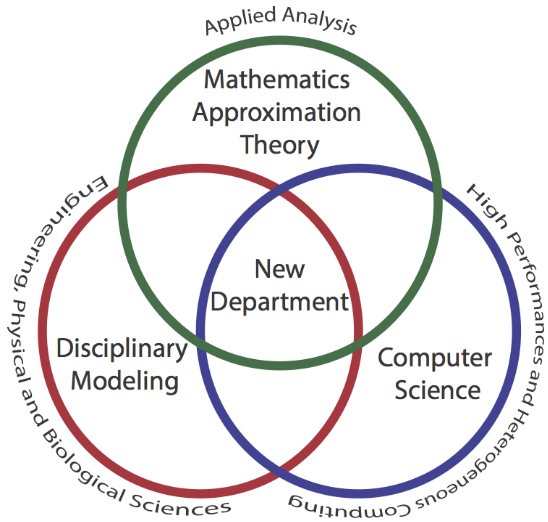
A proposal to make Michigan State University the world leader in Computational Mathematics, Science, and Engineering

Executive Summary: This proposal seeks to transform Michigan State University into the world leader in scientific discovery through large-scale computation. The Colleges of Natural Science and Engineering propose: (1) a new Department of Computational Mathematics, Science and Engineering (CMSE) that is jointly administered by the College of Natural Science and the College of Engineering, to facilitate interdisciplinary science; (2) the injection of 25-30 new faculty lines focusing on the science of computational modeling and data science; and, (3) the foundation for joint cutting-edge graduate and undergraduate programs. This effort will open doors to new scientific challenges, will enable MSU to compete for Center-level funding opportunities in computation-related areas that are currently beyond our reach, and will facilitate the training of scientists and engineers to be an effective 21st century workforce.

The metrics for success are as follows. Within 5 years, we will have hired the 25-30 world-leading research intensive faculty that form the backbone of this Department, who will bring in single-PI grants and small-scale (few-PI) collaborative grants, building the foundation for CMSE to develop large-scale funding. Furthermore, we will have successfully implemented a graduate program (including a graduate certificate, and CMSE and dual PhD and MS programs) and an undergraduate minor. These programs will establish student interest and demonstrate enrollment trends. Finally, this department will facilitate the growth of the university by participating in cross-cutting efforts such as the upcoming quantitative biology initiative. Within 10 years, the initiative will have secured Center-level funding (such as a DOD MURI center, a DOE SciDAC center, an NSF Science and Technology Center, or similar center initiatives coming from NIH or other federal agencies). We will have fully developed our undergraduate curriculum with the addition of Bachelor's programs in computational modeling and data science, and will have strong enrollment numbers in both our minor and B.S. programs - targeting on the order of 400+ minors and 200+ majors. At the graduate level, we will have implemented a professional Master's degree (including an online Master's), and our PhD program will have 75-100 graduate students.

CMSE is unique among computational academic units nationally, the first to comprehensively treat computation as the triple point of algorithm development and analysis, high performance computing, and disciplinary knowledge with applications to scientific and engineering modeling and data science. The CMSE paradigm shift recognizes computation as a new discipline rather than decomposed into isolated sub-disciplines, enabling application-driven computational modeling ("pull"), while also exposing disciplinary computationalists to advanced tools and techniques ("push"), which will ignite new transformational connections in research and education. This research nexus also gives rise to the educational opportunities driven by similar synergy, leveraging common resources among disciplines, and enabling joint programs and unique degrees across the entire computational space.

The key principles behind this proposal were developed over the 2013-2014 terms by an ad hoc committee with members from the Colleges of Natural Science (CNS) and Engineering (EGR). The 17 members of the committee represented a large portion of CNS and EGR[1]. The figure to the right is a visualization of the paradigm shift the new department represents, treating the science of computation as a discipline in its own right, instead of as isolated subdisciplines. In the following sections, we present arguments for the need for a new department as well as provide a strategy for how the University will accomplish the goal of building a world leading Department of Computational Mathematics, Science and Engineering over the next 10 years. We will start by examining national trends, describe the new interdisciplinary research that will be enabled, provide an overview of the graduate and undergraduate programs, outline partnerships with national labs, and conclude by proposing an administrative structure. In addition to what is discussed here, we can provide supporting documentation that includes case studies for world-leading faculty that we would be able to recruit due to this new initiative, case studies of new science that would be facilitated by such an initiative, and proposed degrees (including B.S. degrees in Computational Modeling and, separately, Data Science; an undergraduate minor; a Graduate Certificate, M.S., and PhD degrees).



National Trends

Computational science - i.e., the use of computational methods to solve scientific problems - is a rapidly evolving field, and universities are beginning to capitalize on this trend. Nationwide, there are 11 departments focusing on computational science in general, and 27 departments focusing on data science in particular, in the top 108 universities. Most were created in the last two decades. Furthermore, there are 24 PhD, 28 Masters, and 21 undergraduate programs in applied computing, as well as 37 PhD, 48 Masters and 22 undergraduate programs in data science in the same set of schools[2]. **Michigan State University is clearly behind its peers in this critical area**, to the point where we are the only Big Ten school that does not have an informatics or data science graduate program!

Facilitation of New Research

Modern problems in science and engineering bridge a vast range of temporal and spatial scales and include a wide variety of physical processes. Analysis of such problems is not possible, so

[1] Appendix A is a list of the committee members who helped developed the key ideas behind this effort.

[2] Consult Appendix B for a more complete listing.

one must turn to computation. To develop computational tools for such complex systems that give physically meaningful insight requires a deep understanding of approximation theory, high performance computing, and domain specific knowledge of the area one is modeling. Our national laboratories have addressed the interdisciplinary nature of computing by having experts in numerical algorithms co-located with disciplinary experts who have a deep understanding of computation, and who use scientific computing to address key topics in science (for example, Los Alamos National Laboratory's Computer, Computational, and Statistical Sciences Division[3]). This collaborative arrangement between algorithmic scientists and disciplinary scientists in the STEM fields is what facilitates the exploration of challenging multi-disciplinary and interdisciplinary topics that could not otherwise be addressed. **This key observation motivates the model for the proposed Department** - a place where we will attack the critical problems facing us in the 21st century, including renewable energy, clean water, and the role of DNA in predicting and maintaining human health. Furthermore, this department would strive to use computing as a critical tool to explore fundamental scientific questions in subjects as diverse as nuclear physics and evolutionary biology. In addition, the synergy of data-driven computational modeling, combining aspects of traditional scientific computing with data science and data mining, is an exciting topic that this new unit will be uniquely suited to address. This is a rapidly emerging field that touches many of the STEM disciplines, and attracting world-leading talent in this area is greatly facilitated by the introduction of the nurturing environment of CMSE to serve as their tenure home[4]. **Furthermore, the development of the Department of Computational Mathematics, Science, and Engineering will catapult MSU into the position of being a world leader in this critical new field,** and will open doors to new scientific challenges as well as new Center-level funding opportunities, such as the DoE SciDAC and NSF OCI SI2 programs (as well as similar programs out of NIH).

To jump-start this new department at the 'triple point' of mathematics, computer science and and discipline-specific computation, we propose recruiting faculty who are experts in numerical algorithms as well as those whose primary focus is the use of advanced computation to solve a wide range of challenging scientific problems. In addition, we wish to recruit scientists - *having joint appointments with other units at MSU* - whose expertise is computation on heterogeneous and/or distributed computing platforms, such as hardware-accelerated computing (e.g., GPU computing), cloud computing, and middleware for dynamic optimization across HPC architectures. To provide a critical mass, we propose hiring 25 to 30 new faculty across the aforementioned disciplines. Co-location and research and curriculum ties enable CMSE to break down historical disciplinary boundaries, and become the synergistic leading-edge center of computational activities on campus. Furthermore, co-locating these scientists will enhance the development of new computational algorithms to address pressing scientific needs and enable the creation and deployment of the robust numerical tools required for the pursuit of leadership-class science in virtual laboratories. **Most importantly, this department will**

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[3] http://www.ccs.lanl.gov/

[4] Examples of several new opportunities in terms of recruiting dynamic faculty in exciting areas who focus on algorithmic development are discussed in the supporting documentation (see Appendix C).

enable new science through these unique interdisciplinary collaborations and will become a focal point for computational research at MSU, bringing researchers in computational and data sciences together with domain experts in energy, clean water, neuroscience, digital evolution, accelerators, logistics, data analytics, and more.

Courses and Degree Programs

Creation of a robust, coherent set of undergraduate and graduate degrees, with accompanying courses, supports two complementary goals. First, a coherent program will allow the university to consolidate undergraduate and graduate training in computation in the STEM fields, reducing redundancy in the courses taught and allowing the university of offer a wider range of more specialized advanced courses. Second, we will create a robust set of degree, minor, and certificate programs that are designed to give STEM students a strong introduction to computing that will complement MSU's existing disciplinary training, and which will make them better suited to be a part of the STEM workforce in the 21st century. These programs will include: a B.S. in Computational Modeling; a B.S. in Data Science (including specializations in bioinformatics and mathematical foundations of data science); a M.S. and PhD in Computational and Data Science; and an undergraduate minor and graduate certificate in Computational and Data Science[5]. This range of options will allow some number of students to dive deeply into computation through the degree programs, and will enable a much broader swath of the MSU population to learn about some aspects of computational and data science through the minor, graduate certificate, or by taking individual courses. One desired result of the creation of these courses and programs is the foundation of a strong community of students from different disciplines who use similar techniques to solve a wide range of problems, which will promote broad, interdisciplinary thinking and will help to raise the visibility of computing in the sciences and engineering throughout the MSU campus. We note that a final benefit of these educational efforts is that MSU will become an ideal place to perform research in computational science education, a topic of critical importance that has thus far received little scholarly attention.

External Partnerships

Several national labs have expressed interest in multiple levels of interaction with CMSE. For example, the Computational Mathematics Group at Oak Ridge National Lab has expressed interest in partnering with the new department. The group is a world leader in scientific computing and covers a diverse area of topics including Data Science, Numerical Methods for Partial Differential Equations and scalable parallel algorithms for modern heterogeneous computing platforms, i.e. TITAN. The ORNL Computational Math group's interests align well with the stated goals of the new department, and the ORNL group has expressed strong support for the vision and objectives of the new department. Partnering with our national labs offers a unique opportunity to bring a diverse range of expertise to MSU in a wider area of computational methods. In addition, ORNL focuses on applying the new methods they are developing to some of the world's most challenging problems. The ORNL group represents the

[5] See Appendix D for proposed courses, undergraduate degrees, undergraduate minor, graduate certificate.

interdisciplinary approach to integrated problem solving we are proposing here at MSU. ORNL, LANL, and others have expressed interest in partnering in a variety of ways. These could include, but are not limited to:

1. Joint faculty positions.
2. Team teaching of courses by cross-institutional instructors.
3. Virtual instruction in both directions, supplemented by brief visits by instructors and field trips by students.
4. Bidirectional Sabbaticals.
5. Graduate and undergraduate student internships.

Many other creative ways of interacting with national labs exist. ORNL is only the beginning - if successful, we should partner with multiple labs under bilateral memoranda of understanding that simplify the implementation and diversifying the types of lab-oriented experiences available to students and faculty.

Once we establish ourselves as a leader in this area, we should have a goal of partnering with other universities. For example, Seoul National University in South Korea has expressed interest in partnering with the proposed CMSE Department in a similar way as listed above, as well as developing joint PhD and undergraduate programs. Seoul National is ranked in the top 50 universities in the world, and would be a fantastic international partner, providing a gateway to the East as well as a pipeline for top international graduate students. Similar opportunities leveraging MSU's reputation as a global magnet school will allow CMSE to maintain its leadership once established.

Structure and Justification for Planned Organization

We envision that CMSE will be a truly interdisciplinary unit that strives to focus on algorithmic science and its applications to a range of critical research topics. CMSE will consist of 25-30 faculty, comprising generalists and disciplinary scientists. The generalists develop cross-disciplinary tools addressing large classes of problems. The disciplinary scientists pursue model/algorithm development from a domain-specific perspective, enabling application-specific approximations and optimization of performance on exascale problems. The nexus of these groups is what makes CMSE unique.

The joint College of Natural Science and College of Engineering committee that developed this proposal seeks the creation of a joint, inter-college department as the ideal solution. This structure, where tenure lines would be housed, is necessary to facilitate the recruiting of a core group of faculty whose focus is on algorithmic science that can be applied to new scientific challenges and computational platforms. The reasoning behind this is straightforward - the fundamental science we are interested in developing here at Michigan State University is clearly growing beyond the boundaries of existing STEM disciplines, in the same way that the discipline of computer science grew beyond the boundaries of historical roots in mathematics or electrical engineering. It is advantageous to be at the forefront of this trend.

This new department is at the forefront of a key paradigm shift. Discipline-focused departments tend to only place value on the new science a computer programs can explore, and to not place value on the time or energy it takes to develop critical algorithms and tools that provide a deeper understanding of fundamental processes in science and engineering. By placing the tenure home of computational scientists in this new department, we accomplish two critical goals. First, a single department focused on the science of computation will strengthen the goal of interdisciplinary collaboration, as faculty in this new unit will have a wide range of backgrounds in many traditional STEM disciplines. Second, the new department will break down traditional barriers between departments in the Colleges of Natural Sciences and Engineering, as the common theme of the new department is the science of algorithms and their application to problems in science and engineering, providing a key place for critical interactions between these different scientific communities.

While many faculty will have full appointments in the department, joint appointments will help to cement interdepartmental collaboration and build up a strong interdisciplinary community. This gives MSU the flexibility to grow into this critical area by hiring cutting-edge interdisciplinary scientists, and will also allow existing disciplinary departments the opportunity to grow beyond their current boundaries. In the case of joint appointments, the department with the majority appointment will lead on issues of reappointment, promotion, and tenure. For all faculty appointed in the new unit, either fully or partially, a key consideration in reappointment, promotion, and tenure will include the development of algorithms and computational codes and libraries that contribute broadly to the advancement of research.

A potentially major issue with the proposed format is that a great deal of teaching capacity will be required to launch the new undergraduate and graduate programs. Consolidation of existing classes on campus will free up some teaching slots; however, to ensure success we propose teaching slots be assigned to the new unit based on percentage appointment within the new department. For example, if the faculty has 50% appointment within this new unit and is assigned a 1-1 teaching load, one of the courses they teach each academic year will be assigned by this new department.

A key point in making this new unit work is the creation of a robust community of scholars. To that end, it is key that the new faculty and graduate students in this department be co-located within the same space. We propose the creation of a common space that can hold a substantial number of people, including 25 to 30 faculty, up to 10 visitors, up to 6 support staff, and approximately 100 postdocs and graduate students. This space needs state-of-the-art computing classrooms, conference rooms configured for video conferencing, and resources for teaching in flipped and virtual classroom settings. Currently, this is under discussion between CNS and EGR, and several locations are under consideration.

Another key point in the success of such a department is the influx of new ideas and people. In lieu of teaching specialists, we propose recurring funds to support 50% teaching activities of interdisciplinary postdoctoral researchers (balance supported by fellowships and research grants), as well as funds for a long-term visitor/recruitment program that would aim to have at least two long term faculty-level visitors in residence at any given time in order to inject new ideas. Combined, this will help to keep the unit current in terms of the latest computational methods and scientific problems, and will assist in the attraction of top talent to MSU.

Long term goals and sustainability

The overall goal of this department is to bring together world-leading faculty who combine the most important aspects of computation and disciplinary research, thus enabling cutting-edge interdisciplinary science and the training of both undergraduate and graduate students. This will be realized by the securing of Center-level funding (as well as many single- or few-PI grants), as well as the creation of a coherent academic program with large undergraduate and graduate enrollments. We anticipate that each PI will bring in between $200K-$400K per year in grants, on average[6]. This will fully fund between 3-6 graduate students per PI, plus travel and other associated expenses.

In order to ensure the success of these efforts, the proposed department must be financially sustainable. Continued funding (beyond faculty and support staff salaries) is necessary to support fellowships for top graduate students, speaker series and honoraria, visitor support, hardware purchases, and startup packages. There are a variety of mechanisms to provide this funding, including:

- The development of an online Master's degree in data science and informatics.
- The development of an online Master's degree in applied computation.
- Teaching assistantships for high-quality graduate students who need support. These positions will be TAs for introductory undergraduate and graduate computing courses.
- The program will aggressively pursue endowments for fellowships, visitors, and faculty chairs.

Taken in combination, these sources of continued funding will be critical to the sustained success of this new department.

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[6] This number comes from sampling several PIs at MSU who are focusing on applied computing.

Attached appendices:

Appendix A: Listing of committee members.

Appendix B: Listing of computational science, data sciences, computational mathematics, and similar programs in the top 100 universities in the United States, as ranked by the NRC.

Appendix C: Sampling of new and transformational science that will be enabled by the creation of the proposed unit.

Appendix D: Outline degree programs and courses.

Appendix E: Timeline for implementation

Appendix A: 2013-2014 Steering Committee for the Proposed CMSE Department

The Committee from last year is listed in alphabetical order. The Chair and Co-Chair's of the committee were Andrew Christlieb and Brian O'Shea.

1) Titus Brown - Departments of Computer Science and Microbiology & Molecular Genetics
2) Robin Buell - Department of Plant Biology
3) Andrew Christlieb - Departments of Mathematics and Electrical and Computer Engineering
4) Ian Dworkin - Department of Zoology
5) Michael Feig - Department of Biochemistry
6) Kathy Hunt - Department of Chemistry
7) Mark Iwen - Departments of Mathematics and Electrical and Computer Engineering
8) Ben Levine - Department of Chemistry
9 Vince Melfi - Department of Statistics and Probability
10) Filomena Nunes - National Superconducting Cyclotron Laboratory / FRIB
11) Brain O'Shea - Lyman Briggs College and Department of Physics and Astronomy
12) Charles Ofria - Department of Computer Science
13) Bill Punch - Department of Computer Science
14) Shin-Han Shiu - Department of Plant Biology
15) Yang Wang - Departments of Mathematics
16) GuoWei Wei - Departments of Mathematics
17) John Verboncoeur - Department of Electrical and Computer Engineering

Appendix B: Listing of computational science, data sciences, computational mathematics, and similar programs in the top 100 universities in the United States.

This appendix is a detailed survey of current programs across the United Sates. There is a range of computational science and data science programs across the country. We carried out a survey by forming definitions of computational science and data science, then did a web search of each of the NRC ranking universities looking for departments, centers, and degree programs that satisfy the definitions. This survey does not contain information on schools that do not have a web presence. Further, this survey assumes the information gathered off the web is accurate. For purposes of this survey,

1. University Rankings taken from US News Best Colleges, of the National University Category, retrieved January, 2014.
2. A Department is defined as a dedicated department, with appointed faculty and offering courses.
3. A program is defined as residing within a department, and granting one or more degrees.
4. A center offers computing hardware, resources and services to external departments within the university.

Other metrics could have been chosen.

The committee would like to acknowledge the hard work of the 14 students and post docs in Professors Christlieb's research group who searched the top 108 schools to give us this data.

The Appendix is broken into three sections. The first section is an informal survey of several existing departments that have some aspects that are related to the department we have proposed. This survey was done by directly calling individuals at those institutions asking them to share data with us when they would. The second section has a summary of the data for computational science followed by a complete table of the data. The third section has a summary of the data for data science followed by a complete table of the data.

Appendix B (1) Benchmarking:

Over the past two to three decades, American universities ranked in the top 100 nationally by the National Research Council have instituted eleven scientific computing departments and twenty seven data science departments. The scientific computing departments have developed in two ways. They have either grown out of applied mathematics departments and have evolved to study primarily computational methods (examples include Rice and Northwestern), or they were founded directly as departments of scientific computing (examples include Florida State and Georgia Tech). The latter two departments are on the cutting edge of combining the critical areas of scientific computing for the STEM fields with data science. Of the specifically data science departments, the vast majority are bioinformatics departments, and only six of them are truly broad based. Prominent examples of the latter include the University of Wisconsin and the Georgia Tech. See appendix B parts (2) and (3) for a complete list of departments and programs in the top 100 Universities in the United States.

Student demand and employment opportunities for graduating students in computational science and mathematics are strong. To investigate these issues, members of the Steering Committee for the Proposed CMSE Department talked at length with people in the field, including Professor Max Gunzburger (chair and founder of the Department of Scientific Computing at Florida State University) and Professor Hermann Riecke (undergraduate advisor in the Department of Engineering Science and Applied Mathematics at Northwestern University). Northwestern and FSU represent important benchmarks, because they have both undergraduate and graduate programs in computational science, whereas Georgia Tech currently has only a graduate program. At the graduate level, both Gunzburger and Riecke have confirmed that there is very strong demand for their Ph.D. graduates, with a wide range of available positions in industry, academia, and the national laboratories. At FSU, the department is turning away more than 70% of its applicants for graduate school, and on average they are supporting four graduate students per faculty member. Both programs also confirm that there is strong demand for both science and engineering undergraduates with a minor in this area. Having the minor gives a student a far more rigorous (and transcriptable) background in a critical area not covered by traditional majors. Development of a Ph.D. program, undergraduate minor and a graduate certificate will be a high priority for the new Department at MSU.

Both the Northwestern and Florida State programs currently have a relatively small number of undergraduate majors. Northwestern's undergraduate program has existed for more than 30 years in various forms, currently graduates between 5 to 10 students per year, and does not actively recruit majors. Essentially 100 percent of these graduates find employment upon graduation. This year's graduates took jobs with financial mathematics companies, Google, Dow Corning, and General Motors, and two went to medical school. The average salary of undergraduate student going directly to employment is approximately $65,000. Although Northwestern does not actively recruited students into the program, the number of enrolled undergraduates has grown significantly over the past 5 years, and they expect the numbers to continue to increase. As Professor Riecke remarked, The major role of the NWU department is to teach service courses in the College of Engineering, they are looking to change this. Florida State's undergraduate program is only four years old and graduated its second class in May, 2014. As at Northwestern, essentially 100% of its graduates have found employment. FSU is actively advertising the program and growing the number of undergraduate majors. There are currently 5 to10 students per graduating class, and the objective is to increase this to 22. The number of students is limited, because there are only eleven faculty in the department, and each student does a capstone thesis that is very intensive.

Students graduating from both the Northwestern and Florida State programs are very well-trained in both programming and scientific problem solving. Both institutions agree that employers who are looking for students with a strong background in programming or who are comfortable with using mathematics and computers to solve problems find their graduates to be ideal candidates for positions into which they have traditionally hired mathematics or computer science students.

Appendix B (2) Computational Science:

We start with a summary of the data, followed by a complete list of the universities we looked at. Table 1 summarizes the statistics on the number of departments, programs and centers nationwide in the top 100 universities we surveyed, as well as number of degree granting programs in scientific computing. This is a summary of the full data found later in this section. Table 2 is the 11 departments that exist that are closely related with the department we are proposing here. Note, we color code them based on if they are an applied math department with heavy computing (blue), a applied math department clearly moving towards the department we propose here (red), or are already close to the department we propose here (green).

Table 1:

Summary of Universities Polled
Scientific Computing

Total	95		MSU Existing
Department	11	12%	No
Program	35	37%	Yes
Center	51	54%	No
Minor	23	24%	No
Undergrad	22	23%	No
Masters	29	31%	No
Doctoral	25	26%	No

Table 2:

Summary of Universities With
Departments that Focus on Scientific Computing

National	University	Department?	Department
1	Princeton University	y	http://www.pacm.princeton.edu/
14	Brown University	y	http://www.brown.edu/academics/applied-mathematics/
18	Rice University	y	http://www.caam.rice.edu/index.html
32	New York University-Courant	y	http://www.cims.nyu.edu
36	Georgia Institute of Technolog	y	http://www.cse.gatech.edu
49	Northeastern University	y	http://www.esam.northwestern.edu
52	University of Washington-Seattle	y	http://depts.washington.edu/amath/
82	Stony Brook University	y	http://www.ams.sunysb.edu/index.shtml
86	University of Colorado Boulder	y	http://amath.colorado.edu
91	Florida State University	y	https://www.sc.fsu.edu
121	University of Utah	y	http://www.cs.utah.edu

Key: Blue- Applied Math with Heavy Scientific Computing
Red - Applied Math moving towards new department
Green - Similar to new department

CMSE

Survey of Tier 1 Universities with Scientific Computing Programs

Rank: Math Grad	Rank: National	University	Does the University have a: Department?	Program?	Center?	Does the University offer a: Minor?	B.S?	M.S?	Ph.D?
2	1	Princeton University	y	y	y	y	y	n	y
2	2	Harvard University	n	n	y	n	n	y	n
	3	Yale University	n	n	n	n	n	n	n
10	4	Columbia University	n	n	y	n	n	n	n
2	5	Stanford University	n	y	y	y	y	y	y
6	5	University of Chicago	n	n	y	n	n	n	y
1	7	Massachusetts Institute of Technology	n	y	y	n	n	y	y
18	7	University of Pennsylvania	n	y	n	n	n	y	y
24	7	Duke University	n	n	y	n	n	n	n
7	10	California Institute of Technology	n			y	y	y	y
51	10	Dartmouth College							
16	12	Northwestern University	n	n	n	n	n	n	n
24	12	Johns Hopkins University	n	n	n	y	n	n	n
14	14	Brown University	y	y	y	n	n	n	y
40	14	Washington University in St. Louis	n	n	n	n	n	n	n
13	16	Cornell University	n	y	n	n	n	n	n
51	17	Vanderbilt University	n	y	n	y	n	n	n
30	18	Rice University	y	y	n	y	y	y	y
46	18	University of Notre Dame	n	n	y	n	n	n	n
2	20	University of California, Berkeley	n	y	n	y	y	y	y
63	20	Emory University							
	20	Georgetown University							
8	23	University of California, Los Angeles	n	y	n	n	y	n	n
36	23	Carnegie Mellon University	n	n	y	y	n	n	n
46	23	University of Virginia-Main Campus	n	n	y	n	n	n	n
51	23	University of Southern California	n	n	y	n	n	n	n
	23	Wake Forest University							
8	28	University of Michigan–Ann Arbor	n	y	y	n	n	n	y
83	28	Tufts University	n	n	y	n	n	n	n
30	30	University of North Carolina - Chapel Hill	n	n	n	n	n	n	n
	31	Boston College							
10	32	New York University	y	y	y	n	n	y	n
40	32	Brandeis University	n	n	n	n	n	n	n
63	32	University of Rochester	n	n	y	n	n	n	n
	32	College of William and Mary							
30	36	Georgia Institute of Technology-Main Campus	y	y	y	n	n	y	y
27	37	Pennsylvania State University-Main Campus	n	n	y	y	n	n	n
89	37	Case Western Reserve University	n	n	n	n	n	n	n
20	39	University of California, San Diego	n	y	y	n	n	y	y
36	39	University of California, Davis	n	n	n	n	y	y	y
16	41	University of Wisconsin – Madison	n	n	y	n	n	n	n
20	41	University of Illinois at Urbana–Champaign							
46	41	Boston University	n	n	y	n	n	n	n
46	41	University of California, Santa Barbara	n	y	y	n	n	y	y
56	41	Rensselaer Polytechnic Institute	n	y	y	y	y	n	n
89	41	Lehigh University							
10	47	Yeshiva University	n	n	n	n	n	n	n
98	47	University of Miami							
43	49	University of California, Irvine	n	n	n	n	n	n	n
59	49	Northeastern University	y						
59	49	University of Florida	n	y	n	n	n	y	y
14	52	University of Texas - Austin	n	y	y	y	y	y	y
27	52	University of Washington-Seattle Campus	y	y	y	n	y	n	n
30	52	Ohio State University-Main Campus	n	n	n	y	n	y	n
68	52	Tulane University of Louisiana	n	n	y	n	n	y	n
98	52	George Washington University							
89	57	University of Connecticut	n	n	n	n	n	n	n
	57	Fordham University							
	57	Pepperdine University							
51	60	University of Georgia	n	n	n	n	n	n	n
	60	Southern Methodist University							
20	62	University of Maryland, College Park							
59	62	University of Pittsburgh-Pittsburgh Campus	n	n	y	n	n	n	n
83	62	Syracuse University							
98	62	Clemson University							
	62	Brigham Young University							
	62	Worcester Polytechnic Institute							
27	68	Purdue University-Main Campus	n	y	y	y	n	y	y
18	69	University of Minnesota–Twin Cities	n	y	y	y	n	y	y
20	69	Rutgers–New Brunswick	n	y	y	n	n	y	n
40	69	Texas A&M University	n	n	n	n	n	y	n

59	69	Virginia Tech	n	y	n	n	y	n	n
43	73	Michigan State University	n	n	y	n	y	n	n
56	73	University of Iowa							
30	75	Indiana University - Bloomington	n	n	y	y	n	n	n
76	75	University of Delaware	n	y	n	n	n	y	y
	75	American University							
	75	Baylor University							
	75	Clark University							
	75	Marquette University							
	75	Miami University - Oxford							
24	82	Stony Brook University	y	y	y	n	n	y	y
	82	Stevens Institute of Technology							
	82	Texas Christian University							
	82	University of Vermont							
46	86	University of Colorado - Boulder	y	n	y	y	y	y	y
76	86	University of California, Santa Cruz	n	n	n	n	y	n	n
	86	SUNY College of Environmental Science and Forestry							
	86	University of Alabama							
	86	University of Tulsa							
63	91	University of Massachusetts - Amherst							
76	91	Florida State University	y	y	y	y	y	y	y
	91	Auburn University							
	91	Colorado School of Mines							
	91	University of Denver							
	91	University of San Diego							
63	97	University of Missouri	n	n	n	n	n	n	n
89	97	Binghamton University - SUNY							
	97	Drexel University							
	97	University of New Hampshire							
51	101	North Carolina State University	n	n	y	y	n	n	n
68	101	Iowa State University	n	n	n	y	n	n	n
68	101	University of Kansas							
68	101	University of Nebraska–Lincoln	n	n	y	n	n	n	n
76	101	University of Oklahoma-Norman Campus	n	n	y	n	n	n	n
76	101	University of Tennessee	n	y	y	y	n	n	n
	101	Loyola University							
	101	St. Louis University							
56	109	University of Oregon	n	n	n	n	n	n	n
68	109	University at Buffalo	n	n	y	n	n	y	n
	109	Illinois Institute of Technology							
68	112	University of California, Riverside	n	n	n	n	n	n	n
98	112	University of South Carolina	n	y	y	y	y	n	n
	112	University of Dayton							
	112	University of St. Thomas							
	112	University of the Pacific							
	117	Michigan Technological University							
	117	University of San Francisco							
43	119	University of Arizona	n	n	n	n	n	y	y
76	119	University of Kentucky							
30	121	University of Utah	y	y	y	y	y	y	y
76	121	Colorado State University	n	n	y	n	y	n	n
83	121	Temple University							
	121	Clarkson University							
	121	DePaul University							
	121	Duquesne University							
	121	The Catholic University of America							
36	128	University of Illinois at Chicago							
83	128	University at Albany, SUNY	n	n	n	n	y	n	n
89	128	Washington State University	n	n	n	n	n	n	n
	128	Missouri University of Science & Technology							
	128	Polytechnic Institute of New York University							
	128	Seton Hall University							
	128	University of Arkansas	n	y	n	n	n	y	n
83	135	Louisiana State University	n	n	y	n	n	n	n
89	135	Kansas State University							
	135	Hofstra University							
	135	New School							
	135	Ohio University							
	135	University of Cincinnati-Main Campus	n	n	n	n	n	n	n
	141	George Mason University							
63	142	Arizona State University	n	y	y	y	y	n	n
83	142	Oregon State University	n	n	n	n	n	n	n
89	142	Oklahoma State University							
89	142	Rutgers–Newark							
	142	Howard University							

	142	Mississippi State University	n	n	y	n	n	n	n
	142	St. John Fisher College							
	142	University of Texas - Dallas							
98	150	New Jersey Institute of Technology							
	150	University of Mississippi							
	152	Adelphi University							
	152	Illinois State University							
	152	San Diego State University							
	152	St. John's University							
	152	University of Alabama - Birmingham	n	n	n	n	y	n	n
	152	University of Rhode Island							
98	158	University of Maryland, Baltimore County							
	158	University of Hawaii - Manoa	n	n	n	n	n	n	n
	158	University of Massachusetts Lowell							
	161	Maryville University of St. Louis							
	161	Texas Tech University							
36		CUNY Graduate Center							
68		Claremont Graduate University							
68		University of Houston	n	y	y	n	n	y	y
89		University of New Mexico-Main Campus	n	y	y	n	y	n	n
		Georgia State University	n	n	n	n	n	n	n
		Montana State University	n	n	n	n	n	n	n
		North Dakota State University-Main Campus	n	n	y	n	n	n	n
		Rockefeller University	n	n	n	n	n	n	n
		University of Alabama in Huntsville	n	n	n	n	n	n	n
		University of Central Florida	n	n	n	n	n	n	n
		University of Louisville							
		University of South Florida-Tampa	n	n	y	n	n	n	n
		Virginia Commonwealth University	n	n	n	n	n	n	n
		Wayne State University	n	y	n	n	n	n	n

Notes:

1 University Rankings taken from US News Best Colleges, of the National University Category, retrieved January, 2014

2 A Department is defined as a dedicated department, with appointed faculty and offering courses

3 A program is defined as residing within a department, and granting one or more degrees

4 A center is offers computing hardware, resources and services to external departments within the university

1 Tier 1 Universities as defined by the Carnegie Institute

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Appendix B (3) Data Science:

We start with a summary of the data, followed by a complete list of the universities we looked at. Table 1 summarizes the statistics on the number of departments, programs and centers nationwide in the top 100 universities we surveyed, as well as number of degree granting programs in data science. This is a summary of the full data found later in this section. Table 2 is the 6 departments that exist that are closely related with the department we are proposing here. Note, we color code them based on if they are a full theory and application data science department (red), or are already close to the department we propose here (green). Other data science departments in the full data are highly specialized, focusing on one part or application of data science.

Table 1:
Summary of Universities Polled
Data Science

Total	88		MSU Existing
Department	27	31%	No
Program	50	57%	Yes
Center	40	45%	Yes
Minor	18	20%	No
Undergrad	22	25%	No
Masters	48	55%	No
Doctoral	37	42%	No

Table 2:

Summary of Universities With
Departments that Focus on Both the Theory and Application of Data Scientific

National	University	Department?	Department
28	University of Michgian	y	http://www.lsa.umich.edu/informatics/
36	**Georgia Institute of Technology-Main Campus**	y	http://www.cse.gatech.edu
41	University of Wisconsin – Madison	y	http://www.biostat.wisc.edu/
52	University of Wasington	y	https://ischool.uw.edu
62	University of Pittsburgh	y	http://www.ischool.pitt.edu/ist/
75	Indiana University	y	http://www.soic.indiana.edu/

Key: Red - Data Science Department
Green - Similar to new department

Survey of Tier 1 Universities with Informatics Programs

Rank Math Grad	National Rank	University	Does the University have a Department?	Program?	Center?	Does the University offer a Minor?	B.S?	M.S?	Ph.D?
2	1	Princeton University	N	Y	N	N	N	N	N
2	2	Harvard University	N	Y	Y	N	N	N	Y
	3	Yale University	N	Y	Y	N	N	Y	Y
10	4	Columbia University	N	N	N	N	N	Y	Y
2	5	Stanford University	N	Y	Y	N	N	Y	Y
6	5	University of Chicago	N	Y	N	N	N	N	N
1	7	Massachusetts Institute of Technology	N	N	N	N	N	N	Y
18	7	University of Pennsylvania	N	Y	Y	N	N	N	Y
24	7	Duke University	N	N	N	N	N	Y	Y
7	10	California Institute of Technology	N	N	N	N	N	N	N
51	10	Dartmouth College	N	N	Y	N	N	N	N
16	12	Northwestern University	N	Y	N	N	N	Y	N
24	12	Johns Hopkins University	Y	Y	N	N	N	Y	Y
14	14	Brown University	N	N	N	N	N	N	N
40	14	Washington University in St. Louis	N	N	Y	Y	N	N	N
13	16	Cornell University	Y	N	N	Y	Y	Y	Y
51	17	Vanderbilt University	Y	Y	Y	N	N	Y	Y
30	18	Rice University	N	N	Y	N	N	N	Y
46	18	University of Notre Dame	N	N	N	N	N	N	N
2	20	University of California, Berkeley	Y	Y	Y	N	N	Y	Y
63	20	Emory University	N	Y	Y	N	N	Y	Y
	20	Georgetown University	N	Y	Y	N	N	Y	N
8	23	University of California, Los Angeles	N	Y	Y	N	N	Y	Y
36	23	Carnegie Mellon University	Y	Y	Y	N	N	Y	N
46	23	University of Virginia-Main Campus	Y	Y	Y	Y	Y	Y	Y
51	23	University of Southern California	N	Y	Y	N	N	Y	N
	23	Wake Forest University	N	N	Y	N	N	N	N
8	28	University of Michigan–Ann Arbor	Y	Y	N	Y	Y	N	N
83	28	Tufts University	N	Y	Y	N	N	N	N
30	30	University of North Carolina - Chapel Hill	N	Y	N	N	N	Y	N
	31	Boston College	N	N	N	Y	N	N	N
10	32	New York University	N	Y	Y	N	N	Y	Y
40	32	Brandeis University	N	Y	N	N	N	Y	N
63	32	University of Rochester	Y	Y	N	N	N	Y	N
	32	College of William and Mary	N	N	N	N	N	N	N
30	36	Georgia Institute of Technology-Main Campus	N	N	Y	N	N	N	N
27	37	Pennsylvania State University-Main Campus	N	N	Y	N	N	N	N
89	37	Case Western Reserve University	N	N	Y	N	N	Y	N
20	39	University of California, San Diego	Y	Y	Y	N	N	Y	Y
36	39	University of California, Davis	N	Y	N	N	N	Y	N
16	41	University of Wisconsin – Madison	Y	Y	N	N	N	Y	Y
20	41	University of Illinois at Urbana–Champaign	Y	N	Y	Y	N	Y	Y
46	41	Boston University	N	Y	Y	N	N	Y	Y
46	41	University of California, Santa Barbara	N	Y	Y	N	N	N	N
56	41	Rensselaer Polytechnic Institute	Y	Y	Y	Y	Y	Y	Y
89	41	Lehigh University	N	Y	N	N	N	Y	N
10	47	Yeshiva University	Y	Y	Y	N	N	Y	Y
98	47	University of Miami	N	Y	Y	N	N	Y	Y
43	49	University of California, Irvine	Y	Y	Y	Y	Y	Y	Y
59	49	Northeastern University	N	Y	Y	Y	Y	Y	Y
59	49	University of Florida	N	Y	Y	N	N	N	Y
14	52	University of Texas - Austin	Y	Y	Y	Y	N	Y	Y
27	52	University of Washington-Seattle Campus	Y	Y	Y	N	Y	Y	Y
30	52	Ohio State University-Main Campus	Y	Y	N	N	N	Y	Y
68	52	Tulane University of Louisiana	Y	Y	Y	Y	Y	Y	Y
98	52	George Washington University	N	Y	N	N	N	Y	N
89	57	University of Connecticut	N	Y	Y	Y	N	Y	Y
	57	Fordham University	y	Y	N	Y	Y	Y	N
	57	Pepperdine University	N	N	N	N	N	N	N
51	60	University of Georgia	N	N	Y	N	N	Y	Y
	60	Southern Methodist University	N	N	N	N	Y	Y	N
20	62	University of Maryland, College Park	N	N	N	N	Y	Y	Y
59	62	University of Pittsburgh-Pittsburgh Campus	Y	Y	Y	N	Y	Y	Y
83	62	Syracuse University	Y	N	N	Y	Y	Y	Y
98	62	Clemson University	N	N	N	N	Y	N	N
43	73	Michigan State University	N	N	Y	N	N	N	N
56	73	University of Iowa	N	Y	N	Y	Y	Y	Y
30	75	Indiana University - Bloomington	Y	N	Y	N	N	N	N
76	75	University of Delaware	N	N	N	N	N	N	N
	75	American University	N	N	N	N	N	N	N
	75	Baylor University	Y	Y	N	N	Y	N	N
	75	Clark University	N	N	N	N	N	N	N

	75	Marquette University	N	Y	N	N	Y	N	N
	75	Miami University - Oxford	N	N	Y	Y	N	N	N
24	82	Stony Brook University	Y	N	N	N	Y	N	N
	82	Stevens Institute of Technology	N	N	N	N	Y	N	N
	82	Texas Christian University	N	N	N	N	N	N	N
	82	University of Vermont	N	N	Y	N	Y	N	N
46	86	University of Colorado - Boulder	Y	N	N	N	N	N	N
76	86	University of California, Santa Cruz	N	Y	N	Y	Y	Y	Y
	86	University of Tulsa	N	N	N	Y	Y	N	N
63	91	University of Massachusetts - Amherst	N	Y	N	Y	Y	N	N
76	91	Florida State University	N	N	N	N	N	N	N
	91	Auburn University	Y	Y	N	N	N	Y	N
	91	Colorado School of Mines	N	N	N	N	N	N	N
	91	University of Denver	N	Y	N	N	N	Y	N
	91	University of San Diego	N	Y	N	N	N	Y	N
63	97	University of Missouri	Y	Y	N	N	N	Y	Y

Notes:

1 University Rankings taken from US News Best Colleges, of the National University Category, retrieved January, 2014
2 A Department is defined as a dedicated department, with appointed faculty and offering courses
3 A program is defined as residing within a department, and granting one or more degrees
4 A center is offers computing hardware, resources and services to external departments within the university

1 Tier 1 Universities as defined by the Carnegie Institute

Appendix C: Sampling of new and transformational science that will be enabled by the creation of the proposed unit.

Computational science is a strong emerging area, and is now being increasingly recognized as the third leg of science and engineering, providing answers to questions that neither experiment nor theory can address. The research and development community has made it evident that with a well-framed scientific question and adequate resources, computational science can have enormous impact, identifying the most promising directions for experiment, accelerating the pace of discovery, and even enabling new research opportunities. Associated with this realization, the funding agencies have adapted their portfolios, and increased the investment in this direction. In this supplement, we pick a few of the many scientific and funding opportunities that are within reach, if a strong CMSE were put in place at Michigan State University.

Unravelling the mysteries of the nucleus

The most prominent large collaborations at the forefront of computational science in nuclear physics are in the area of lattice quantum chromodynamics. A recent collaboration NUCLEI, funded by SciDac (DOE Scientific Discovery through Advanced Computing) is transforming the field of low energy nuclear physics, using large scale computing to solve the many-body problem, and providing not only a good description of existing experiments but also predictability with known uncertainties of the properties of nuclei at the limits of stability and their reactions with matter. While the recent large-scale computations of nuclear properties show the potential impact of computational science in low energy nuclear physics, we are truly behind compared to the lattice efforts. Untapped is the problem of describing microscopically fission/fusion which has been identified as the most computationally challenging problem in our field today. This problem is relevant to both energy and National Security (note that the Nuclear National Security Administration funds universities through “Centers of Excellence” at a multi-million dollar level). A serious computational effort to develop a predictive microscopic model for fission/fusion represents an incredible opportunity to MSU, as the home of FRIB. Additional related activities enhanced by computational modeling include the development of tools for design and analysis of accelerator components and diagnostics, including ion and electron sources, high field gradient acceleration modules, beam lines, turns, beam splitters, charge strippers, and decelerators and collectors. Computational tools will play a critical role in the design of next generation accelerators at MSU and elsewhere, enabling cutting edge discovery at the scale of the nucleus.

Discovery through simulations of advanced materials:

In the past, new materials were produced in the lab. Here again large scale computing has enabled a deep renewal of the field. President Obama introduced the Materials Genome Initiative (MGI), a multi-agency program aiming to “discover, manufacture, and deploy advanced materials twice as fast, at a fraction of the cost” as is presently possible. With an eye towards materials for energy, defense, space exploration, and other applications, the MGI is working with academia and industry to develop resources for the determination and sharing of massive quantities of data on new materials to accelerate the research and development work of all involved. Such work requires the development of highly efficient simulation techniques capable of providing useful information on a large number of lead materials in a short time. Additionally, researchers must develop tools to mine the large datasets produced by such simulations to identify directions for future experimental and theoretical work. With its core group of researchers working in the simulation of materials (Duxbury, Eisenlohr, Levine, Qi, Promislow, Tomanek) and machine learning (Jin, Liu, Ross, Tan), Michigan State University is well positioned to build itself into a leader in this field. Advanced materials engineering expertise in the Fraunhofer Center, Composite Materials and Structures Center, and the Composite Vehicle Research Center enbles translation of the basic research in devices and products. The addition of experts in high-performance parallel computing (graphics processing units, exascale computing) and numerical algorithm development would create opportunities for the simulation experts above to accelerate their simulations using the latest hardware and algorithmic developments. In addition, the hire of big-data scientists would facilitate the mining of large databases of the physical properties of material to guide both future experimental and computational research. With these pieces in place, and MSU's existing researchers in experimental materials science (e.g. Anthony, Beaulac, Hamann, Lunt, Morelli, McGuire, Poltavets), MSU would be positioned to compete for large multi-investigator funding opportunities in materials genomics.

Resolving the mysteries of the cosmos:

A true revolution has taken place in the field of astrophysics with the advent of astronomical data and access to peta-scale simulations. The astronomical scene is growing at a fantastic pace. Following the operations of the Sloan Digital Sky Survey, which has produced photometric and spectroscopic observations of half a billion astronomical objects covering more than one third of the entire sky that is visible from Earth, two much larger projects are in the pipeline: NSF is now investing 1B in the Large Synoptic Survey Telescope and NASA's plan is to build the 8B James Webb Space Telescope. Accompanying the pace of growth of astronomy, theoretical astrophysics has been transformed with multi-petaflop supercomputers (such as the National Center for Supercomputing Applications' Blue Waters machine) and the sort of simulations that are required to understand the outputs from observatories such as LSST and JWST, are becoming reality. One of the greatest challenges faced by computational astrophysicists is that of scaling their simulation tools to run on cutting-edge petascale (and, in the near future, exascale) computational resources, and to extract meaningful information from the massive data sets produced. Fully exploiting the potential of the massive supercomputers that will be available to scientists over the coming decades will require intense collaboration with mathematicians and computer scientists. Mining the data to generate its full scientific potential poses a "Big Data" challenge that will keep both astronomers and computer scientists fully engaged for the next decade. It is expected that both NSF and NASA will introduce funding opportunities to reap the science from the large investments in LSST and JWST.

Understanding living organisms at a molecular level:

Life sciences are undergoing a fundamental transition from macroscopic and phenomenological into molecular-based studies with predictive power. These new directions spontaneously promote new achievements in other areas (e.g. mathematics).

A major challenge to quantitative biology is how to build integrated models that span wide time and spatial scales, for example the efforts to connect empirical models describing cellular processes with the physical/molecular world. We now have enough information to build whole-cell molecular models - or whole-organ cellular models - and simulate such models on the biggest computers available. However, there are enormous challenges going forward: high-performance computing with > 100,000 cores which require new, scalable algorithms and new numerical methods, in addition to new tools that will make sense of the enormous data output in such simulations. Building truly multi-scale models that connect different levels, and are both descriptive and predictive, is the challenge for the future. Critical areas for facing this challenge include numerical method development, multi-scale model building, automatic data analysis. These areas are currently weak at MSU but would find a natural home in a Computational Science Department. Without bringing together biophysicists, systems biologists, applied mathematicians, HPC experts, model developers, and bio-engineers, MSU will not be competitive in this area.

The big-data revolution:

The NIH Data Intensive Working Group report lays out a clear mandate for the data science side of the proposed department: "Given the current and emerging needs of the biomedical research community, the NIH has a number of key opportunities to encourage and better support a research ecosystem that leverages data and tools, and to strengthen the workforce of people doing this research. The need for advances in cultivating this ecosystem is particularly evident considering the current and growing deluge of data originating from next-generation sequencing, molecular profiling, imaging, and quantitative phenotyping efforts." The big-data challenge will be at the forefront of biology research in the next few years. Indeed, scientific output will be tied to being able to transform the research ecosystem, recruiting experts in big-data and training students in this growing area. Furthermore, key opportunities for engineering systems in business supply chain. marketing, health, and information sciences will depend strongly on advanced data science and optimization,, This will be achieved most effectively within the multidisciplinary CMSE Department.

Appendix D: Outline of degree programs and courses.

This appendix briefly summarizes the set of certificate, minor, and degree programs that will be administered by the new Department of Computational Mathematics, Science, and Engineering. These programs are intended to give students a broad introduction to the use of computational and data science, in-depth engagement with some subset of computational topics, and hands-on experience using computational techniques to solve problems in one or more STEM disciplines. The range of offerings gives students the opportunity to engage with computational science at a variety of levels - from a single introductory course through an undergraduate or graduate degree in computational modeling or data science. Market research has indicated that engaging with one or more of the proposed programs will substantially enhance a STEM student's career prospects. In conjunction with the proposal for a new department, a separate proposal for this minor and graduate certificate will be going through governance at the same time. The proposal for the minor and graduate certificate will also be accompanied with proposals for instantiation of new courses in the physics department, as physics has agreed to allow us to run our initial courses for the new department through physics. The new classes will move to the new department once the new department opens its doors.

Graduate Certificate in Computational Modeling and Data Science (launch in 2016). This certificate is intended to supplement a disciplinary M.S. or PhD program, and in 14 credits will give students a broad introduction to computational science techniques (CMSE-801), a deeper introduction to a variety of computational topics (CMSE-802-806), a survey of computational and data science topics (CMSE-890), and a discipline-focused computational course or research experience. As designed, the graduate certificate will be able to function with the creation of just one class, CMSE-801. This is because we have made an extensive list of computational courses on campus that we will count towards a student earning the graduate certificate. The new courses we intend to offer, CMSE 802-806 which will also count as part of the certificate, are part of the new PhD program and will be brought online by 2017 and we plan to offer these courses as we hire new faculty. This certificate requires the creation of CMSE 801 and will benefit from the creation of CMSE 802-806 new courses, including:

- CMSE-801, Methods in Computational Science, I (4 credits)
- CMSE-802, Parallel Computational methods, I (3 credits)
- CMSE-803, Monte Carlo methods (3 credits)
- CMSE-804, Mathematical Foundations of Data Science (3 credits)
- CMSE-805, Visualization of scientific datasets (3 credits)
- CMSE-806, Numerical methods for differential equations (3 credits)
- CMSE-890, Seminar in Computational and Data Science (1 credit)

In addition, a variety of computation-focused courses in the Departments of Mathematics, Statistics, Computer Science, and Physics, among others, will count for credit toward this certificate.

M.S. and PhD in Computational Mathematics, Science, and Engineering (launch in 2016). These degrees are designed to produce individuals that are broadly skilled in problem solving, computational modeling, data exploration, and high-performance computing. The graduate of these programs will have acquired a broad range of computational skills, as well as substantial expertise in solving mathematical and statistical problems using scientific methods. We anticipate that the M.S. program will be of interest to students planning careers in government, business, and industry, or who plan to go on to pursue a PhD in a STEM discipline where a strong computational background will be advantageous. We anticipate that the PhD program - including an option to pursue a joint PhD between CMSE and a second department in the College of Natural Science or College of Engineering - will be of interest to students who plan to pursue a research path that requires the development of novel computational algorithms, and which is more computationally in-depth than is possible for a standard disciplinary PhD program. In addition, the new department will offer an online MS program in specialized areas, such as data science or high performance computing, to enable individuals who wish to further their career by seeking additional off campus training beyond their BS.

These degrees will be based on the same set of courses described above, but will require both computational coursework and discipline-focused coursework. The PhD degree will, in addition, require the student to pursue a substantial and novel computationally-focused research program in consultation with at least one research advisor in CMSE.

M.S. in Bioinformatics (launch in 2017). This program targets an urgent need for training in computational aspects of biological research that involve large datasets generated using modern genomic or other approaches. This degree is designed as a non-thesis M.S. that provides students with the requisite technical training and knowledge to perform advanced analysis of datasets from all disciplines of biology, and includes coursework in computational science techniques, in-depth training in data mining techniques, statistics and probability, and bioinformatics. This degree will be administered jointly by CMSE and MSU's life science departments.

Undergraduate minor in Computational Modeling and Data Science (launch in 2015). This minor is targeted primarily at STEM students, but in principle could be pursued by any student at the university with a suitable computational background. The general principle behind this minor is to give students a solid background in programming and computational science through a 2-3 semester introductory course sequence, exposure to a breadth of methods in computational and data science, including a disciplinary-specific computational course, and possibly also a research experience or project-focused "capstone" experience. This minor would require 16-18 credits of coursework, and requires the creation of three additional courses in addition to the course sequences described previously, which will also have undergraduate versions. The new courses required are:

- CMSE-201, Methods in Computational Science, I (4 credits)
- CMSE-202, Methods in Computational Science, II (4 credits)
- CMSE-301, Advanced Computational Techniques (4 credits)

Only two new courses need to be introduced in 2015 to launch the minor, CMSE 201 and CMSE 202. Leveraging existing courses, a minimum of one additional course would need to be introduced in 2016 to complete the minor, CMSE 301. Ideally, several courses on computational biology would be introduced in 2016, but could weight until 2017. The minor can be taught with existing faculty who will move to the new department.

Undergraduate B.S. degrees in (1) Computational Modeling and (2) Data Science(launch in 2018). These degrees are designed for students who wish to combine both a deep understanding of computational and data science with a strong grounding in a STEM discipline. Students in both degrees will acquire a strong foundational in computational methods, but will either pursue a specialization in computational modeling or in data science, which will require substantial additional coursework in mathematics, statistics, and programming. In addition, students will take advanced coursework in a secondary discipline of their choosing (e.g., physics, molecular biology, bioinformatics, applied mathematics) that will give them a B.A.-level background in that discipline.

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Appendix E: Proposed timeline for new department.

In this section we provide an aggressive timeline for the development of the new department. This timeline is based on goal of rapidly developing a world leading computational department with dual expertise in data science and scientific computing. This involves hiring key faculty to enable the installation of a world leading research programs in these areas, which necessarily means building a world leading graduate program in these areas. This will be followed by the development of key MS programs and undergraduate degrees. The one notable exception is we plan to offer an undergraduate minor early on, as it can be accomplished with existing FTEs we plan to move into the department.

Time Line

Faculty	Programs	Time to faculty governance	Projected Date of Implementation
Existing FTE ~ 6	Graduate certificate Undergraduate Minor(x)	Dec. 2014	Fall 2015
10 NEW FTEs 4 in progress start Fall 2015(*) 8 searches in Fall 2015(**)	Graduate programs PhD MS	Aug. 2015	Fall 2016
6+ FTEs search in fall 2016	Graduate programs MS Bio informatics (Joint with Plant Bio) (***) Dual PhD's Phy. Chem, Bio, EGR	Dec. 2016	Dec. 2017
5+ FTEs search in fall 2017	Start Work Undergraduate Programs Jan. 2015 BS - CMSE Comp Phy BS - CMSE Comp Chem BS - CMSE Comp Bio	Aug. 2017	Fall 2018

Notes

(x) The proposed undergraduate minor can be taught with existing faculty

(*) Open Rank Searches 2015	**Data Science**	**Joint With**
	1) One in Applied Harmonic Analysis	75% CMSE - 25% Math
	2) One in Topology of Big Data	75% CMSE - 25% Math
	3) One in Bayesian Analysis	75% CMSE - 25% Stat
(*) Assistant Prof. Searches 2015	**Computational Modeling**	
	1) Two in computational fluid dynamics	One 75% CMSE - 25% Mech Egr
		One 25% CMSE - 75% Mech Egr
	2) One in Computational Bio Chemistry	One 25% CMSE - 75% Bio Chem
	3) One in Computational Chemistry	One TBD% CMSE - TBD% Chem

(**) 2 of the 8 Searches in 2016 Need to focus on Bio Informatics
1 or 2 of the remaining 8 in Data Science and 4 or 5 on Computational Modeling

(***) The two in Bio Informatics are to help support the joint MS