RAMAPO COLLEGE OF NEW JERSEY

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To: Steven Rice, Chair, Academic Review Committee
From: Scott Frees, Professor of Computer Science
Amanda Beecher, Associate Professor of Mathematics
Benjamin Fine, Assistant Professor of Computer Science
Date: October 28th, 2020
Re: New Program Proposal: MS in Computer Science and MS in Applied Mathematics

We submit two proposals for Master of Science programs - an MS in Computer Science (MSCS) and an MS in Applied Mathematics (MSAM), along with a shared budget that also encompasses the MS in Data Science (MSDS). We envision MSCS, MSAM and MSDS forming an interlocking set of programs sharing significant resources. We have submitted our feasibility study to the Provost's Office and have been given permission to proceed with the ARC and Graduate Council approval process.

In launching the MSDS program in Fall 2020, we've learned more about student demand and our regional competitors. Ramapo's liberal arts backbone, the MSDS's Fieldwork Experience, and hybrid course delivery method have received very positive feedback from students. These attributes have given us a competitive advantage in the eyes of students who value these features. The new proposals share these advantages.

The strength of an MS program is greatly enhanced by a wide selection of technical coursework available to students. Large course catalogs are difficult to support at an institution with only one technically-focused MS program - unless that program has very significant enrollment. This has been a challenge in student recruitment. A key driver behind these proposals is to take advantage of their interdisciplinary nature to create a shared pool of coursework and attract a larger set of students.

Each program stands on its own curricularly, however they are a result of focused and deliberate effort to design curriculums such that all courses fulfill requirements of multiple programs simultaneously - ensuring multiple cohorts will fill each section. This is critical for efficient delivery, given our constrained resources. We've made strategic decisions in curricular design to ensure the interlocking aspects of the programs, and we are confident each curriculum delivers an excellent educational experience.

Ramapo College has invested significantly in the MSDS program, and enrollment has exceeded our projections in Fall of 2020, even with the difficulties created by the pandemic. We have designed these new programs such that they leverage - <u>but do not add to</u> - the investments made in MSDS, and are confident the programs will provide Ramapo an increased return on its initial investment.

Program Independence

We have created separate proposals, however the proposals share a significant amount of content. We ask reviewers to evaluate the proposals **together**, as a unit, from both a curricular and financial perspective. The curricula draw from a pool of courses put together differently to serve students in different disciplines.

Wherever possible, we describe curriculums in a stand-alone manner - identifying courses as electives in programs where the same course might be a required course in another. We've approached the marketing research independently - however also describe the benefit of having synergistic programs for students to explore. We have identified competing NJ and regional institutions for each program independently. Enrollment projections are individual to programs.

The sole area where we do not believe an independent evaluation is possible is profit and loss projections. While these programs are distinct, they easily share the same software / hardware resources (see below), marketing efforts, and most importantly, courses and faculty. In each proposal, we have referred to financial projections as a unit of three interlocking MS programs - not individually.

Resources

The MSDS program was granted five new faculty lines to be filled for the start of the Fall 2020 semester. Three of those lines were filled (two Data Science and one Mathematics faculty). Two Computer Science lines were unable to be filled before March 2020, and were suspended due to the pandemic. We have carefully analyzed the expected course loads over the next five years, and have revised anticipated enrollment gains at the undergraduate level to reflect new realities at the College. We have concluded that filling one of the previously allocated Computer Science positions by Fall 2022, and another by Fall 2023 is enough to staff the additional programs. **No new faculty lines are requested to support MSCS and MSAM exclusively.** Our ability to do this stems from the fact MSDS requires 9 courses to run annually, while our combined model (with more than double the projected enrollment) requires 13-14 courses. In addition, the inclusion of multiple 500-level CMPS courses through MSCS allows undergraduates to take those courses as electives, reducing the need to run as many advanced undergraduate courses.

The MSDS program included $20,000 annually for software/hardware in its approved budget, based on needs for cloud computing. We have concluded this budget is sufficient to support the programs being proposed now as well. There are significant cost efficiencies in using cloud resources, the marginal increase in usage to support more students and disciplines results in limited additional costs. **The yearly shared budget for the 3 programs (MSDS, MSCS, and MSAM) remains unchanged from the original MSDS approved budget**.

The MSDS program included an annual marketing and recruitment budget, starting at $35,000, and reducing to $15,000 by its fifth year (2025). We believe all three programs described here can share much of the same marketing materials and advertising venues - and in fact are marketed best together. We've adjusted the budget to anticipate a constant $25,000 marketing and recruitment budget, along with a one year (pre-launch year - 2021) increase to $50,000. **While not mandatory from a delivery perspective, this represents a $45,000 increase in marketing and recruitment budget over the next five years.**

1. Course Catalog

This document summarizes all courses, their student learning outcomes, relationship to proposed MS programs, and describes when individual courses will be offered.

R - Required for Degree
E - Elective for Degree
*New courses in **bold,** otherwise the courses are already created or in the process of being created for MSDS*

Course	Pre-Req	Semester	Frequency	MSDS	MSCS	MSAM
CMPS 530 - Python for Data Science		Fall	Yearly	R	E	E
CMPS 531 - Data Structures and Algorithms		Spring	Yearly	E	R	E
CMPS 547 - Foundations of Computer Science		Fall	Yearly	E	R	
CMPS 550 - Foundations and Applications of IoT		Fall	Biennial	E	E	
CMPS 611 - Operating System Design		Fall	Biennial		E	
CMPS 620 - Machine Learning	CMPS 530 or CMPS 547	Spring	Yearly	E	E	E
CMPS 631 - Computer Architecture		Fall	Biennial		E	
CMPS 645 - Analysis of Algorithms	CMPS 530 or CMPS 547	Spring	Biennial	E	E	E
CMPS 664 - Big Data and Database Design	CMPS 530 or CMPS 547	Spring	Yearly	R	E	E
CMPS 688 - Networks	CMPS 530 or CMPS 547	Spring	Biennial		E	
DATA 601 - Introduction to Data Science		Fall	Yearly	R		E
DATA 620 - Ethics in Data Science[1]		Spring	Yearly	R	R	R
DATA 672 - Data Visualization[2]		Spring	Biennial	E	E	E
DATA 687 - Time Series Data	CMPS 530 or CMPS 547	Fall	Biennial	E	E	E
MATH 654 - Applied Probability and Stochastic Processes		Spring	Biennial	E	E	R
MATH 562 - Applied Linear Algebra[2]		Fall	Yearly	E	E	R
MATH 570 - Applied Statistics		Fall	Yearly	R	E	E
MATH 680 – Math Modeling		Fall	Yearly	R	E	R
MATH 645 - Numerical Analysis	MATH 562	Spring	Biennial	E	E	E
Fieldwork Experience	DATA 620	N/A	N/A	E	E	E
Thesis		N/A	N/A	R	R	R

[1] This course is likely to be renamed to “Ethics in Technology”
[2] Course to be proposed to ARC in Fall 2021 to support MSDS independently.

2. Course Descriptions

Course *New courses in **bold***	**Description**
CMPS 530 - Python for Data Science	This course introduces students to fundamental programming concepts and skills utilized by Data Scientists – in particular parallel computing, I/O, and visualization – all through the Python programming language and associated libraries (i.e. numpy, pandas, etc.). The course is suitable for students with a basic knowledge of programming, and prepares students to take more advanced computing courses in databases, big data analytics, machine learning, and other DATA and CMPS electives.
CMPS 531 - Data Structures and Algorithms	A study of the basic data structures and related algorithms. Stacks, queues, deques, arrays, linked lists, trees, graphs, strings, sorting, searching, and file structures are among the topics presented in this course.
CMPS 547 - Foundations of Computer Science	A study of the fundamental ideas of computing and the principles of programming. Presents several models of computing and introduces several representative programming languages.
CMPS 611 - Operating System Design	A study of the design, use, and analysis of operating systems. The course will include a study of supportive computer architecture, memory management, process management, information management, device control, operating systems structure, and evaluation.
CMPS 550 - Foundations and Applications of IoT	This course introduces students to the foundations of IoT design and implementation. Students will explore several real-world applications to better understand the challenges based in IoT based applications along with current best practices to address them. Students will also apply the foundations learned in this course to design and build IoT applications.
CMPS 620 - Machine Learning	Machine learning uses interdisciplinary techniques such as statistics, linear algebra, optimization, and computer science to create automated systems that can sift through large volumes of data at high speed to make predictions or decisions without human intervention. Machine learning as a field is now incredibly pervasive, with applications spanning from business intelligence to homeland security, from analyzing biochemical interactions to structural monitoring of aging bridges, and from emissions to astrophysics, etc. This class will familiarize students with a broad cross-section of models and algorithms for machine learning, and prepare students for research or industry application of machine learning techniques.
CMPS 631 - Computer Architecture	Interaction between low-level computer architectural properties and high-level program behaviors: instruction set design; digital logic and assembly language; processor organization; the memory hierarchy; multicore and GPU architectures; and processor interrupt/exception models.
CMPS 645 - Analysis of Algorithms	This course provides a comprehensive introduction to computer algorithms. The emphasis is on the design of efficient algorithms and data structures, proofs of their correctness, and analysis of their complexity. A number of algorithmic concepts and techniques are covered, including recursion, incremental design, divide-and-conquer, greedy algorithms, amortized analysis, and dynamic programming. The algorithms studied include sorting, searching, breadth-first search, depth-first search, minimum spanning trees, shortest paths, network flow, and string matching. Data structures studied include hash tables, heaps, binary search trees, and red-black trees. This course is meant as a follow-up to a course in data structures. Knowledge of elementary data structures such as stacks, queues, and linked lists are assumed. In addition, a module will be given on algorithms relevant to bioinformatics, which studies molecular sequence data (DNA, RNA, and protein). Much of the material learned in this course, such as graphs, trees, dynamic programming, and search algorithms apply to this new discipline.
CMPS 664 - Big Data and Database Design	The study of the design and implementation of both relational and distributed databases. The course will include parallel programming models for large-scale data processing on a large number of computing systems, file systems to store large data sets across a network of machines, tools to create and manage clusters of large number of processing units, methods to maintain data consistency during large-scale I/O operation on disk
CMPS 688 - Networks	The design and implementation of network applications will be presented in this course. TCP/IP using Berkeley Sockets will provide the network interface.
DATA 601 - Introduction to Data Science	This course serves as the foundation for all DATA graduate level coursework. It will cover programming, data analysis, data visualization, ethics and security / privacy concerns surrounding data, and other topics students are expected to master in the program. The course will also feature a Seminar component designed to acclimate students to working with Industry Sponsors and to hear first hand from people working in Data Science.

DATA 620 - Ethics in Data Science [To be renamed to Ethics in Technology]	This course is focused on ethical concerns, case studies, and discussion revolving around the acquisition, storage, and usage of data in Data Science. The course will include, but not be limited to, privacy concerns, security techniques, data anonymization, and proper vs. misuse of collected data.
DATA 672 - Data Visualization	This course focuses on the tools to critique and improve visualizations of statistical data. Through readings and discussion of seminal work, students learn the principles of graphical perception and the visual encoding of quantitative information and learn how to use these principles to evaluate an effective visualization.
DATA 687 - Time Series Data	Students in this course will learn to leverage data sets that represent sequential information, such as stock prices, annual rainfall, sunspot activity, the price of agricultural products, etc. The course will cover several mathematical models used to describe the processes which generate these types of data. Students will use data visualization skills to present data effectively and machine learning to forecast and generate prediction on the sequential data.
MATH 654 - Applied Probability and Stochastic Processes	Topics covered include an overview of probability including random variables, expected values, random walks, probability densities, moment-generating functions, and normal variable theorems, Wiener process, Ornstein-Uhlenbeck processes, Langevin equations, Markov processes, Poisson process, and applications including survivability and reliability.
MATH 562 - Applied Linear Algebra	Topics covered include vector spaces and linear transformations, including inner product, matrix representations, binary and quadratic forms, eigenvectors, canonical forms, and functions of matrices. Applications include singular value decomposition, least squares approximation, and linear programming/optimization
MATH 570 - Applied Statistics	This course gives an introduction to statistical methods used in data science with an emphasis on applications. Topics may include foundations of probability, univariate and multivariate random variables and distributions, special distributions, Central Limit Theorem, one- and two-sample methods, point estimation, interval estimation, hypothesis testing, regression analysis, Bayesian analysis, data analysis and model building.
MATH 680 – Math Modeling	This course requires students to develop, use, and assess models to solve real-world problems. Models developed in a variety of disciplines, including linear programming, network science, decision theory, machine learning, are studied and used to solve problems in other disciplines. Models studied in this course include deterministic, stochastic, optimization, static and dynamic ones. Emphasis is placed on the initial phase of building mathematical models and the final phase of interpreting the solutions in terms of real-life applications.
MATH 645 - Numerical Analysis	The purpose of this course is to introduce numerical methods for mathematical problems found in science and engineering. The main topics to be covered are numerical roundoff errors, finding roots of an equation, Non-linear and linear simultaneous equations. numerical integration, Numeric solutions for ordinary and partial differential equations and Regression analysis.
Fieldwork Experience	This is a projects-based course, developed in conjunction with Industry Sponsors and Faculty. Students work closely with faculty and sponsors over one or more semesters on a domain-specific project. The program merges aspects of a co-op or internship and faculty-mentored independent study or thesis. Students will be required to file progress reports with the faculty project leader, along with a final report submitted to the convening group.
Thesis	All M.S. students will be required to complete a Master's Thesis under the advisement of a faculty member. This requirement is distinct from any Fieldwork Experiences the students participate in - however students participating in Fieldwork Experiences for more than one semester may have their thesis requirement waived. A Master's Thesis may or may not involve industry sponsorship. Students may propose their own independent projects, or participate in a faculty-driven project. Students will be required to file progress reports, along with a final Thesis paper.

3. Student Learning Outcomes

The following table combines the learning outcomes for all three MS programs. The short name will be used in the SLO matrix that follows Note we have limited the SLOs documented here to those identified as **Program Outcomes** in one of the proposed MS programs. Individual courses may have additional outcomes.

Data Acquisition	Students must understand the technical and ethical aspects of collecting data and storing data.
Data Analysis	Students must have the mathematics and computing skills to effectively analyze collected data
Presentation and Communication	Students must be able to communicate their analysis, model, and implementation strategies and create effective visualizations to support their analysis.
Integrated Skills	Students will be able to integrate the skills described above in fieldwork/thesis projects
Data Driven Decisions	Students must be able to use their analysis to drive domain-specific decision
Software Development	Apply computing theory and programming principles to analyze, design, implement, and evaluate computer-based systems, processes, components, and programs to meet desired needs.
Problem Solving	Engage effectively and creatively in problem solving, including exploring multiple approaches, and assessing potential solutions.
Mathematical Reasoning	Reason in mathematical arguments at an advanced level, including posing problems precisely, articulating assumptions and limitations of the approach, and reasoning logically to conclusions.
Ethics in work	Recognize ethical and responsible conduct and learn to apply them in practice

4. Program Outcomes

The following table maps SLOs in Section 3 to the three programs. Individual program proposals outline how the course's SLOs relate to each program's set of outcomes.

Outcome	**MSDS**	**MSCS**	**MSAM**
Data Acquisition	X		
Data Analysis	X		X
Data Driven Decisions	X		
Ethics in work	X	X	X
Integrated Skills	X	X	X
Mathematical Reasoning		X	X
Presentation and Communication	X	X	X
Problem Solving	X	X	X
Software Development		X	

M.S. in Applied Mathematics

1. Program Summary

An Applied Mathematics degree can open doors into many different industries including operations research, actuary, finance, statistics, and research. The mathematical reasoning, computational skills, and ability to apply them to solve real problems are all skills valued by employers and provide most of the goals on which we built this program. The additional intersectionality of the Data Science and Computer Science programs will give our students an interdisciplinary perspective in all of their courses, including mathematics courses, that will make them highly effective team members in the workplace.

The job market for Mathematicians and Statisticians is growing with high paying jobs. The US News and World report's 100 Best Jobs list[1] ranks Statistician as #6, Mathematician as #14, and Operations Research Analyst as #20 demonstrating the value of this career path.

This Applied Mathematics degree will require three Mathematics foundational courses, along with an ethics course and thesis. Students will select five electives from two categories. The first category is a mathematics category including four courses with the potential to add more. The second category is an applications category including courses from the Computer Science and Data Science programs that build students computational skills and interdisciplinary understanding. Students may also participate in Fieldwork experience to satisfy this elective category. The opportunity to work with industry partners is a relatively rare component of a MSAM degree.

The unique feature of our program is the required Ethics course, which does not appear to be in any Master's in Applied Mathematics program. Traditionally, mathematical theory is seen as pure and true based on logical arguments, and therefore avoids ethical responsibilities associated with its applications. We believe students will be attracted to this program to engage in these conversations alongside Data and Computer scientists.

In conjunction with the MS in Data Science, and the simultaneously proposed MS in Computer Science, Ramapo will have an exciting and strong core of technology-related graduate programs. The interlocking aspects of the three curriculums will provide the opportunities for interdisciplinary collaboration Ramapo is known for in its undergraduate programs.

[1] 100 Best Jobs. US News & World Report. Accessed from: https://money.usnews.com/careers/best-jobs/rankings/the-100-best-jobs

2. Curriculum and Assessment

2.1. Program Goals

Goal 1: Problem Solving: Engage effectively and creatively in problem solving, including exploring multiple approaches, and assessing potential solutions.
Goal 2: Reason mathematically: Reason in mathematical arguments at an advanced level, including posing problems precisely, articulating assumptions and limitations of the approach, and reasoning logically to conclusions.
Goal 3: Data Analysis: Students must have the mathematics and computing skills to effectively analyze collected data.
Goal 4: Presentation and Communication: Students must be able to communicate their analysis, model, and implementation strategies and create effective visualizations to support their analysis.
Goal 5: Integrated Skills: Students will be able to integrate the skills described above in fieldwork/thesis projects.
Goal 6: Ethics in work: Recognize ethical and responsible conduct and learn to apply them in practice.

2.2. Student Learning Outcomes

Outcome 1 Demonstrate advanced problem solving skills.

Outcome 2 Demonstrate advanced reasoning skills.

Outcome 3 Demonstrate advanced skills in data analysis techniques using mathematics and statistical principles.

Outcome 4 Demonstrate advanced skills in data presentation, communication, and visualization.

Outcome 5 Demonstrate the ability to integrate skills in a multi-faceted data science project.

Outcome 6 Demonstrate ethical awareness, the ability to do ethical reflection, and the ability to apply ethical principles in decision-making.

2.3. Courses

The Master's degree curriculum requires students to complete five 500/600 level MATH/DATA required courses, and two additional mathematics courses and three application electives. In addition, students may fulfill one of their elective requirements through Fieldwork, which provide students first-class experiences applying their skills towards real-world problems working closely with sponsors from industry.

Table 2. MS in Applied Mathematics Curriculum[2]

Masters of Applied Mathematics (MSAM)	30
MATH 562 - Applied Linear Algebra	3
MATH 654 - Applied Probability and Stochastic Processes	3
MATH 680 – Mathematical Modeling*	3
DATA 620 - Ethics in Data Science*	3
Thesis	3
Category 1 Electives (Pick 2)	6
- MATH 570 - Applied Statistics*	
- MATH 645 - Numerical Analysis	
- MATH 699 - Advanced Topics in Mathematics	
- CMPS 645 - Analysis of Algorithms	
Category 2 Electives (Pick three)	9
- CMPS 530 - Python for Data Science*	
- CMPS 531 - Data Structures and Algorithms	
- CMPS 620 - Machine Learning*	
- CMPS 664 - Big Data and Database Design*	
- DATA 601 - Introduction to Data Science*	
- DATA 672 - Data Visualization	
- DATA 687 - Time Series Data	
- Fieldwork	

Courses with an * after their name are existing courses created for the MSDS program. All other courses are new courses, however many are also part of the MSCS and MSDS programs also being proposed. Please see the shared **course catalog document** for additional details.

[2] Students are required to be in compliance with RCNJ's policy on academic standing, as described here: https://www.ramapo.edu/provost/policy/graduate-academic-standing/

2.4. 2-year Course Plan

Table 3. Possible 2-Year Sequence for M.S. Degree

Master of Applied Mathematics (MSAM)			
Year 1			
Fall	**Credits**	**Spring**	**Credits**
MATH 562 - Applied Linear Algebra	3	**MATH 654 - Applied Probability and Stochastic Processes**	3
		DATA 620 - Ethics in Data Science	3
Pick two:	6	**Pick one:**	3
- MATH 570 - Applied Statistics		- CMPS 531 - Data Structures and Algorithms	
- CMPS 530 - Python for Data Science		- CMPS 620 - Machine Learning	
- DATA 601 - Introduction to Data Science		- CMPS 645 - Analysis of Algorithms	
- DATA 687 - Time Series Data		- CMPS 664 - Big Data and Database Design	
- MATH 699 - Advanced Topics in Mathematics		- DATA 672 - Data Visualization	
		- MATH 645 - Numerical Analysis	
		- MATH 699 - Advanced Topics in Mathematics	
Total	9	Total	9
Year 2			
Fall	**Credits**	**Spring**	**Credits**
MATH 680 – Mathematical Modeling	3	**Thesis**	3
Pick one:	3	**Pick one:**	3
- MATH 570 - Applied Statistics		- CMPS 531 - Data Structures and Algorithms	
- CMPS 530 - Python for Data Science		- CMPS 620 - Machine Learning	
- DATA 601 - Introduction to Data Science		- CMPS 645 - Analysis of Algorithms	
- DATA 687 - Time Series Data		- CMPS 664 - Big Data and Database Design	
- MATH 699 - Advanced Topics in Mathematics		- DATA 672 - Data Visualization	
- Fieldwork		- MATH 645 - Numerical Analysis	
		- MATH 699 - Advanced Topics in Mathematics	
		- Fieldwork	
Total	6	Total	6

We have left the 3rd and 4th semesters with only two courses. These are the semesters that students will likely choose Fieldwork Experiences as their electives, and this provides space to invest additional time in these projects.

2.5. Program Entry Requirements

Entry into the Master's program will require students to have obtained a B.S. or B.A. from a four year institution in mathematics, applied mathematics, statistics, or closely related field, with a GPA of 3.0 or above.

2.6. Core MSAM Graduate Courses

The courses indicated in Sections 2.3 and 2.4 are described in the **shared curriculum document** attached to this proposal.

2.6.1. Fieldwork Experience

An innovative and important feature of the M.S. is our Fieldwork Experience projects. These projects focus on real-world problems brought to the program by external sponsors. Students work closely with faculty and sponsors over one or more semesters. The program merges aspects of a co-op or internship and faculty-mentored independent study or thesis.

Projects may be worked on by a single student and faculty member, multiple students led by a faculty member, or a team of students and faculty. Faculty from **outside** DATA/CMPS/MATH are also encouraged to advise as an individual or on a team.–Faculty will not only mentor students, they will be working collaboratively **with** them - delivering real, measurable value to the sponsor's project beyond simple guidance.

Through the MSDS Advisory Board, we have already begun developing these opportunities for Data Science students, and we look forward to including Applied Mathematics in this program as well.

2.6.2. Master's Thesis

All M.S. students will be required to complete a Master's Thesis under the advisement of a faculty member or a multi-semester Fieldwork project with an industry partner.

A key difference between Master's Thesis and Fieldwork Experiences is the scope of the project *but not the student's contribution to the project*. While some projects (particularly with Industry Sponsors) may span multiple years, require deep faculty involvement, and involve many students - Master's Thesis are shorter term, and have scopes suitable for a single student to complete in a semester.

A Master's Thesis may or may not involve industry sponsorship, and unlike Fieldwork Experiences, faculty will play only an advisor/mentor role in this work. Students may propose their own independent projects, or participate in a faculty-driven project. Similar to the college honors program, faculty should receive a small stipend for their advisement/mentorship efforts, on a per-student basis.

2.7. Direct and Indirect Measures

Direct Measure - Review of student work: For each outcome, specific coursework (or thesis outcome) will be directly evaluated by faculty in the MATH, CMPS, or DATA disciplines. In the case of courses, a faculty member not teaching the course from which the assignment is drawn will be selected to perform the evaluation. In the case of fieldwork and thesis work, a faculty member other than the advisor/mentor will evaluate progress/final reports submitted by the student.

The following indirect methods will be used to assess student outcomes

- Student Exit Surveys
- Industry Partner Surveys

2.8. Assessment Process

Each of the student learning outcomes are addressed and can be assessed through core required MSAM courses as outlined in Section 2.9. These courses will be taken by all MSAM students and expected to be offered annually. Each of these courses will be taken at different points in the students' curriculum, thus allowing us to be able to see how the program is developing students to meet the programmatic goals. **Direct measures** will include review of course assignments / exam question responses.

The **Thesis** course is a requirement of all graduating students[3], and will be a primary point of assessment. All outcomes must be demonstrated in this course. Assessing this course through direct measures will include faculty review of progress reports and final Thesis reports. **Indirect measures** will include exit surveys from students.

In addition to the core courses, there is also sufficient opportunity to assess within the elective courses.

The **Fieldwork Experience** course is an elective, however this will be another place where each of the student learning outcomes will be assessable both directly (progress/final reports) and indirectly (student and sponsor surveys). We view the sponsor surveys as enormously critical to the assessment process - as it is our best measure of whether our students are meeting industry expectations. As described above, the goal is to have all students participate in this course - however we cannot guarantee there will be enough industry-sponsored projects for all students - which is why the course is an elective.

[3] Students may receive credit for their Thesis by completing an extended Fieldwork Experience (2 semesters). It would be excellent if this becomes the norm - as it would mean we have a healthy sponsorship program - however we would need to adjust our assessment plan to include the FIeldwork Experience in future semesters.

2.9. Alignment of Program Outcomes to Courses

Note, individual courses indicated with a “X” may contain learning objectives phrased differently than the program outcome indicated, but align.

	Problem Solving	**Reason mathematically**	**Data Analysis**	**Presentation and Communication**	**Integrated Skills**	**Ethics in work**
Required Courses						
MATH 562 - Applied Linear Algebra	X	X				
MATH 654 - Applied Probability and Stochastic Processes	X	X	X			
MATH 680 – Mathematical Modeling	X	X	X	X	X	
DATA 620 - Ethics in Data Science	X			X	X	X
Thesis	X	X	X	X	X	X
Elective Courses						
- MATH 570 - Applied Statistics	X	X	X	X		
- MATH 645 - Numerical Analysis	X	X	X			
- MATH 699 - Advanced Topics in Mathematics	X	X				
- CMPS 645 - Analysis of Algorithms	X	X				
- CMPS 530 - Python for Data Science				X		
- CMPS 531 - Data Structures and Algorithms	X	X	X			
- CMPS 620 - Machine Learning	X	X				
- CMPS 645 - Analysis of Algorithms	X	X				
- CMPS 664 - Big Data and Database Design	X					
- DATA 601 - Introduction to Data Science		X	X	X		X
- DATA 672 - Data Visualization				X	X	
- DATA 687 - Time Series Data					X	
- Fieldwork	X	X	X	X	X	X

3. Alignment with College Mission and Strategic Plan

The proposed program fulfills several aspects of the College’s mission:

- **Interdisciplinary Learning**: Applied Mathematics is a field that utilizes mathematical reasoning and constructs to solve problems stemming from a variety of areas, thus is an interdisciplinary field.

Moreover, this program offers students three electives to explore the applications and tools derived in Computer Science and Data Science.

- **Experiential Learning**: The proposed program has a Thesis and a Fieldwork Experience component that provides students substantial opportunity for experiential learning by working with faculty and industry partners.
- **Community Involvement**: Industry partners play a large role in the project work students will complete in their Fieldwork Experience and Thesis courses - enhancing Ramapo's connection to local businesses in the area.

The M.S. in Applied Mathematics program is well aligned with the College's Strategic plan - in particular goals three and four: (3) Advance Innovation as the College's Promise and Obligation to its Students, Community, and the State of New Jersey, **and**, (4) Improving Long-term Financial Strength.

We can further link the M.S. project to specific objectives outlined in the Strategic Plan:

Objective 1.3: To increase the number of students transferring from partner institutions: While not being proposed immediately, the possibility of a future 4+1 offering for B.S. and M.S. increases the ability to attract graduate students from partnered undergraduate schools through articulation agreements, and also provides a clear pathway for students in Mathematics undergraduate programs to transfer to Ramapo to take advantage of the program.

Objective 1.7: To support and develop a diverse, highly qualified, engaged, and accessible faculty through activities centered on teaching, learning, and advising; scholarship and creative work; and service and college governance: The Fieldwork Experiences and emphasis on industry involvement offers professional and academic opportunities to our faculty that are otherwise difficult to engage in. While primarily designed to provide students with experiential learning, the program also encourages faculty to form relationships with industry partners, earning stipends for their involvement in the projects and increasing their scholarship opportunities on campus.

Objective 1.8: To facilitate student success, in terms of completion and employment, via experiential learning: As described above, the Fieldwork Experience course and the M.S. Thesis is designed such that students have several experiential opportunities throughout while completing their M.S. degree. Employment opportunities are strong for graduates, and the industry partnerships integrated into the degree program only increase student opportunity for future employment.

Objective 4.4: To publicly position the College through advocacy, marketing and public relations as the premier public college in the region: The combination of a B.S. programs in Computer Science, Data Science, Mathematics, coupled with the MSDS, MSCS, and MSAM programs along with 4+1 programs and industry Fieldwork sponsors creates a powerful technology core at Ramapo to enhance the College's brand recognition. We intend to highlight at all levels how these technology fields have broad interdisciplinary impact and integration as a way of positioning Ramapo as unique - a liberal arts environment with first-class technology opportunities.

4. Impact on other Programs

The presence of an MS in Applied Mathematics at Ramapo College strengthens our ability to mount and promote all of our interrelated technical MS programs - Computer Science and Data Science. Students in these fields, along with potentially others (MBA) will benefit from the availability of the entry level coursework in this program. Students from MSDS, MSCS, and MSAM will enroll in several courses across all our technical programs - strengthening those program's ability to run more courses each semester.

The MS in Applied Mathematics strengthens our undergraduate mathematics program. The MS creates a 4+1 pathway for our students to directly enter graduate school. The MS curriculum is an applied program, while our undergraduate program is a more traditional pure mathematics program. Thus, some of the 500-level courses could serve as electives in the undergraduate program, broadening our ability to serve those interested in either pure or applied mathematics.

The degree requires no additional faculty or resources, and is sufficiently distinct from other degrees as to not cannibalize enrollment.

5. Other Programs in the Region

The seven programs listed are the Master's of Applied Mathematics programs in the State of New Jersey and those geographically close to Ramapo College. These programs show the variability in the disciplinary and interdisciplinary mix of applied mathematics programs reflected in national trends. In general, these programs are at Doctoral granting institutions, such as NJIT, Stevens Institute of Technology, Princeton University, and Stony Brook University, or have related Master's programs, such as at Montclair State University, Manhattan College, and Adelphi University. The combination of MSCS, MSDS, and MSAM at Ramapo would have a similar clustered Master's program as these last set of schools.

An obvious difference between these programs is the capstone experience. Institutions on our list that offer Ph.D.s in a related field, do not have a capstone experience at the Master's level. Princeton University, however, does require students to complete the preliminary Ph.D. examinations. They do not admit students into their Master's in Applied and Computational Mathematics program, but offer it for those that do not complete the Ph.D. program in the field. Manhattan and Adelphi University have an experience built into the coursework, while Montclair State University requires several culminating options. While both fieldwork and internships are provided by industry partners, the Fieldwork experience are projects tailored for the students by our industry partners in collaboration with faculty, so have higher expectations than a traditional internship. We are offering students a Thesis or extended Fieldwork experience as their culminating experience of the program. We believe this to be an attractive option for students that want to gain practical experience in the field.

Students seeking a graduate experience with small class sizes, engaged faculty that are accessible to their students, and a liberal arts atmosphere will choose Ramapo. These students will be taking coursework with students in Computer Science and Data Science for nearly all of their work. This will forge an interdisciplinary perspective throughout their courses, including the mathematics courses. This computational perspective is in line with current industry needs, particularly in Northern New Jersey.

Our unique feature of our program is the required Ethics course, which is not common in Master's in Applied Mathematics programs and not in any of these programs. Traditionally, mathematical theory is seen as pure and true based on logical arguments, and therefore avoids ethical responsibilities associated with its applications. We believe students will be attracted to this program to engage in these conversations along with Data and Computer scientists.

School	Program Name	# of Credits	Required credits	Elective Math credits	Elective non-Math credits	Culminating Experience	Distance to RCNJ (miles)
Montclair State University	MS in Applied Mathematics	30	12	15	Some options available	Thesis, Capstone, or Internship	23
NJIT	MS in Applied Mathematics	30	15	9	6	None	33
Stevens Institute of Technology	MS in Applied Mathematics	30	9	9	12	None	33
Manhattan College	MS in Applied Mathematics - Data Analytics	30	24	6	Some options available	4 embedded exams	35
Adelphi University	MS in Applied Mathematics and Statistics	30	6	21	0	Capstone Course	55
Princeton University	MA in Applied and Computational Mathematics			select 3 of 6 AM topics		Preliminary Exam	66
Stony Brook University	MS in Computational Applied Math	30	21	9	0	None	77

6. Student and Labor Market Demand

The US Bureau of Labor Statistics[4] identifies several occupations in mathematics.

[4] Occupational Outlook handbook. US Bureau of Labor Statistics. *Math occupations*. Accessed from: https://www.bls.gov/ooh/math/home.htm

OCCUPATION	JOB SUMMARY	2019 MEDIAN PAY	GROWTH
Actuaries	Actuaries use mathematics, statistics, and financial theory to analyze the financial costs of risk and uncertainty.	$108,350	18% (Much faster than average)
Mathematicians and Statisticians	Mathematicians and statisticians analyze data and apply mathematical and statistical techniques to help solve problems.	$92,030	33% (Much faster than average)
Operations Research Analysts	Operations research analysts use advanced mathematical and analytical methods to help solve complex issues.	$84,810	25% (Much faster than average)

Additionally, the US News and World report's 100 Best Jobs list[5] ranks Statistician as #6, Mathematician as #14, and Operations Research Analyst as #20. These sources show that this field is growing with good pay opportunities and a great experience.

7. Enrollment

We are targeting an initial cohort of **four** MSAM students, with a fall retention rate of 80% and Spring retention rate of 90%. Please note that financial projections must include MSDS, MSCS, and MSAM together, given their shared curricular structure. **Please see the accompanying shared enrollment and budget document for details.**

Table 4. Enrollment Projection for MSAM

Year	Entering Cohort	Headcount
2022	4	4
2023	4	7
2024	4	7
2025	5	8
2026	5	8

8. Space, Personel, and Faculty Line Requirements

The MSAM program does not require any additional space, faculty lines, or resources beyond what is already scheduled for FY 21. This includes the opening of the new computing classroom, new computing research lab

[5] 100 Best Jobs. US News & World Report. Accessed from: https://money.usnews.com/careers/best-jobs/rankings/the-100-best-jobs

(associated with the MSDS program), and the two new faculty (Computer Science) that were approved in the Spring of 2020. Please see the **shared budget document for additional details on resources**.

8.1. Program Director

MSAM will have a **Program Director** to lead the program, curricular developments, advisement, and admissions. They develop and enhance our industry partnerships within fields related to their program by assisting in developing fieldwork placements, ensuring representation on the Advisory Council, and engaging them in on campus activities (such as Computing Fair). They will need to work closely with the Mathematics Convening group to coordinate course load and course assignments. They will also need to coordinate with the Program Directors of the MSDS and MSCS for scheduling and sequencing of courses, marketing, budgeting, and Advisory Board membership as these are shared components of the three programs.

8.2. Classroom Requirements

As part of the Data Science (BS and MS) launch, a new computer classroom was scheduled for completion in Fall 2020. This classroom will be required to support the launch of the MSCS and MSAM programs - however no other classrooms are necessary.

8.3. Conference Rooms

As part of the Data Science (BS and MS) launch, a conference room was approved to serve the programs and house advisory board meetings. This space was approved, but not allocated - and put on hold in Spring 2020. The new MS programs will create an increased urgency that this space be allocated.

8.4. Computer / Research Labs

As part of the Data Science (BS and MS) launch, a new computer research lab to support faculty/student work was approved, but not allocated - and put on hold in Spring 2020. The new MS programs will create an increased urgency that this space be allocated.

9. Course Descriptions

Please see the accompanying shared course catalog for a complete listing of course descriptions.

M.S. in Computer Science

1. Program Summary

Computer Science is one of the largest undergraduate majors at Ramapo College, enrollment has more than doubled since 2013. The major is also a significant draw for international students, with one of the largest percentage of international students among the College's majors. Computer Science and Mathematics are the pillars underpinning our new Data Science curriculums. We propose the creation of a Masters of Science in Computer Science to further capitalize on our strengths in these fields.

The job market for Computer Scientists is exceptional. In 2020, US News and World Report listed their "Best Jobs" in the United States[1]. Software Developer was ranked #1 **overall**, #1 for best STEM job, and #1 for the best technology job. In their analysis, they listed three steps to success as a computer scientist: (1) a BS degree, (2) hands-on experience, and (3) pursue a MS degree. We wish to deliver all three at Ramapo.

The Computer Science degree will contain two required Computer Science foundational courses, along with an ethics course and thesis. Students will select six additional electives from two categories. The first category contains ten courses featuring core computer science concepts (i.e. Operating Systems, Architecture) and their applications (i.e. Machine Learning, Big Data). The second category provides the depth in mathematics expected of graduate students in Computer Science, including Numerical Analysis and Analysis of Algorithms.

The curriculum is distinctive in its Ethics requirement and Fieldwork opportunities. Typical Computer Science graduate curricula solely focus on technical, and usually theoretical skills - and do not emphasize hands-on fieldwork experiences or the more circumspect ethical responsibilities of computer scientists. Not only is our emphasis on these aspects in line with the mission of Ramapo College, it is in high demand by employers and students alike.

In conjunction with the MS in Data Science, and the simultaneously proposed MS in Applied Mathematics, Ramapo will have an exciting and strong core of technology-related graduate programs. The interlocking aspects of the three curriculums will provide the opportunities for interdisciplinary collaboration Ramapo is known for in its undergraduate programs.

[1] https://money.usnews.com/careers/best-jobs/rankings/the-100-best-jobs

2. Curriculum and Assessment

2.1. Program Goals

Students will have the following capabilities:

1. **Software Development.** Apply computing theory and programming principles to analyze, design, implement, and evaluate computer-based systems, processes, components, and programs to meet desired needs.
2. **Problem Solving:** Engage effectively and creatively in problem solving, including exploring multiple approaches, and assessing potential solutions.
3. **Mathematical Reasoning:** Reason in mathematical arguments at an advanced level, including posing problems precisely, articulating assumptions and limitations of the approach, and reasoning logically to conclusions.
4. **Presentation and Communication**: Students must be able to communicate their analysis, model, and implementation strategies and create effective visualizations to support their analysis.
5. **Integrated Skills:** Students will be able to integrate the skills described above in fieldwork/thesis projects.
6. **Ethics in Work.** Recognize ethical and responsible conduct and learn to apply them in practice

2.2. Student Learning Outcomes

The following are specific objectives of the program, and are met by required MSCS coursework.

1. Demonstrate advanced computational and programming skills
2. Demonstrate advanced problem solving skills.
3. Demonstrate advanced mathematical reasoning skills.
4. Demonstrate advanced skills in data presentation, communication, and visualization.
5. Demonstrate the ability to integrate skills in a multi-faceted technical project.
6. Demonstrate ethical awareness, the ability to do ethical reflection, and the ability to apply ethical principles in decision-making

Through a variety of elective opportunities, students can also achieve skills in deeper mathematical principles, data science, hardware, machine learning, and visualization techniques.

2.3. Courses

The Master's degree curriculum requires students to complete two 500 level foundational CMPS courses, an ethics course, and complete a thesis. Six electives are chosen among 16 different courses. In addition, students may fulfill one of their elective requirements through Fieldwork, which provide students first-class experiences applying their skills towards real-world problems working closely with sponsors from industry.

Table 2. M.S. Degree Requirements[2]

Masters of Computer Science (MSCS)	30
CMPS 547 - Foundations of Computer Science	3
CMPS 531 - Data Structures and Algorithms	3
DATA 620 - Ethics in Data Science *	3
Thesis	3
Elective Category 1 (Pick 4)	12
- CMPS 530 - Python for Data Science *	
- CMPS 550 - Foundations and Applications of IoT	
- CMPS 611 - Operating System Design	
- CMPS 631 - Computer Architecture	
- CMPS 664 - Big Data and Database Design *	
- CMPS 620 - Machine Learning *	
- CMPS 688 - Networks	
- DATA 672 - Data Visualization *	
- DATA 687 - Time Series Data *	
- Fieldwork	
Elective Category 2 (Pick 2)	6
- CMPS 645 - Analysis of Algorithms *	
- MATH 645 - Numerical Analysis	
- MATH 570 - Applied Statistics *	
- MATH 654 - Applied Probability and Stochastic Processes	
- MATH 680 – Mathematical Modeling *	
- MATH 562 - Applied Linear Algebra *	

Courses with an * after their name are existing or upcoming courses created for the MSDS program. All other courses are new courses, however many are also part of the MSAM program also being proposed. Please see the shared **course catalog document** for additional details.

[2] Students are required to be in compliance with RCNJ's policy on academic standing, as described here: https://www.ramapo.edu/provost/policy/graduate-academic-standing/

2.4. 2-year Course Plan

Table 3. Possible 2-Year Sequence for M.S. Degree

Master of Computer Science (MSCS)			
Year 1			
Fall	**Credits**	**Spring**	**Credits**
CMPS 547 - Foundations of Computer Science	3	**CMPS 531 - Data Structures and Algorithms**	3
Pick two:	6	**DATA 620 - Ethics in Data Science**	3
- CMPS 530 - Python for Data Science		**Pick one:**	3
- CMPS 550 - Foundations and Applications of IoT		- CMPS 620 - Machine Learning	
- CMPS 611 - Operating System Design		- CMPS 664 - Big Data and Database Design	
- CMPS 631 - Computer Architecture		- CMPS 645 - Analysis of Algorithms	
- DATA 687 - Time Series Data		- CMPS 688 - Networks	
- MATH 562 - Applied Linear Algebra		- DATA 672 - Data Visualization	
- MATH 570 - Applied Statistics		- MATH 654 - Applied Probability and Stochastic Processes	
Total	9	Total	9
Year 2			
Fall	**Credits**	**Spring**	**Credits**
Pick 2:	6	**Thesis**	3
- CMPS 530 - Python for Data Science		**Pick one:**	3
- CMPS 550 - Foundations and Applications of IoT		- CMPS 620 - Machine Learning	
- CMPS 611 - Operating System Design		- CMPS 664 - Big Data and Database Design	
- CMPS 631 - Computer Architecture		- CMPS 645 - Analysis of Algorithms	
- DATA 687 - Time Series Data		- CMPS 688 - Networks	
- MATH 562 - Applied Linear Algebra		- DATA 672 - Data Visualization	
- MATH 570 - Applied Statistics		- MATH 654 - Applied Probability and Stochastic Processes	
- Fieldwork		- Fieldwork	
Total	6	Total	6

We have left the 3rd and 4th semesters with only two courses. These are the semesters students will likely choose Fieldwork Experiences as their electives, and this provides space to invest additional time in these projects. This also allows students to “catch up” if there is a need for remedial coursework on program entry.

2.5. Program Entry Requirements

Entry into the Master’s program will require students to have obtained a B.S. or B.A. from a four year institution in a computer science, computer engineering, or related field that involved computer programming, with a GPA of 3.0 or above.

2.6. Core MSCS Graduate Courses

Course descriptions for each course indicated in Sections 2.3 and 2.4 are found in the **shared curriculum document** attached to this proposal.

2.6.1. Fieldwork Experience

An innovative and important feature of the M.S. is our Fieldwork Experience projects. These projects focus on real-world problems brought to the program by external sponsors. Students work closely with faculty and sponsors over one or more semesters. The program merges aspects of a co-op or internship and faculty-mentored independent study or thesis.

Projects may be worked on by a single student and faculty member, multiple students led by a faculty member, or a team of students and faculty. Faculty from **outside** DATA/CMPS/MATH are also encouraged to advise as an individual or on a team.–Faculty will not only mentor students, they will be working collaboratively **with** them - delivering real, measurable value to the sponsor’s project beyond simple guidance.

Through the MSDS Advisory Board, we have already begun developing these opportunities for Data Science students, and we look forward to including Computer Science in this program as well.

2.6.2. Master’s Thesis

All M.S. students will be required to complete a Master’s Thesis under the advisement of a faculty member. This requirement is distinct from any Fieldwork Experiences the students participate in.

A key difference between Master’s Thesis and Fieldwork Experiences is the scope of the project *but not the student’s contribution to the project*. While some projects (particularly with Industry Sponsors) may span multiple years, require deep faculty involvement, and involve many students - Master’s Thesis are shorter term, and have scopes suitable for a single student to complete in a semester.

A Master’s Thesis may or may not involve industry sponsorship, and unlike Fieldwork Experiences, faculty will play only an advisor/mentor role in this work. Students may propose their own independent projects, or

participate in a faculty-driven project. Similar to the college honors program, faculty receive a small stipend for their advisement/mentorship efforts, on a per-student basis.

Note: Students participating in a multi-semester Fieldwork project will have their Thesis requirement waived.

2.7. Direct and Indirect Measures

Direct Measure - Review of student work: For each outcome, specific coursework (or thesis outcome) will be directly evaluated by faculty in the MATH, CMPS, or DATA disciplines. In the case of courses, a faculty member not teaching the course from which the assignment is drawn will be selected to perform the evaluation. In the case of fieldwork and thesis work, a faculty member other than the advisor/mentor will evaluate progress/final reports submitted by the student.

The following indirect methods will be used to assess student outcomes

- Student Exit Surveys
- Industry Partner Surveys

2.8. Assessment Process

Each of the student learning outcomes are addressed and can be assessed through core required MSCS courses. CMPS 547 Foundations of Computer Science will be offered once a year (at a minimum) and all students must take this course before other required courses. This course introduces students to all the skills involved in computer programming and computational thinking. It serves as a foundational course. **Direct measures** will include review of course assignments / exam question responses.

The **Thesis** course is a requirement of all graduating students[3], and will be a primary point of assessment. All outcomes must be demonstrated in this course. Assessing this course through direct measures will include faculty review of progress reports and final Thesis reports. **Indirect measures** will include exit surveys from students.

With the above two courses, we have a basic framework for assessing student outcomes at the beginning of the program and at the end. It will also be critical to assess how these skills are being developed in other electives. There are 3 electives - CMPS 611, CMPS 631, and CMPS 664 - that share a number of SLO's with the program itself, and are additional opportunities for assessment because they will be offered frequently

The **Fieldwork Experience** course is an elective, however this will be another place where each of the student learning outcomes will be assessable both directly (progress/final reports) and indirectly (student and sponsor surveys). We view the sponsor surveys as enormously critical to the assessment process - as it is our best

[3] Students may receive credit for their Thesis by completing an extended Fieldwork Experience (2 semesters). It would be excellent if this becomes the norm - as it would mean we have a healthy sponsorship program - however we would need to adjust our assessment plan to include the FIeldwork Experience in future .

measure of whether our students are meeting industry expectations. As described above, the goal is to have all students participate in this course - however we cannot guarantee there will be enough industry-sponsored projects for all students - which is why the course is an elective.

2.9. Alignment of Program Outcomes to Courses

Note, individual courses indicated with a “X” may contain learning objectives phrased differently than the program outcome indicated, but align.

	Software Development	Problem Solving	Mathematical Reasoning	Presentation and Communication	Integrated Skills	Ethics in Work
Required Courses						
CMPS 547	X	X	X		X	
CMPS 531	X	X	X			
DATA 620		X		X	X	X
Thesis	X	X	X	X	X	X
Electives						
CMPS 530	X	X		X		
CMPS 550	X	X				
CMPS 611	X					
CMPS 620	X	X	X			
CMPS 631	X	X				
CMPS 645	X	X	X			
CMPS 664	X	X				
DATA 672	X			X	X	
DATA 687	X				X	
MATH 562		X	X			
MATH 645		X	X			
MATH 570		X	X	X		
MATH 645			X			
MATH 680		X	X	X	X	
Fieldwork	X	X	X	X	X	X

3. Alignment with College Mission and Strategic Plan

The proposed program fulfills several aspects of the College’s mission:

- **Experiential Learning**: The proposed program has a Thesis and a Fieldwork Experience component that provides students substantial opportunity for experiential learning by working with faculty and industry partners.

- **Community Involvement**: Industry partners play a large role in the project work students will complete in their Fieldwork Experience and Thesis courses - enhancing Ramapo's connection to local businesses in the area.

The M.S. in Computer Science program is well aligned with the College's Strategic plan - in particular goals three and four: (3) Advance Innovation as the College's Promise and Obligation to its Students, Community, and the State of New Jersey, **and**, (4) Improving Long-term Financial Strength.

We can further link the M.S. project to specific objectives outlined in the Strategic Plan:

Objective 1.3: To increase the number of students transferring from partner institutions: While not being proposed immediately, the possibility of a future 4+1 offering for B.S. (Computer Science, Mathematics, Data Science) and M.S. increases the ability to attract graduate students from partnered undergraduate schools through articulation agreements, and also provides a clear pathway for students in Computer Science, Data Science, and Mathematics undergraduate programs to transfer to Ramapo to take advantage of the program.

Objective 1.7: To support and develop a diverse, highly qualified, engaged, and accessible faculty through activities centered on teaching, learning, and advising; scholarship and creative work; and service and college governance: The Fieldwork Experiences and emphasis on industry involvement offers professional and academic opportunities to our faculty that are otherwise difficult to engage in. While primarily designed to provide students with experiential learning, the program also encourages faculty to form relationships with industry partners, earning stipends for their involvement in the projects and increasing their scholarship opportunities on campus.

Objective 1.8: To facilitate student success, in terms of completion and employment, via experiential learning: As described above, the Fieldwork Experience course and the M.S. Thesis is designed such that students have several experiential opportunities throughout while completing their M.S. degree. Employment opportunities are strong for graduates, and the industry partnerships integrated into the degree program only increase student opportunity for future employment.

Objective 4.4: To publicly position the College through advocacy, marketing and public relations as the premier public college in the region: The combination of a B.S. programs in Computer Science, Data Science, Mathematics, coupled with the MSDS, MSCS, and MSAM programs along with 4+1 programs and industry Fieldwork sponsors creates a powerful technology core at Ramapo to enhance the College's brand recognition. We intend to highlight at all levels how these technology fields have broad interdisciplinary impact and integration as a way of positioning Ramapo as unique - a liberal arts environment with first-class technology opportunities.

4. Impact on other Programs

The presence of an MS in Computer Science at Ramapo College strengthens our ability to mount and promote all of our interrelated technical MS programs - Data Science and Applied Mathematics. Students in these fields, along with potentially others (MBA) will benefit from the availability of the entry level coursework in this program. Computer Science is inherently interdisciplinary - allowing our students to team up with students from other disciplines in Fieldwork and research projects, and can provide a base of expertise to the College as a whole. Students from MSDS, MSCS, and MSAM will enroll in several courses across all our technical programs - strengthening those program's ability to run more courses each semester.

The MS in Computer Science strengthens our (already strong) undergraduate computer science program. The MS creates a 4+1 pathway for our students, especially for our international students who are heavily represented in the Computer Science major, and who often pursue graduate degrees. The MS curriculum also contains several 500-level courses which will be appropriate electives for our more advanced computer science undergraduates.

The degree requires no additional faculty or resources, and is sufficiently distinct from other degrees as to not cannibalize enrollment.

5. Other Programs in the Region

A Master's in Computer Science is a common degree, found in many schools in the region. This should not be surprising, Computer Science on the whole has seen a rapid rise in enrollment over the past 10 years. At the Bachelor's level, The Computing Research Association (CRA) reports[4] a 300% increase in Computer Science enrollment since 2009. CRA also reports an 8% increase YoY for MS enrollment. The average number of MS students at Computer Science departments across the country is 278, with the average number of **new** MS students in 2019 of 101 in each department (a survey of 108 departments). While the region has plenty of competition for Computer Science students, the market is large.

5.0.1. Regional Institutions

The following institutions have MS in Computer Science

- Fairleigh Dickenson
- Monmouth University
- Montclair State University
- New Jersey Institute of Technology
- Princeton University
- Rowan University
- Rutgers University
- Stevens Institute of Technology

[4] https://cra.org/wp-content/uploads/2020/05/2019-Taulbee-Survey.pdf

5.0.2. Curricular Differentiation

Most MS programs share similar core coursework - foundational computer science and computing theory, operating systems design, computer architecture, databases - along with a variety of different electives. Our curriculum cannot offer students quite as many choices as our larger competitors, however we have created a list of 16 courses from which our students take 6. This is not outside the norm.

Where our curriculum does standout is in our **Ethics requirement**, and our **Fieldwork opportunities**. We were not able to find another curriculum with a focus on ethics or hands-on fieldwork opportunities, which we believe will be a way to attract students looking for these qualities in a program. Typical Computer Science graduate curriculum solely focus on technical, and usually theoretical skills - and do not emphasize hands-on fieldwork experiences or the more circumspect ethical responsibilities of computer scientists. Not only is our emphasis on these aspects in line with the mission of Ramapo College, it also sets our program apart from other MS programs in the State.

Finally, our curriculum offers a rich set of technical electives slanted towards Data Science. Unlike typical Computer Science programs, we have not started with Computer Science - rather we are building on a new Data Science curriculum. Our course offerings reflect the trends of *industry*, focusing on practical applications of Computer Science rather than solely the theoretical aspects of the discipline. Offerings such as Machine Learning, Data Visualization, Time Series Data, and Big Data make our curriculum particularly attractive to students with an interest in Data Science, but who identify primarily as computer scientists and intend to pursue careers more rooted in software development.

5.0.3. How does Ramapo Compete?

Feedback from MSDS students appears clear, students seeking a graduate experience with small class sizes, engaged faculty that are accessible to their students, and a liberal arts atmosphere chose Ramapo for Data Science over large regional competitors at tech/engineering schools. We believe Ramapo competes at the MS level for Computer Science for the same reasons we compete at the undergraduate level - Ramapo's undergraduate computer science enrollment has more than kept up with national trends reported in CRA surveys, year after year.

Ramapo College, in fact, is already well recognized for its Computer Science undergraduate program. Simpson Scarborough, a firm hired by the College to help shape our marketing strategies, found that Computer Science was one of our most recognized programs among the broader community. Coupled with new programs in Data Science and Applied Mathematics, our core of graduate programs in math and computing will further boost Ramapo's brand in these rapidly growing markets.

The strength of our undergraduate program also creates an opportunity for Ramapo to retain our students for a fifth year through 4+1 BS to MS programs. We intend to have this as an option for our students at the onset of the program.

6. Student and Labor Market Demand

The U.S. Bureau of Labor Statistics identifies several occupations for computer scientists. Those where MS degrees are most common include the following:

Occupation	**Description**	**National Avg. Salary**	**Projected Job Growth**
Computer and Information Research Scientists	Computer and information research scientists invent and design new approaches to computing technology and find innovative uses for existing technology.	$122,840	15% (Much faster than average)
Software Developers	Software developers create the applications or systems that run on a computer or another device.	$107,510	22% (Much faster than average)
Computer Systems Analysts	Computer systems analysts study an organization's current computer systems and find a solution that is more efficient and effective.	$90,920	7% (Faster than average)

The salary data and job growth data in the table above are taken from the US Bureau of Labor Statistics. Regionally, salary averages are far higher. Software Developers in the NJ/NY commonly earn over $200,000 per year.

In 2020, US News and World Report listed their "Best Jobs" in the United States[5]. Software Developer was ranked #1 overall, #1 for best STEM job, and #1 for the best technology job. In their analysis, they listed three steps to success as a Computer Scientist: (1) a BS degree, (2) hands on experience, and (3) pursue a MS degree.

7. Enrollment

We are targeting an initial cohort of **fifteen** MSCS students (MSDS had 15 in its initial cohort), with a fall retention rate of 80% and Spring retention rate of 90%. Please note that financial projections must include MSDS, MSCS, and MSAM together, given their shared curricular structure. **Please see the accompanying shared enrollment and budget document for details.**

Table 4. Enrollment Projection for MSCS

[5] https://money.usnews.com/careers/best-jobs/rankings/the-100-best-jobs

Year	Entering Cohort	Headcount
2022	15	15
2023	16	27
2024	17	28
2025	17	29
2026	18	31

8. Space, Personel, and Faculty Line Requirements

The MSCS program does not require any additional space, faculty lines, or resources beyond what is already scheduled for FY 21. This includes the opening of the new computing classroom, new computing research lab (associated with the MSDS program), and the two new faculty (Computer Science) that were approved in the Spring of 2020. The two CMPS faculty lines will be searched in Fall 2021 and Fall 2022, and are restarts of the Fall 2019 search which could not be completed due to the pandemic. Please see the **shared budget document for additional details on resources**.

8.1. Program Director

MSCS will have a Program Director to lead the program, curricular developments, advisement, and admissions. They develop and enhance our industry partnerships within fields related to their program by assisting in developing fieldwork placements, ensuring representation on the Advisory Council, and engaging them in on campus activities (such as Computing Fair). They will need to work closely with the Computer Science Convening group to coordinate course load and course assignments. They will also need to coordinate with the Program Directors of the MSDS and MSAM for scheduling and sequencing of courses, marketing, budgeting, and Advisory Board membership as these are shared components of the three programs.

8.2. Classroom Requirements

As part of the Data Science (BS and MS) launch, a new computer classroom was scheduled for completion in Fall 2020. This classroom will be required to support the launch of the MSCS and MSAM programs - however no other classrooms are necessary.

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As part of the Data Science (BS and MS) launch, a conference room was approved to serve the programs and house advisory board meetings. This space was approved, but not allocated - and put on hold in Spring 2020. The new MS programs will create an increased urgency that this space be allocated.

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As part of the Data Science (BS and MS) launch, a new computer research lab to support faculty/student work was approved, but not allocated - and put on hold in Spring 2020. The new MS programs will create an increased urgency that this space be allocated.

9. Course Descriptions

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