The University Senate of Michigan Technological University

Proposal 14-18
(Voting Units: Academic)

"A Proposal for a New Master of Science Degree in Applied Statistics"

(Department of Mathematical Sciences)

1. **Date submitted:** October 9, 2017.
2. **Contact:** Mark S. Gockenbach, Professor and Chair, Department of Mathematical Sciences (msgocken@mtu.edu, 487-2068).
3. **Interdisciplinary support:** not applicable.
4. **General description and characteristics of program:** There is no accrediting agency for degree programs in Statistics. However, the American Statistical Association organized a working group that recently published the "Report of the ASA Workgroup on Master's Degrees" (November 2012[1]). This report made the following recommendations:

   (a) Graduates should have a solid foundation in statistical theory and methods.

   (b) Programming skills are critical and should be infused throughout the graduate student experience.

   (c) Communication skills are critical and should be developed and practiced throughout graduate programs.

   (d) Collaboration, teamwork, and leadership development should be part of graduate education.

   (e) Students should encounter non-routine, real problems throughout their graduate education.

   (f) Internships, co-ops or other significant immersive work experiences should be integrated into graduate education.

   (g) Programs should be encouraged to periodically survey recent graduates and employers of their recent graduates as a means of evaluating the success of their programs and to examine if other programmatic changes are warranted.

   The first five recommendations imply desirable learning goals and outcomes. We have designed the proposed degree program so that students will achieve the corresponding outcomes, as follows.

   (a) **Graduates can choose a statistical method that is appropriate for a given problem, can apply that method, and can draw appropriate conclusions.** All students must take a two-semester sequence on Mathematical Statistics, the basic theory of statistics. They take a survey course on traditional Statistical Methods, a cutting-edge course on Predictive Modeling, and a course on Computational Statistics. In addition, each student must take five elective courses on statistics.

[1] http://magazine.amstat.org/wp-content/uploads/2013an/masterworkgroup.pdf

(b) **Graduates can use popular statistical software to solve realistic problems.** Programming and the use of statistical software are taught directly in the required course on Computational Statistics (currently, the packages SAS and R are emphasized.) Most of the other required courses and electives (except the Mathematical Statistics sequence) involve significant use of statistical software for course homework and projects.

(c) **Graduates can summarize and explain the results of statistical analyses orally and in writing.** Several of the required courses and electives assign significant projects with oral or written reports. For instance, Predictive Modeling requires two in-class presentations and a written report. Computational Statistics requires an in-class presentation and a final written report. Statistical Consulting gives students experience in communicating with clients.

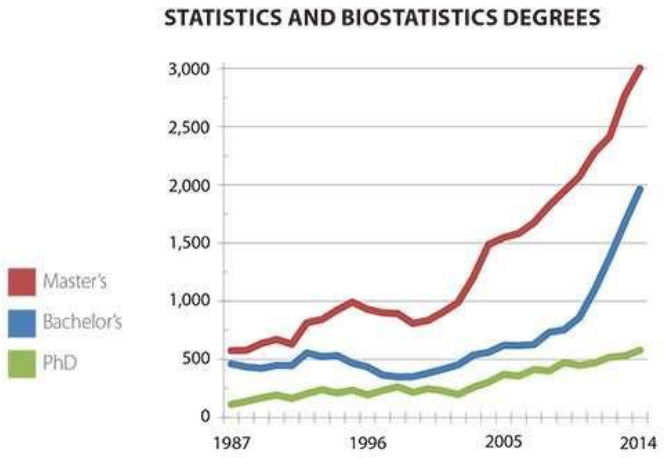
(d) **Graduates have experience working in teams.** One of the required courses (Predictive Modeling) assigns a team project. The elective course on Statistical Consulting also requires a team project. Many of the courses involve occasional group work.

(e) **Graduates know how to work with real data. They can clean the data, deal with missing data values, and generally appreciate the complexities of handling real-world data.** Most of the required courses and electives (again, excluding the Mathematical Statistics sequence) assign problems or projects involving real data. Several of the courses require significant projects.

Students are encouraged, but not required, to complete an internship.

5. **Rationale:** "Statistician" is number seven on the Bureau of Labor Statistics (BLS) list of fastest growing occupations, with a predicted increase of 33% in positions over the period 2016-2026. (The average growth for all occupations is predicted to be about 7%.) According to the BLS, "[s]tatisticians typically need at least a master's degree in statistics, mathematics, or another quantitative field. However, a bachelor's degree is sufficient for some entry-level jobs."

   Across the United States, the number of statistics degrees awarded has been steadily increasing, as shown in the following chart[2]:



[2]Taken from *Statistics Degrees Continue Strong Growth*, Amstat News (American Statistical Association), 1 October 2015, http://magazine.amstat.org/blog/2015/10/01/statistics-degrees-continue-strong-growth/

As these data show, there is strong demand for advanced degrees in Statistics, both from students and the job market. The proposed M.S. in Applied Statistics aims to prepare students for the job market, where the master's degree is the most common entry-level degree.

6. Related programs:

(a) At Michigan Tech:

i. M.S. in Data Science (interdisciplinary program). This is a broader curriculum, including work in computer science and application areas in addition to statistics. Depending on the individual student's choice of electives, 10% to 50% of the course-work in the Data Science curriculum consists of statistics courses.

ii. M.S. in Statistics (new degree, also proposed Fall 2017). This curriculum is some-what more theoretical, requiring a two-semester graduate sequence on Mathematical Statistics, as well as a graduate-level course on Linear Models. Many graduate elec-tives in Statistics are available to both programs.
The M.S. in Statistics should definitely be preferred by students considering a PhD in Statistics.
Note: The M.S. in Statistics is a new degree, but it is essentially the same as the current M.S. in Mathematics Sciences (Statistics focus area). It is being changed to a stand-alone degree to give it more visibility.

(b) At other institutions: Numerous institutions in the state and around the country offer a master's degree in Applied Statistics. Here are three examples from the state of Michigan:

i. Michigan State University, M.S. in Applied Statistics. This degree requires five courses, three graduate electives in statistics, and three additional electives in statis-tics or a cognate discipline. Four of the required courses correspond directly to courses we require.

ii. University of Michigan—Ann Arbor, M.S. in Applied Statistics. The prerequisite re-quirements are greater (a course in probability and a course in mathematical statis-tics) and therefore there is less overlap in degree requirements with our proposed program. There are five required courses, plus at least three electives in statistics or biostatistics and one or two electives in a cognate discipline.

iii. Oakland University, M.S. in Applied Statistics. Requirements include a two semester sequence in Applied Linear Models, a two-semester Introduction to Mathematical Statistics, 20 credits of electives (at least 12 in Statistics or Biostatistics), and an applied statistics project.

7. **Projected capacity:** We are simultaneously proposing an accelerated option for Michigan Tech students to complete the B.S. in Statistics and M.S. in Statistics in five years. Combined capacity for the two programs is 10 students with no new resources, 25 students with an additional faculty position. The majority of new enrollment is expected from this degree.

8. Scheduling plans:

(a) Regular (3 semesters in residence). The degree requires ten courses (30 credits), which can be completed during three semesters in residence. A model schedule is provided below. Note that new students will be admitted only in the fall.

(b) Online/on-campus hybrid (2 semesters in residence). The required courses MA4760 and MA4770 (Mathematical Statistics I and II) will be offered in an online format starting with the 2018-19 academic year. By completing these courses online, students will be able to complete the M.S. in Applied Statistics with two semesters in residence. A model schedule is provided below.

(c) Accelerated (4+1 B.S./M.S. option) The M.S. in Applied Statistics will be available in an accelerated format to Michigan Tech students with any undergraduate major other than Statistics, provided the required prerequisites are satisfied. These are the three-semester sequence in calculus (MA1160, MA2160, MA3160), linear algebra (MA2320 or MA2321 or MA2330), introductory statistics (MA2710 or MA2720 or MA3710 or MA3715), and probability (MA3720). (Note that engineering students complete all of these course, with the exception of MA3720, as part of their degree requirements.)

We do not anticipate a significant enrollment from this option, but it does not cost anything to offer it. A model schedule is provided below.

9. **Curriculum design:** The M.S. in Applied Statistics will be offered under the Coursework option (no comprehensive examination). Here are the course requirements:

(a) Complete the following required courses.

MA4760	Mathematical Statistics I	Fall
MA4770	Mathematical Statistics II	Spring
MA5701	Statistical Methods	Fall
MA5761	Computational Statistics	Fall
MA5790	Predictive Modeling	Fall

(b) Complete five electives, chosen from among the following:

MA3740	Statistical Programming & Analysis	Fall, Spring
MA4710	Regression Analysis	Fall
MA4720	Design & Analysis of Experiments	Spring
MA5702	Statistical Consulting	Spring
MA5711	Mathematical Statistics I	Fall
MA5712	Mathematical Statistics II	Spring
MA5730	Nonparametric Statistics	Fall (alternate years)
MA5731	Linear Models	Fall
MA5732	Generalized Linear Models	Spring (alternate years)
MA5741	Multivariate Statistical Methods	Spring
MA5750	Statistical Genetics	Spring (alternate years)
MA5770	Bayesian Statistics	Fall (alternate years)
MA5781	Time Series Analysis and Forecasting	Spring
MA5791	Categorical Data Analysis	Spring (alternate years)

With prior approval of an advisor, cognate courses (at most two) may also be used as electives.

10. **New course descriptions:** None. The schedule of offered courses is being modified to meet the needs of the different model schedules; also, MA4760 and MA4770 will be offered online to allow for the hybrid online/on-campus option.

11. **Model schedules:**

Model schedule to complete degree in three semesters Students must enter with prerequisites (a three-semester sequence in calculus, linear algebra, introductory statistics, probability) already completed. Students are only admitted to begin in the fall semester.

Year 1:

Fall: MA4760, MA5701, plus an elective chosen from the following:

- MA3740 Statistical Programming & Analysis
- MA4710 Regression Analysis
- MA5730 Nonparametric Statistics (offered in odd years)
- MA5731 Linear Models
- MA5770 Bayesian Statistics (offered in even years)

Spring: MA4770, plus three electives chosen from the following:

- MA3740 Statistical Programming & Analysis
- MA4720 Design & Analysis of Experiments
- MA5702 Statistical Consulting
- MA5741 Multivariate Statistics
- MA5750 Statistical Genetics (offered in odd years)
- MA5781 Time Series Analysis & Forecasting
- MA5791 Categorical Data Analysis (offered in even years)

Year 2:

Fall: MA5761, MA5790, plus one elective chosen from the following:

- MA3740 Statistical Programming & Analysis
- MA5730 Nonparametric Statistics (offered in odd years)
- MA5731 Linear Models
- MA5770 Bayesian Statistics (offered in even years)

Model schedule for hybrid online/on-campus option Students can take all necessary prerequisites (three semesters of calculus, linear algebra, introductory statistics, probability) at their home university, take MA4760 and MA4770 online from Michigan Tech, and then complete the degree with two semesters in residence, as follows:

Fall: MA5701, MA5761, MA5790, plus MA4710 or MA5730 or MA5770

Spring: Four electives chosen from among the following:

- MA4720 Experimental Design
- MA5702 Statistical Consulting
- MA5741 Multivariate Statistics
- MA5750 Statistical Genetics (offered in odd years)
- MA5781 Time Series Analysis & Forecasting
- MA5791 Categorical Data Analysis (offered in even years)

Model schedule for accelerated M.S. Students must be admitted to the accelerated M.S. degree before graduation and preferably before the beginning of the senior year. The following courses, to be taken in the senior year, will count toward the M.S. degree and also toward the B.S. degree (though possibly only as free electives):

MA4710	Regression Analysis	Fall
MA4720	Design and Analysis of Experiments	Spring

The following model schedule completes the Mathematics major (General Mathematics concentration) and the M.S. in Applied Statistics in five years. A student from another major must complete the prerequisites, which are indicated in bold type.

Year 1

Fall: (14 credits)

- UN1015 (Composition)
- CH1150 (University Chemistry I)
- CH1151 (University Chemistry Lab I)
- MA1910 (Exploring Symmetry Groups) (free elective credit)
- **MA1160 (Calculus with Technology I)**

Spring: (16 credits)

- UN1025 (Global Issues)
- GE 2000 (Understanding the Earth)
- **MA2160 (Calculus with Technology II)**
- **MA2330 (Introduction to Linear Algebra)**
- General Education Critical and Creative Thinking Core course

Year 2

Fall: (16 credits)

- **MA3160 (Multivariable Calculus with Technology)**
- MA3210 (Introduction to Combinatorics)
- General Education Social Responsibility and Ethical Reasoning Core course
- HASS Communication/Composition course (3 credits)
- Free electives (3 credits)

Spring: (15 credits)

- MA1600 (Introduction to Scientific Simulation)
- **MA2710 (Introduction to Statistical Analysis)**
- MA3560 (Math Modeling with Differential Equations)
- HASS Humanities and Fine Arts course (3 credits)
- Free electives (3 credits)

Year 3

Fall: (16 credits)

- MA3310 (Introduction to Abstract Algebra)
- **MA3720 (Probability)** (free elective credit)
- HASS Social and Behavioral Sciences course (3 credits)
- Free electives (7 credits)

Spring: (16 credits)

- MA3450 (Introduction to Real Analysis)
- MA4410 (Complex Variables)
- HASS course (3 credits)
- Free electives (7 credits)

Year 4

Fall: (16 credits)

- MA4450 (Real Analysis)
- **MA4710 (Regression Analysis)**
- MA4945 (History of Mathematics)
- Free electives (7 credits)

Spring: (15 credits)

- MA4310 (Abstract Algebra)
- **MA4720 (Design & Analysis of Experiments)**
- MA4908 (Number Theory with Technology)
- Free electives (6 credits)

Year 5:

Fall: MA4760, MA5701, MA5761, MA5790

Spring: MA4770, plus three electives chosen from the following:

- MA5702 Statistical Consulting
- MA5732 Generalized Linear Models (offered in even years)
- MA5741 Multivariate Statistics
- MA5750 Statistical Genetics (offered in odd years)
- MA5781 Time Series Analysis & Forecasting
- MA5791 Categorical Data Analysis (offered in even years)

Note that this schedule assumes that students will take four courses per semester during year 5. To reduce this load, students can opt to take one or two courses in year 4 under the senior rule (if practical—this will work for the schedule of some students, and not for others).

12. **Library and other learning resources needed:** None.

13. **Faculty resumes:** www.math.mtu.edu/~msgocken/StatisticsCVs.

14. **Description of available/needed equipment:** The Tech standard computer lab image includes the statistical software packages R and SAS, and also standard office productivity software. This is sufficient for students in the M.S. in Applied Statistics. No other equipment is needed.

15. **Program costs, years 1, 2, and 3:** Projected enrollments are as follows:

Year	# of students
2018-19	5
2019-20	10
2020-21	20
steady state	25

Program costs consist of additional sections that must be offered to accommodate the projected enrollment. Note that no new courses will be offered, but certain popular courses will be offered twice per year instead of once per year to meet the demand.

Year	# additional sections	Cost
2018-19	2	$18,000
2019-20	3	$27,000
2020-21 and after	4	$36,000

16. **Space:** No new space is needed.

17. **Policies, regulations, and rules:**

(a) Admission to the degree under the regular and hybrid online/on-campus schedules follows usual departmental and graduate school policies.

(b) For the accelerated M.S., Michigan Tech students must apply before graduation and, for purposes of advising, are encouraged to apply before the beginning of the senior year. A cumulative GPA of 3.0 is required.

18. **Accreditation requirements:** not applicable.

19. **Planned implementation date:** Fall 2018

APPENDIX A

Department of Mathematical Sciences Information for Financial Evaluation

Proposed Master of Science degree in Applied Statistics Proposed Master of Science degree in Statistics Proposed PhD degree in Applied Statistics

1. **Introduction**

The Department of Mathematical Sciences currently offers an MS and PhD in Mathematical Sciences that can be completed with one of four focus areas: Computational and Applied Mathematics, Discrete Mathematics, Pure Mathematics, and Statistics. We propose to spin off the Statistics focus area to a stand-alone MS in Statistics, and PhD in statistics. The financial evaluation focuses on the MS in applied statistics which is an additional program, with the MS in Statistics and PhD in Statistics being existing programs continuing under different names.

2. **Relation to university Strategic Plan** This proposal supports Goal 2 (A distinctive and rigorous action-based learning experience grounded in science, engineering, technology, sustainability, business, and an understanding of the social and cultural contexts of our contemporary world), especially the sub-goals listed under 2.3:

    a. expand Ph.D. and masters enrollments, degrees awarded, and scholarly productivity;

    b. improve access via non-traditional delivery of graduate programs;

The main purpose of this proposal is to increase enrollment in master's degree programs. The proposed hybrid option (part online, part on-campus) is intended to improve access to the degree program.

3. **Impact on university enrollment**

    (a) We plan for a steady-state enrollment of 25 students for the MS in Applied Statistics

    (b) We expect the enrollment to represent new students (i.e. students who would not other- wise have enrolled in a graduate program at Michigan Tech).

    (c) There is considerable evidence of an increased national demand for statistics degrees (see our original proposal for details). This appears to be uncorrelated with existing enrollment patterns at Michigan Tech.

    (d) The department currently enrolls 114 BS, 9 MS, and 31 PhD students.

4. **Impact on resources required by department in which the program is housed**

    (a) The program will require no new courses, but we expect to offer as many as four new sections of existing courses (certain courses will be offered twice per year instead of the current once per year). This equates to one tenure-track faculty line. However, the department is in the process of filling a Lecturer position in Statistics that may make it possible to cover the required sections without a new faculty line.

    (b) Existing computer labs are adequate for the anticipated increased enrollment.

(c) Advising will be done by existing faculty, detracting slightly from time otherwise spent on teaching and research.

(d) The department will have to perform regular assessment of the new program, adding somewhat to faculty service loads. As with advising, this will have a small detrimental effect on faculty efforts in research and teaching.

5. **Impact on resources required by other units within the university**

(a) All required and most elective coursework will be delivered by the department. Students can take up to two cognate courses from other departments that count toward degree requirements. The additional enrollments should be small and spread out over various courses and departments. Therefore, this is not expected to be a significant burden on other departments.

(b) Existing library and IT resources are expected to be adequate for the additional enroll- ment. There may be a small additional need for Career Services (advising and employer outreach).

6. **Assessment of the ability to obtain the necessary resources assuming requested funds are obtained** There is no question that it is difficult to hire and retain statisticians. Nevertheless, the department has hired three tenured or tenure-track faculty in this area in the past five years and is about to fill a Lecturer position.

7. **Past proposals** The department created a BS in Statistics (effective Fall 2014). We proposed to increase the number of students graduating with the bachelor's degree in statistics from

2.75 per year to 10 per year. (Note: 2.75 was the average number of students graduating each year with a bachelor's degree in mathematics and concentration in statistics, before the degree in statistics was created.) This increase was to occur over five to six years. In the first three years since the degree was created, we graduated an average of four students per year, whereas we had hoped to be up to six or seven students per year by now.

The cost of the new degree program has been minimal. No new faculty were associated with the bachelor's degree in statistics.

The bachelor's degree in statistics has only slightly increased enrollment in the department (possibly by a handful of students).

8. **Departmental budget contribution**

(a) The Department of Mathematical Sciences General Fund base budget for FY17 was

$4,282,706. In addition, internal support for graduate students (GTAs) amounted to

$759,697, for a total of $5,042,403.

(b) During FY17, the department delivered 22,812 Student Credit Hours (SCH) at the under- graduate level (14,433 lower division and 8,380 upper division) and 930 SCH at the gradu-

ate level. The approximate (undiscounted) tuition revenue was
$6,898,974+$4,433,020+$856,530, a total of $12,188,524.

9. **How do the benefits from this program compare to other alternatives that are**

currently under consideration or development? The only other program being considered by the department is to offer this degree (M.S. in Applied Statistics) as an online degree. The approval of this degree will make that option possible. The department is not considering other programs at this time.