validated mathematical model of cell-mediated immune response to tumor growth Cancer Research

  Result: [Name Redacted] did fantastic work on a course grained tumor model which was recently developed in LG de Pillis, AE Radunskaya, CL Wiseman. A validated mathematical model of cell-mediated immune response to tumor growth Cancer Research 65 (17), 7950-7958. [Name Redacted] has cranked through a lot of the dynamical systems calculations and a publication is expected.

- [Name Redacted] (Co-mentored by David Uminsky during the summer UCLA research experience)

  Project: Plume detection on hyperspectral data

  Results: A refereed conference proceedings paper has been published on the material.

- [Name Redacted] (advised by David Uminsky)

  Project: On the isotropic assembly problem

  Results: [Name Redacted] began working directly on the isotropic assembly problem. He worked diligently through the first theoretical papers Uminsky had written but found he did not have enough time to continue the work and keep up with his studies. [Name Redacte is in graduate school in Statistics at the University of Chicago.

- [Name Redacted] (advised by David Uminsky)

  Project: Unsupervised Learning algorithm for clustering mutual fund performance

  Results: [Name Redacted] is now enrolled in UC Boulder's Ph.D. program in mathematics.

- [Name Redacted] (advised by David Uminsky and Mario Micheli)

  Project: Image Processing

  Results: She learned the fundamental theory and practice of image processing, and implemented different algorithms for the purpose of sharpening images that were affected by excessive blur caused by different factors: for example, (i) by aging in analog photos that were digitized, or (ii) by atmospheric turbulence in long range imaging or astronomical imaging. In addition she was co-mentored during a UCLA summer research project using image processing on imaging of nano-gold particles. A manuscript has been accepted for publication. [Name Redact is now attending graduate school in applied mathematics at Imperial College (London).

2.5 The Majors

Student Profile for Data Science and Mathematics Majors

With the addition of data science, our student numbers have approximately doubled over the last several years. The data science program was introduced in Fall 2013. That first year, there were only two students enrolled in the major. Since then, the number of majors has consistently increased each year, and as of Fall 2016 there were 44 students who have declared data science as their major. Presently, data science and mathematics majors are equally split in numbers with 43 mathematics majors.

The growth of the data science major does not appear to have strongly affected the number of enrolled mathematics majors. Indeed since Fall 2012, there have been between 38 and 48 majors, and the there is no apparent increasing or decreasing trend in these numbers. Since our last program review for 2003 – 2010, the number of mathematics majors has grown approximately 23% from an average of 35 in the prior time period to an average of 43 in this time period. See the figure below for more detail.

The gender profile for both data science and mathematics is promising relative to the national average. For mathematics, nearly 50% of students enrolled as a major are female, and this trend has remained consistent since Fall 2012. Compared to the 2014 national average of 42%, the USF Mathematics Department is attracting a diverse pool of both men and women. In data science, only 33% of majors are female; however, according to a 2015 poll only 25% of current data science majors are female. This suggests again that we have a more diverse pool of students than the average university program. This trend of 33% female majors has remained consistent since Spring 2014.

Approximately 25% of our majors are international students. It appears that the proportion of international mathematics majors have decreased by about 5 percent in the past year, although the

Figure 3: A breakdown of new and continuing students of data science and math majors since 2012.

proportion of international students in data science has consistently increased since 2014.

Student groups and activities

In Fall 2016, several of our data science majors founded the undergraduate Data Science Club. The club has about 45 members, of which approximately 10 students are majors outside of Data Science. Professor James Wilson is the faculty advisor for the club. The club has been active in many ways. Two notable initiatives of the students include:

- leading a volunteer group to help middle and high school students learn to code, which is sponsored by Facebook, and
- leading outreach initiatives within USF, where members are helping students in other majors solve data-driven problems in their studies.

Students also have their own LinkedIn group, which will help with job placement and networking for old and new graduates from the program.

We also have a chapter of Pi Mu Epsilon on campus (a mathematics honor society). Every spring, we have an induction ceremony for the new members, organized by Professor Steve Devlin.

Other student activities include a combination of social and academic activities. Every December, many of our students take the Putnam Exam. In the spring, the women professors host the Women in Math Senior Lunch. Every Wednesday, students attend Math Tea, and our department's End-of-Semester Pizza Party is always a huge success.

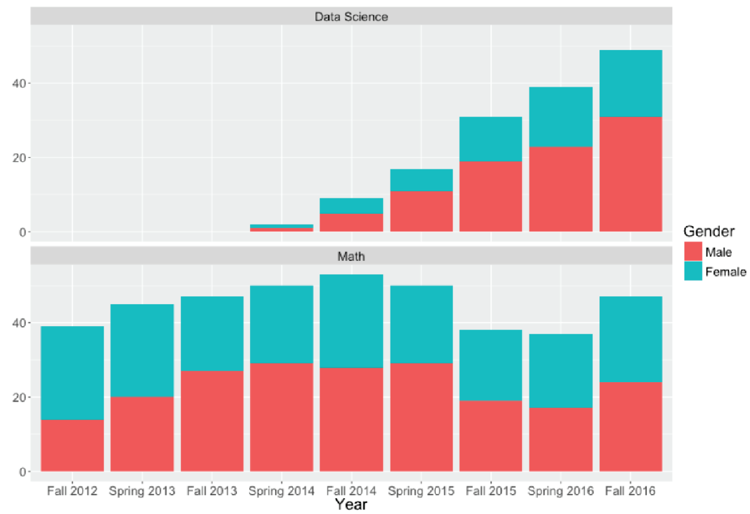

Figure 4: A breakdown of the gender of student majors in data science and math since 2012.

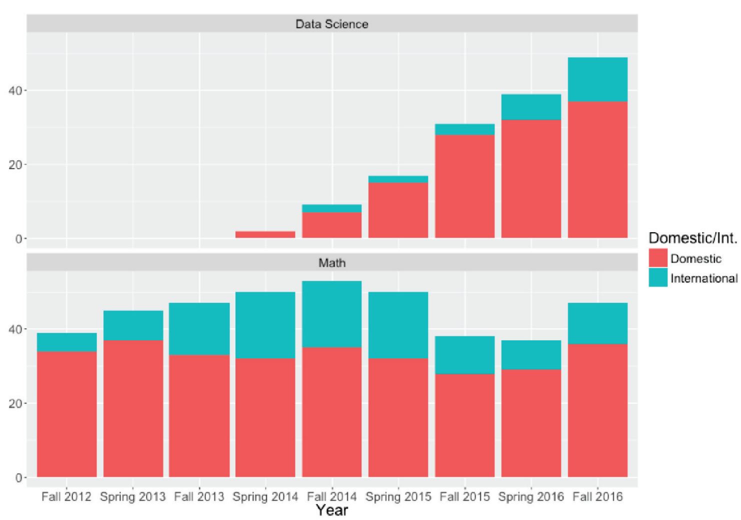

Figure 5: The domestic status of data science and math majors since 2012.

Student job placement after graduation

Our students follow an array of paths following graduation. A few become teachers, but currently most of our majors enter the workforce or go to graduate school. In the past calendar year, recent grads went off to graduate school at University of Washington, University of Chicago, North Carolina State University, University of Colorado-Boulder, and Imperial College in London. We also had a student enroll in the USF Analytics master's program—something we expect to see more and more as our program grows.

Beyond this recent history, we only have anecdotal information about where our students end up professionally. In an effort to better track our graduates, in March 2016 we started a LinkedIn group for our alumni. The group currently has 53 members. Through this group, our current majors can look at our alumni's professional profiles and envision concrete possibilities for their own careers.

Attracting Majors

Our goal is to take advantage of every opportunity to attract interested, talented students to our department. The fact that we are centrally located in the "Tech capital of the world" will continue to attract new and diverse majors. However, to fully capitalize on our unique position, we plan to continue growth in several ways, including

- speaking and participating in events with prospective students in conjunction with the USF Office of Admissions
- communicating with admitted students interested in mathematical sciences who have not yet agreed to attend USF
- recruiting talented students in our lower division courses to either the math or data science major
- developing courses that are particularly useful to outside departments. Our first aim is to promote our newly developed courses in statistics such as regression, intro to data science, and machine learning.
- establishing a strong online presence by promoting use of LinkedIn for students and alumni
- providing a link between the BSDS program and the MSAN program through a $4+1$ program that, conditional on performance, guarantees acceptance to the prestigious MSAN program.

3 Summary and Preliminary Development Plan

Our last few self-studies have described a typical midlevel liberal arts mathematics department, notable for its unusual collegiality, struggling somewhat to maintain an adequate number of majors, followed by a preliminary development plan that focused on recruiting new faculty, making the curriculum more attractive to new majors, and improving departmental space.

This is no longer an accurate description. Our department, or more precisely, our departmental ecosystem, now has grown dramatically in both majors and faculty, and is no longer a traditional liberal arts department. The only pressing development need that has not changed is the acute need for better space for our faculty. Besides this, our concerns are more subtle, but extremely important: we have grown so much and so quickly, that it is not clear what kind of department we are, and what we should become. As outlined in 2.1.2, we are at a crossroads, and decisions made over the next few years will have important consequences for our future.

The crucial issue is organizational: are we to divide into three independent entities (math, data science, analytics), perhaps splitting off a fourth (statistics), or can we find a way to coordinate all of these "mathematical sciences" activities in one cohesive entity? One of the greatest qualities of our department has been its unusually strong collegiality. The recent changes have not harmed this, at least not yet, but change is inherently destabilizing. It is essential that we evolve in a collegial way.

Consequently, we welcome this program-review visit, and we are hopeful that you may be able to provide a fresh, outside perspective to help us to decide (in tandem with our dean) on the best path forward.

Besides this complex "crossroads" question, our needs are clear:

- We should continue our efforts to recruit more and better majors, although we no longer have the pressure to succeed that obtained just 6 years ago. We have offered our assistance to the Admissions Office in increasing the yield of admitted students with a declared interest in mathematics, and we are hopeful that this effort may bear fruit.
- The momentum put in place by hiring Stevens and Wilson should lead to a growing investment in statistics, which means we will need the Administration to allow us to hire more faculty in the near future, most likely with degrees in statistics or hybrid data science training.
- Even if the Administration will agree to our proposal to use the Getty Study in the CSI for our weekly Math Tea, this will still not provide a dedicated, congenial space where math-stats majors can work and socialize together. The shortage of offices for adjunct faculty remains dire and will certainly only get worse. More seriously, even the creation of two new windowed offices (by reconfiguring our existing space) for tenure-track faculty will certainly not completely solve our shortage of professional offices, and the hiring of additional tenure-track statistics faculty will only exacerbate this problem.

Our ancillary materials include a brief description of assessment issues, below. Not included with this document is Excel file (**enrollment.xlsx**) showing trends in enrollment in our non-service courses, along with CVs of all faculty.

A Assessment

This is the first Self Study that includes "assessment boilerplate" materials, since there has been pressure (from WASC to our deans, and then from our deans to us) to do more of this. Presumably, like most mathematical sciences departments, we are not unique in resisting this trend, and indeed what is included here is pretty sketchy, and not quite what our deans requested. The general trend is toward "matrices" and "curricular maps". We have tried to keep things more holistic; the jury is still out.

A.1 Departmental Mission Statement

To provide our students with an understanding of mathematical thought and knowledge; the ability to use this understanding to produce and communicate mathematics; and the preparation to apply these skills in advanced degree programs and/or careers requiring expertise in mathematics.

A.2 Program Learning Outcomes

1. Use techniques of differentiation and integration of one and several variables;
2. Use differentiation and integration to solve problems in mathematics and other disciplines
3. Solve and understand linear systems;
4. Give direct proofs, proofs by contradiction, and proofs by induction; formulate definitions and construct counterexamples
5. Read mathematics without supervision; write mathematics with correct style, including typsetting
6. Apply mathematics to problems in other disciplines; and
7. Use technology to solve mathematical problems.

A.3 Assessment Plan

We have decided not to reinvent the wheel, nor to go the map-and-matrix route. So we administered an ETS exit exam last May (2016) to 12 graduating seniors. With only one cohort it is hard to interpret, but our initial (but not fully formed) impression is that our students are doing fine (i.e., close to national medians).