Board of Governors, State University System of Florida

Request to Offer a New Degree Program

(Please do not revise this proposal format without prior approval from Board staff)

Florida Atlantic University	**Fall 2019**
University Submitting Proposal	**Proposed Implementation Term**
CES College of Science/College of Engineering & Computer Science/College of Business/DFS College of Arts & Letters	**Math/CEECS/ITOM/Political Science**
Name of College(s) or School(s)	**Name of Department(s)/ Division(s)**
Data Science and Analytics	**MS in Data Science and Analytics**
Academic Specialty or Field	**Complete Name of Degree**
30.0601	
Proposed CIP Code	

The submission of this proposal constitutes a commitment by the university that, if the proposal is approved, the necessary financial resources and the criteria for establishing new programs have been met prior to the initiation of the program.

Date Approved by the University Board of Trustees	**President**	**Date**	
Signature of Chair, Board of Trustees	**Date**	**Vice President for Academic Affairs**	**Date**

Provide headcount (HC) and full-time equivalent (FTE) student estimates of majors for Years 1 through 5. HC and FTE estimates should be identical to those in Table 1 in Appendix A. Indicate the program costs for the first and the fifth years of implementation as shown in the appropriate columns in Table 2 in Appendix A. Calculate an Educational and General (E&G) cost per FTE for Years 1 and 5 (Total E&G divided by FTE).

Implementation Timeframe	Projected Enrollment (From Table 1)		Projected Program Costs (From Table 2)				
	HC	FTE	E&G Cost per FTE	E&G Funds	Contract & Grants Funds	Auxiliary Funds	Total Cost
Year 1	20	400	$32,581	$544,095	0	0	$544,095
Year 2	30	600					
Year 3	40	800					
Year 4	50	1000					
Year 5	60	1200	$20,843	$1,042,152	$29,300	0	$1,071,452

Note: This outline and the questions pertaining to each section must be reproduced within the body of the proposal to ensure that all sections have been satisfactorily addressed. Tables 1 through 4 are to be included as Appendix A and not reproduced within the body of the proposals because this often causes errors in the automatic calculations.

INTRODUCTION

I. Program Description and Relationship to System-Level Goals

A. Briefly describe within a few paragraphs the degree program under consideration, including (a) level; (b) emphases, including majors, concentrations, tracks, or specializations; (c) total number of credit hours; and (d) overall purpose, including examples of employment or education opportunities that may be available to program graduates.

The proposed degree is a Master of Science in Data Science and Analytics (MS-DSA). This is a multi-college interdisciplinary program, jointly administered by the Charles E. Schmidt College of Science, the College of Engineering & Computer Science, the College of Business, and the Dorothy F. Schmidt College of Arts & Letters. It is designed to provide students with interests in Data Science and Data Analytics a unique and multifaceted educational opportunity within and across each of its areas of concentration. The four concentrations are Data Analytics in Business, Data Science and Engineering, Data Science in Society, and Data Science via Scientific Inquiry. The program will feature both a thesis and a non-thesis option. Students are required to complete 30 credits for either option. Students will complete a series of core courses, courses within their respective concentrations, and electives from across the various concentrations. Appropriate concentration courses and electives will be determined by the student and his or her advisory committee. This will allow students within each of the four concentrations the opportunity to benefit from the expertise in Data Science and Analytics of faculty from across four colleges. These faculty are actively integrating Data Science and Analytics in their research, teaching and community engagement. The multidisciplinary collaborations fostered between research faculty and graduate students across the various colleges will be extremely valuable in advancing research in the field, and in preparing students for 21st century jobs that require individuals to employ skills across industries, platforms, and disciplines.

The primary educational objective is to provide graduate students with the essential skill sets needed to analyze real world data (RWD). Students will emerge from the program with a broad understanding of data challenges and opportunities, along with the research and inquiry skills necessary to conduct independent research and answer questions within their area of specialization. They will be well prepared with rich hands-on experience and data analytics skills to enter the high demand workforce in the era of big data and quantum information processing as Data Curator, Data Analyst, Statistician, Data Scientist, Market Analyst, Software Engineer, etc.

The market analysis report (December 2017) by Hanover, contracted by FAU, shows that careers linked to the proposed program are expected to produce jobs at a rate faster than 6.5%. In particular, projections indicate accelerated job growth for Operations Research Analysts and Statisticians. In addition, computer programmers and application/software programmers are projected to add over 50,000 job openings per year. Altogether, the data suggest that employment prospects for students with degrees related to Data Science and other Analytics

programs are promising at the national level. Furthermore, Hanover's market analysis report shows that the employment outlook for Data Science and Analytics graduates in Florida is strong with relevant occupations projected to grow at a rate of 23.8% through 2024, which is significantly faster than the aggregate rate of growth for all occupations in Florida (18.3%). The employment outlook for graduates with skills in Data Science/Data Analytics is similarly strong in Palm Beach County, with relevant occupations projected to grow at an above average 15.2% between 2016 and 2024. (By comparison the aggregate rate of growth for all occupations in the county is 12.6%).

B. Please provide the date when the pre-proposal was presented to CAVP (Council of Academic Vice Presidents) Academic Program Coordination review group. Identify any concerns that the CAVP review group raised with the pre-proposed program and provide a brief narrative explaining how each of these concerns has been or is being addressed.

The pre-proposal was presented on February 6, 2018 to CAVP. There were no formal concerns against the degree pre-proposal. One recommendation was to form a program steering committee and reach agreement among the colleges on operational, curricular and commitments of offering the degree. Following the CAVP's recommendation, a program steering committee was formed on February 9, 2018 with one member from each participating college. The program steering committee has reached agreement to create four concentrations in the MS-DSA master program, each housed in a department within each college. The initial pre-proposal also included College of Medicine (COM), but COM cited a lack of resources for creating a medicine-specific concentration and was dropped from the proposal moving forward.

The program steering committee agreed that the Department of Mathematical Sciences will develop a common core course for the new program and decided to identify existing fundamental data related courses from each participating department and college as the other required two core courses from a poll of core courses. Thus, the degree will require three core courses for a total of nine core credits. The program steering committee will meet to discuss curriculum changes when necessary in the future. Each of the four departments (one from each participating college) will propose the admission requirements and the curriculum for its concentration, which will have to be approved by the program oversight committee. Each department will be in charge of recruiting, admitting and advising students in its concentration, as well as dealing with complaints, petitions, or other issues. In addition, each department will be responsible for confirming that students have met all requirements for the MS-DSA degree for students pursuing the concentrations in their department. Future changes in admission and/or curriculum in any concentration will have to be approved by the program oversight committee, as well as existing academic governance committees, before implementation.

C. If this is a doctoral level program please include the external consultant's report at the end of the proposal as Appendix D. Please provide a few highlights from the report and describe ways in which the report affected the approval process at the university.

NA

D. Describe how the proposed program is consistent with the current State University System (SUS) Strategic Planning Goals. Identify which specific goals the program will directly support and which goals the program will indirectly support (see link to the SUS Strategic Plan on the resource page for new program proposal).

The proposed program supports specific university and SUS missions

The three critical points of emphasis for the 2025 goals are Excellence, Productivity and Strategic Priorities for a Knowledge Economy.

Excellence

With contributions from interdisciplinary research faculty for the proposed degree program, we will provide an academic program of the highest quality. Research into the hardware, software, algorithms, and mathematical and statistical approaches needed to develop the next generation of scalable techniques and technologies for complex networks will be conducted. Data science, using advanced approaches such as deep learning and transfer learning, can be applied to many different domains. The new program will integrate world-class research expertise from FAU's Big Data Platform, FAU's NSF Big Data Training and Research Laboratory, and FAU's Center for Cryptology and Information Security (nationally recognized as CAE-R through DHS/NSA), as well as individual faculty conducting research in Departments across four Colleges. Participating graduate faculty from those colleges will contribute to deliver a graduate curriculum to students. The abundance of data-driven research opportunities should increase the research, scholarship and commercial endeavors of FAU faculty. This program will also foster interdisciplinary collaboration among the participating colleges and industry partners.

Productivity

This program will engage students in STEM, Business, and Social Science related research projects. Data scientists are increasingly critical for the effective operation of industry, business, government and healthcare across the nation and the world. FAU will produce graduates who are competitive in analytic data-driven research and knowledge discovery positions related to the dynamics of our explosive data age. While FAU offers many courses related to data analytics, there has not been a degree program that focused on data science and analytics. Bringing together the research faculty for this degree program provides an unprecedented opportunity to develop a degree that targets the workforce demands of the future and responds to student demand for a structured curriculum in data science and analytics. Since the proposed degree program will be delivered both on campus and as an online or distance learning curriculum, access for students will be easier than with traditional degrees that otherwise require on site attendance for all activities related to degree completion.

Strategic Priorities for a Knowledge Economy

One of the priorities of the BOG Strategic Plan is to increase the number of degrees in STEM and other areas of strategic emphasis. This proposed program supports FAU's Race to Excellence platform of Big Data Analytics which is listed as a top priority with a strong research component. Additionally, this program supports the state and university mission for advanced education in STEM disciplines while serving one of the most diverse student bodies in the SUS system.

This multi-college interdisciplinary nature of the program is what makes it significantly different from other programs in the State, none of which features a program that incorporates four colleges. It emphasizes the fusion of theoretical and applied components, which will prepare students with deep foundations and also exposure to real-world research. UCF's MS in Data Analytics is heavily oriented toward Computer Science, FIU's MS in Data Science is housed in the School of Computing and Information Sciences. New College's MS in Data Science is a mixture of Computer Science and Statistics. Besides the uniqueness of a multi-college program, the

proposed MS program will, as mentioned, also be offered both online and in a hybrid format, which will create opportunities for collaboration within the SUS.

FAU's 2015-2025 Strategic Plan and Signature Themes

The FAU's 2015-2025 strategic plan for Race to Excellence identifies signature pillars and platforms. Some of which will be addressed through this new degree program. In fact, this new degree proposal is a cornerstone for one of these signature platforms: the Big Data Platform. It will also support one of the signature pillars of Biomedical Research. The platforms such as Community Engagement and Economic Development; Leadership, Innovation and Entrepreneurship; and Big Data Analytics are addressed through departments and colleges working with external partners.

All participating colleges have strategic plans in support of the University Strategic Plan

CESCOS strategic plan:

The vision statement of CESCOS is to be recognized for interdisciplinary educational and research programs in science, and to be a leader in the international academic community. Priority 1 in the College's strategic plan is to enrich the educational success experience of students. Within Priority 1, objective A involves increasing the hiring of Tenure-track faculty to meet enrollment curricular needs which requires increasing the number of affiliate faculty involved in the graduate programs (graduate faculty from E&CS, Business and A&L); objective B is to promote curriculum and pedagogical innovation; objective C involves increasing support to design new courses to increase undergraduate and graduate programs, as well as provide competitive graduate student stipends. Some courses of the new proposed program will be developed into synchronous online courses. Increased collaboration between different departments will also encourage applications to new funding agencies, many of which favor cross-disciplinary research.

DFS College of Arts & Letters Strategic Plan:

The College provides essential foundational skills in writing, communication, critical thinking, and creative achievement. These foundations not only enable students to succeed in their disciplines, majors, and careers, but also add a holistic dimension to disciplinary knowledge. This fosters an understanding not simply of culture, but of the ways in which knowledge circulates across jobs and careers and into a larger society that is increasingly global and always human. Comprehending current events within the contexts provided by history, political science, philosophy, sociology, and anthropology provides students firmer ground for making decisions and shaping the world around them. We support this approach through three areas of focus. First, we focus on student enrichment initiatives, including developing workforce oriented programs and preparing the whole citizen. Second, we promote cultures of inquiry and the production of knowledge. Lastly, we connect the college faculty and students to the community.

College of Engineering and Computer Science (COECS) Strategic Plan:

The College of Engineering and Computer Science (COECS) is committed to provide high quality programs of education and research, along a stimulating and productive environment of work, study, and scholarly inquiry for students, faculty, and staff. The College's goals are results-oriented, and can be summarized as follows: (1) encourage students to consider careers

in engineering and computer science, (2) prepare graduates with a basis for lifelong personal and professional development that enables them to make lasting contributions in their disciplines, (3) engage students in research and discoveries in emerging disciplines and in related interdisciplinary areas, (4) provide top education preparation that working professionals need to keep pace with developments in their field, and (5) build mutually beneficial linkages with business, industry, schools, and other constituencies.

College of Business (COB) strategic plan:
The College seeks to develop a spirit of inquiry in its graduates and impart relevant techniques for solving problems in a global business environment. In doing so, it instills skills and knowledge that serve as a basis for change in a world where change is the norm. In response to the changing environment of both the University and surrounding region, FAU launched a bold new strategic plan in 2015 to build on strengths of the institution. FAU's College of Business faculty and administration followed with the adjusting and altering of our strategic plan, already in development, to complement the strengths and initiatives of the University. Our new plan harnesses the College's assets to enhance our engagement and impact initiatives, and boldly launches collaborative efforts among faculty, students, staff, alumni, and the business community of our region, and beyond. By committing to action, we are guided by our strategic initiatives to attract and support faculty and students in scholarship and business engagement, while harnessing innovative means to sustain the College's mission. The vision statement of College of Business is that we aspire to be an internationally known and a nationally ranked business school. The mission statement is that Florida Atlantic University's College of Business sustains an environment of entrepreneurial action and intellectual achievement through research and teaching, creating access to educational programs and opportunities for our constituents emphasizing the diverse people, industries, and issues of the south Florida region and beyond.

E. If the program is to be included in a category within the Programs of Strategic Emphasis as described in the SUS Strategic Plan, please indicate the category and the justification for inclusion.

The proposed degree program follows into the Strategic Emphasis Categories described in the SUS Strategic Plan:

1. **Critical Workforce**
   - Education: The broad education received by the students will make them capable and skillful data scientists filling the critical workforce demand that has been identified in education, industrial units and governments.

2. **Economic Development**
   - Global Competitiveness: All participating colleges offer Ph.D. programs, and participating faculty are active in research and teaching. Faculty are world class leaders in data security and computing, data science and data analytics. The university supports a combination of academic research and collaboration with for-profit partners, with the goal of developing products which are competitive in global markets. In addition, South Florida in general is a highly populated, highly developed area with small businesses and innovative and technologically advanced companies. The FAU Tech Runway offers initial support for qualified small business owners. FAU has established several core facilities

such as a Biostatistics and Study Design core, as well as the Bioinformatics and Data Science core. Through its Center for Cryptology and Information Security, FAU is recognized as National Center of Academic Excellence in Information Assurance/Cyber Defense Research (CAE-R), and FAU is home to a NSF Big Data Training and Research Laboratory. Thus, research performed at FAU is locally and globally significant.

3. Science, Technology, Engineering, and Math (STEM)

The proposed MS in Data Science and Analytics offers coursework and laboratory training at the graduate level in a wide array of science (including the social sciences), technology, engineering, art and humanities, and mathematics (STEAM) disciplines. These early career scientists and engineers will be entering Florida's workforce with the capabilities to fill emerging needs. This addresses more than STEM development in "Sciences and Technology" as identified in the Programs of Strategic Emphasis.

Table below partially shows a list of job titles for potential graduates from the proposed MS-DSA (December 2017, page 19).

SOC Title	Employment		Change 2014-2024		Avg. Annual Openings
	2014	2024	Number	Percent	
Computer and Information Systems Managers	343,330	419,080	75,750	22.1%	11,730
Computer and Information Research Scientists	23,120	27,240	4,120	17.8%	730
Computer Programmers	320,410	323,910	3,500	1.1%	9,280
Software Developers, Applications	726,010	931,180	205,170	28.3%	31,030
Software Developers, Systems Software	398,640	484,630	85,990	21.6%	14,270
Computer Occupations, All Other	226,850	249,660	22,810	10.1%	5,280
Mathematicians	1,760	2,130	370	21.0%	50
Operations Research Analysts	90,040	122,440	32,400	36.0%	4,900
Statisticians	31,050	42,280	11,230	36.2%	1,730
Mathematical Science Occupations, All Other	1,040	1,160	120	11.5%	300
Cartographers and Photogrammetrists	11,670	15,660	3,990	34.2%	770
Total – All Data Science Occupations	**2,173,920**	**2,619,370**	**445,450**	**20.5%**	**79,800**

This degree will also prepare students for careers in government and industry positions that require data skills to see patterns in society and human behavior. Potential jobs include political data analyst, survey statistician, research analyst, intelligence data analyst, quantitative social scientist, computational linguist, linguistic analyst, and urban regional planner. Currently, there are over 1600 listings for these positions on Indeed.com.

The Charles E. Schmidt College of Science is the primary source of scientific research and education for more than three million people living and working in our service region of Southeast Florida. Through its academic departments and research centers, our College provides outstanding opportunities for both undergraduate and graduate science majors. The education and research programs of our College span the sciences and mathematics with major efforts in many fields ranging from biotechnology, bioinformatics, and brain science to cryptology, developmental systems, dynamical systems, environmental sciences, geo-information science, marine science and space-time physics. Besides providing general education in science to all FAU students, the College currently provides educational and

research opportunities to 6,105 undergraduate and 477 graduate science majors. Science faculty members throughout the college have developed state-of-the-art research programs in diverse disciplines and important new interdisciplinary areas. Our faculty members have active collaborations that extend not only across FAU's colleges and campuses but also with local research institutions such as Scripps Florida, the Torrey Pines Institute for Molecular Studies, and the Max Planck Florida Institute; as well as affiliations with National Laboratories such as those at Los Alamos and Oak Ridge and international collaborations that span the globe. In the knowledge-based and innovation-dependent economy of the 21st Century, The College's undergraduate and graduate programs prepare students who can enter the workforce ready to meet local, national and international needs in a globally competitive environment.

The Dorothy F. Schmidt College of Arts and Letters provides a strong foundation for the teaching of research methodologies that link data to community needs and development. Students are trained in using quantitative methodologies to understand how state and society function -- preparing them to play a crucial role in a wide variety of organizations concerned with using data and data analysis to make informed decisions on policy, politics, economics, etc.

The College of Engineering and Computer Science offers traditional degrees with specializations in areas of national priorities such as cybersecurity, big data analytics, transportation and supply chain management. Each academic program is designed to impart the specialized knowledge and competencies appropriate to the particular degree, while providing for a broad overview of the discipline area and an appreciation of its relationship to other fields of learning. Cutting edge research conducted by the faculty and their teams expose students to the latest advances in the field and get them ready for tomorrow’s job opportunities.

The College of Business is accredited by AACSB - The Association to Advance Collegiate Schools of Business International, a recognition that only the top 5 percent of the world’s leading business colleges have earned. FAU is among the top-15 largest AACSB-accredited colleges of business in the United States, with a comprehensive slate of interdisciplinary and professional development programs. The FAU College of Business has been recognized by numerous media outlets, including U.S. News & World Report, which ranked FAU’s online graduate business programs 32nd in the nation in 2017, and Bloomberg Businessweek, which ranked our Professional and Executive MBA 27th among public universities in the nation. Named one of the “Best Business Schools” by The Princeton Review and ranked as the best business school for veterans in Florida by U.S. News & World Report, the College of Business strives to inspire students, faculty and the regional business community to innovate and make fundamental and positive changes to the way business is conducted. The College offers undergraduate programs in Accounting, Economics, Finance, Health Administration, Hospitality and Tourism Management, International Business, Management, Management Information Systems and Marketing. Master's degree programs are available in Accounting, Business Administration, Economics, Health Administration, Information Technology and Management and Taxation. A doctoral program is offered in Business Administration. In addition, the School of Accounting offers an Honors Program. The College of Business's largest and most diverse constituency resides in its upper-division baccalaureate and professional programs. Additionally, the College of Business provides lifelong learning experiences through professional weekend programs and centers that focus on services marketing, technology, entrepreneurship and international business. The College's research and services advance business knowledge by synthesizing ideas

in creative ways, thus contributing to South Florida's economic vitality and making the community a better place to live and work.

F. Identify any established or planned educational sites at which the program is expected to be offered and indicate whether it will be offered only at sites other than the main campus.

The program will be offered via courses at both FAU main and FAU branch campuses. The first semester for incoming graduate students will consist of all core courses offered both online and in a hybrid format. All concentration and elective courses are offered on the Boca campus or the Davie campus, depending on the concentration of the individual student. Many courses will include a distance learning component so that they may be attended from any campus.

INSTITUTIONAL AND STATE LEVEL ACCOUNTABILITY

II. Need and Demand

A. Need: Describe national, state, and/or local data that support the need for more people to be prepared in this program at this level. Reference national, state, and/or local plans or reports that support the need for this program and requests for the proposed program which have emanated from a perceived need by agencies or industries in your service area. Cite any specific need for research and service that the program would fulfill.

As presented in the report by McKinsey Global Institute on "Big Data: The Next Frontier for Innovation, Competition, and Productivity", the United States faces a growing shortage of 140,000 to 190,000 workers with analytical expertise and shortage of 1.5 million managers and analysts with the skills to understand and make decisions based on the analysis of big data. In 2015 4.4ZB data were generated and only less than 10% was analyzed in time. Furthermore, the data will be doubled every two years. All federal, public and private foundations are highly supportive of data science initiatives. For example, University of Michigan created the Institute for Data Science in 2015. Up to $10M of funding has awarded to proposals relevant to methodological foundations of data science. National Science Foundation supports the Transdisciplinary Research in Principles of Data Science (TRIPODS) award in the range of $1,200,000 and $1,500,000 to develop data science programs and to develop the theoretical foundations of data science through integrated research and training activities. Data Analytics and Automating Data Science, Machine Learning, Quantum Computing and Quantum Cryptography, and Social Network are listed among the top twenty science and technology trend areas according to the US Army's 2016-2045 Emerging Science and Technology Trends Report published in 2016.

Today's demand for expertise in data science and analytics far exceeds the current supply. The White House pledged $200 million of financial support in 2012 to fund new data-driven projects in the sciences. In 2012, the Harvard Business Review branded data scientists as "the sexiest job of the 21th Century." Admission administrators at top-tier institutions like Columbia University and University of California-Berkeley report very high numbers of applicants for their newly launched master's degree programs in data science, despite their intention to keep enrollment in the new programs small and highly selective. IBM predicts that the demand for Data Scientists will increase by 28% by 2020 (https://www.forbes.com/sites/louiscolumbus/2017/05/13/ibm-predicts-demand-for-data-scientists-will-soar-28- by-2020/#47dc948d7e3b).

The 2017 Market Analysis by Hanover (contracted by FAU) shows that the number of conferrals for many master's programs related to data analytics has grown nationally, particularly in science/mathematics and GIS, in the last five years. In total, master's degree awards related to data science and analytics increased from 9,755 in 2012 to over 14,000 in 2016. This represents an average annual growth rate of 10.1 percent – significantly faster than the average growth across all master's degrees.

The 2017 Market Analysis by Hanover of national degree completions indicate growing demand for data science programs, particularly in the natural sciences and social sciences. Student completions in these fields in Florida are more modest than for the nation as a whole - an average annual rate of increase of about 3% across Florida, compared to 10% across the United States. Additionally, as a major Hispanic Serving Institution, the proposed program will provide learning opportunity for large number of underserved populations. We project to offer the proposed MS program onsite and online. Hanover identified only one public university in Florida (FIU) that offers a similar degree fully online.

Table 1 from Hanover Marker Analysis shows that careers linked to the proposed program are expected to produce jobs at a faster rate than 6.5% annually. In particular, projections indicate accelerated job growth for Operations Research Analysts and Statisticians. In addition, computer programmers and application/software programmers are projected to add over 50,000 job openings per year. Altogether, the data suggest that employment prospects for students with degrees related to Data Science and other analytics programs are promising at the national level. Florida job growth for data science and analytics is projected at 40.4% over 2017-2025 time period.

Table 1: National Occupational Projections, 2014-2024*

SOC Title	Employment		Change 2014-2024		Avg. Annual Openings
	2014	2024	Number	Percent	
Computer and Information Systems Managers	343,330	419,080	75,750	22.1%	11,730
Computer and Information Research Scientists	23,120	27,240	4,120	17.8%	730
Computer Programmers	320,410	323,910	3,500	1.1%	9,280
Software Developers, Applications	726,010	931,180	205,170	28.3%	31,030
Software Developers, Systems Software	398,640	484,630	85,990	21.6%	14,270
Computer Occupations, All Other	226,850	249,660	22,810	10.1%	5,280
Mathematicians	1,760	2,130	370	21.0%	50
Operations Research Analysts	90,040	122,440	32,400	36.0%	4,900
Statisticians	31,050	42,280	11,230	36.2%	1,730
Mathematical Science Occupations, All Other	1,040	1,160	120	11.5%	300
Cartographers and Photogrammetrists	11,670	15,660	3,990	34.2%	770
Total – All Data Science Occupations	**2,173,920**	**2,619,370**	**445,450**	**20.5%**	**79,800**

Source: Bureau of Labor Statistics[48]

Furthermore, Hanover's market analysis shows the employment outlook for data science and analytics graduates in Florida is strong with relevant occupations projected to grow at a rate of 23.8% through 2024, which is significantly faster than the aggregate rate of growth for all occupations in Florida (18.3%) in Table 2.

Table 2: Florida Occupational Projections, 2014-2024*

SOC Title	Employment		Change 2014-2024		Avg. Annual
	2014	2024	Number	Percent	Openings
Computer and Information Systems Managers	10,560	13,210	2,650	25.1%	390
Computer and Information Research Scientists	510	570	60	11.8%	10
Computer Programmers	12,550	12,580	30	0.2%	310
Software Developers, Applications	30,710	40,090	9,380	30.5%	1,380
Software Developers, Systems Software	13,290	16,470	3,180	23.9%	510
Computer Occupations, All Other	7,750	9,220	1,470	19.0%	250
Mathematicians	120	150	30	25.0%	10
Operations Research Analysts	6,270	8,450	2,180	34.8%	330
Statisticians	820	1,310	490	59.8%	60
Cartographers and Photogrammetrists	540	830	290	53.7%	50
Total – All Data Science Occupations	**83,120**	**102,880**	**19,760**	**23.8%**	**3,300**

Source: Projections Central

*Some occupations are not listed due to lack of available data at the state level.

It also shows that master's degree completions for data science-related fields in Florida and FAU's local region, including St. Lucie, Martin, Palm Beach, Broward, and Miami-Dade counties are still growing. Student completions in data science-related fields in Florida are more modest than for the nation as a whole, increasing at an average annual rate of about three percent. Of these fields, Information Science/Studies and Medical Informatics have made the largest gains, with both showing significant increases in student conferrals over the past five years. Almost all institutions in FAU's region, except FIU, reported increasing conferrals rates in data science-related fields over the period, including Nova Southeastern University and University of Miami.

Salaries for data analysts are well above average. BLS reports annual national average wages for data analysts exceeding the national median salary of $50,620 by over 75% with computer programmers earning $87,930 and statisticians earning $88,980 annually.

The employment outlook for graduates with skills in data science/analytics is similarly strong in Palm Beach County (Table 3), with relevant occupations projected to grow at an above average 15.2% between 2016 and 2024. (By comparison the aggregate rate of growth for all occupations in the county is 12.6%).

Table 3: Palm Beach County Occupational Projections, 2014-2024*

SOC Title	Employment		Change 2016-2024		Avg. Annual
	2016	2024	Number	Percent	Openings
Computer and Information Systems Managers	970	1,172	202	20.8%	36
Computer Programmers	1,054	1,029	-25	-2.4%	26
Software Developers, Applications	3,010	3,542	532	17.7%	108
Software Developers, Systems Software	802	934	132	16.5%	28
Computer Occupations, All Other	360	415	55	15.3%	11
Operations Research Analysts	288	373	85	29.5%	16
Statisticians	22	32	10	45.5%	2
Total – All Data Science Occupations	**6,506**	**7,497**	**991**	**15.2%**	**227**

Source: Florida Department of Economic Opportunity

*Some occupations are not listed due to lack of available data at the county level.

B. Demand: Describe data that support the assumption that students will enroll in the proposed program. Include descriptions of surveys or other communications with

prospective students.

The interdisciplinary nature of the data science and analytics requires strong skills in computing, quantitative and statistical thinking, solving big data problems, and communicating findings. No currently existing program at FAU directly addresses the intense market demand.

The proposed MS in Data Science and Analytics will provide graduates with the key skills and hands-on experience in data science to meet the market demand locally, statewide, nationally and internationally. It will build interdisciplinary teaching and research teams at FAU. The proposed MS-DSA program will increase the research funding opportunities for faculty members who are involved in the program. Faculty will work together on case studies for research intensive courses and foster new collaborations in multi-disciplinary research.

FAU has built research expertise, supported by NIH, NSF and other substantial funding partners. For example: NSF funded "Big Data Training & Research Laboratory"; NSF funded Genomics and Genetic Research involving large data sets; High Performance Computing; Cyber Security and Cryptology. FAU is also recognized as a National Center of Academic Excellence in Information Assurance/Cyber Defense Research (CAE-R) for academic years 2014-2019. Our partnership with the Max Planck Florida Institute, the Scripps Research Institute affiliation; our NIH grant for dementia, our active research in aging prevention and risk factor analysis will also contribute to the culture of research centering on data science and analytics.

Students will take a core curriculum with the participating graduate faculty, and will have opportunities to take additional courses and work with researchers that have external funding and existing partnerships outside of FAU. These partnerships may include data pre-processing, data integration and visualization, computing and algorithm programming, data mining and machine learning, technical writing and communications. This is in addition to research faculty who have established other funded research programs. FAU has established partnerships with local business partners such as SIVTEC, JM Family, Modernizing Medicine, Cornerstone Solutions, Magic Leap, SurfBigData, FPL-NextEraEnergy, and others which offer additional training and research opportunities. The 2018 Inaugural Big Data Science Conference held in October 2018 at FAU attracted 180 participants indicating high local demand of Data Science and Analytics. Many local companies such as Office Depot and Magic Leap emailed us inquiring about FAU degree offering in Data Science and Analytics. A degree that adds the hands-on data experience partnering with local companies along with the required courses across the data science and analytics at FAU would prepare students well for the high workforce demand.

Many inquiries have been received during the development of the program. A few are included here as illustration. A student at FAU wrote to the chair of the program steering committee that "… I would be very interested in the new MS in Data Science and Analytics program but would like to start taking courses that will help me earn that MS degree. Do you know what are the required courses of the new MS(-DSA) program?" Office Depot in Boca Raton wrote to the steering committee chair that "We are in the search for junior level data scientists. I'm not sure if you have any good graduating students for reference. Let me know. Thank you." and "We are currently looking to fill intern positions for this summer in Machine learning/data science…. We can meet at FAU briefly…" etc. The program director will continue to work closely with the

Graduate college, and all participating colleges to develop a comprehensive advertising and recruitment plan.

C. If substantially similar programs (generally at the four-digit CIP Code or 60 percent similar in core courses), either private or public exist in the state, identify the institution(s) and geographic location(s). Summarize the outcome(s) of communication with such programs with regard to the potential impact on their enrollment and opportunities for possible collaboration (instruction and research). In Appendix C, provide data that support the need for an additional program.

Within the State system six schools offer Master Programs related to Data Science and Analytics. The programs' names and universities are listed below:

Table 4: MS program related to Data Science and Analytics within the SUS

Institution	Degree Program* (CIP Code)	Delivery Format	Program Cost (In-State)	Credit Hours
New College of Florida	MS, Data Science (11.9999)	On-campus	$17,079	36
University of Central Florida	MS, Data Analytics (30.3001)	On-campus	$36,300	30
Florida Gulf Coast University	MS, Information Systems and Analytics (52.1201)	On-campus	$11,211	30
Florida International University	MS, Data Science (11.9999)	On-campus, Online	$13,680	30

UCF offers a MS in Data Analytics which is heavily oriented toward Computer Science, FIU offers a MS in Data Science which is housed in the School of Computing and Information Sciences. New College's MS in Data Science is a mixture of Computer Science and Statistics. The MS programs at UF and FGCU focus on Information System and Operational Management and Analytics. FPU's MS degree focuses on Innovation and Technology.

The proposed MS program at FAU is a multi-college interdisciplinary program with an emphasis on linking data science and analytics to community and industry needs. With the growth of data centric jobs in government and multiple industries, there is an urgent need for a program that can apply data learning and analytics in varied environments and application domains. This program includes multiple offerings in varied disciplines providing an unmatched scope of learning that allows students to prepare for jobs that are still developing. The program will be offered both online and hybrid. As a result, the proposed degree program is unique in the content and scope of the program along with being offered in a more accessible format. Our scope should provide a template for other SUS schools and an opportunity for greater collaboration.

Since this is the first proposed MS in Data Science and Analytics with CIP 30. 0601 in the FL SUS, it is not possible to separate out the other university students, as the CIP codes for their degrees are listed below:

Science and Mathematics	Business and Management Programs
● 11.0104-Informatics ● 11.0401-Information Science/Studies ● 27.0304-Computational and Applied Mathematics ● 30.3001-Computational Science ● 45.0702-GIS and Cartography ● 51.2706-Medical Informatics	● 52.1201-Management Information Systems, General ● 52.1299-Management Information Systems and Services, Other ● 52.1301-Management Science ● 52.1399-Management Sciences and Quantitative Methods, Other

D. Use Table 1 in Appendix A (1-A for undergraduate and 1-B for graduate) to categorize projected student headcount (HC) and Full Time Equivalents (FTE) according to primary sources. Generally undergraduate FTE will be calculated as 30 credit hours per year and graduate FTE will be calculated as 24 credit hours per year. Describe the rationale underlying enrollment projections. If students within the institution are expected to change majors to enroll in the proposed program at its inception, describe the shifts from disciplines that will likely occur.

The program steering committee projects conservatively an average of five students for each concentrations for a total of twenty students in the first year and recommended to fund the TAships by provost office on average two graduate assistants for each concentration to support the proposed program. Students working towards other disciplines might change majors only in the first year of offering the program. This project is truly conservative comparing most recently established programs such as the MS in Data Science and Analytics at Clemson University which projects 35 students in the first summer of offering (pages 8-9). The program will attract more students from bachelor graduates from FAU, SUS institutions, other public or private institutions local, national and international institutions as the program matures over the years. See Table 1-B in Appendix A.

E. Indicate what steps will be taken to achieve a diverse student body in this program. If the proposed program substantially duplicates a program at FAMU or FIU, provide, (in consultation with the affected university), an analysis of how the program might have an impact upon that university's ability to attract students of races different from that which is predominant on their campus in the subject program. The university's Equal Opportunity Officer shall review this section of the proposal and then sign and date Appendix B to indicate that the analysis required by this subsection has been completed.

Graduate students are drawn from local, statewide, out-of-state and international populations. Under-represented minorities (URM) will be well represented as FAU is the most ethnically diverse institution in the State of Florida (29th nationwide). Minorities currently make up 44.83% of the FAU enrollment, and FAU is designated by the DOE Office of Postsecondary Education as a minority serving institution. Indeed, of the 29,606 students enrolled at FAU (all colleges) in Fall 2018 whose ethnicity was known, 12,574 were white and 13,376 were URM. Over the last five years, black and Hispanic enrollments have increased more than that of any other groups; FAU's student body will soon be a "majority minority" mirroring the predicted demographic composition of the USA in the near future. Thus there is already a large and diverse pool of students from which this program can recruit. Approximately 33.22% of graduate students at FAU in related programs belong to underrepresented minority groups. This number continues to grow each year and we assume that it will eventually reach numbers similar to the undergraduate distribution of 46.88% URM. This information was provided by FAU IEA office and approved.

FAU faculty and students are actively taking leadership for many organizations in South Florida. For example, the president and several other officers of South Florida Chapter of American Statistical Association are FAU faculty members. Recently FAU graduate students established AMS Women Student Chapter (South Florida), as well as Women in Science South Florida chapter initiated by FAU faculty members. FAU faculty members are active F-GAP Faculty Facilitators in mentoring applicants for Math Alliance (National level), etc. The multi-college nature of the program will be able to attract diverse graduate students seeking for the degree as well.

III. Budget

A. Use Table 2 in Appendix A to display projected costs and associated funding sources for Year 1 and Year 5 of program operation. Use Table 3 in Appendix A to show how existing Education & General funds will be shifted to support the new program in Year 1. In narrative form, summarize the contents of both tables, identifying the source of both current and new resources to be devoted to the proposed program. (Data for Year 1 and Year 5 reflect snapshots in time rather than cumulative costs.)

Education & General funds will be reallocated to support the new program in Year 1. We anticipate needing to reallocate resources in the amount of 25% annual effort for one faculty member to run the new common core course, Introduction to Data Science, offered each fall and spring semester. Most of the other approximately 50 courses listed in the program are already being taught as part of other programs. Students in this new program would occupy a few seats across several existing courses in Year 1 without the need for additional sections. Each college has this capacity in its current offerings, and one such course would be approximately 6.25% of annual effort for one faculty member. Since this degree is distributed over four different colleges, Table 4 projects that most faculty would teach only one or two such courses per year. This cost is reflected in the Reallocated Base in Table 3 for Year 1. In total these non-core courses represent approximately the equivalent of three full graduate courses in the first year for each of the four colleges.

The faculty salaries and benefits projection in Table 3 is based on the effort projection in Table 4. Increased effort is projected if a faculty member would be responsible for supervising master's thesis students or GRA's in the amount of 3.75% annual effort for each thesis student. Also, one faculty member in each college would have advising and oversight roles in the program which is approximated as 1% annual effort. In Year 5, due to tripling of the projected enrollment in the program, the effort is approximately doubled based on tripling of MS thesis and GRA supervision effort, the doubling of sections of elective courses that would have enrollment from this program, and doubling the number of sections of the common core course. In this calculation, some of the projected increase in enrollment is absorbed by having a few more seats taken in elective courses without extra sections being added and increased size of the sections of the common core course.

We anticipate needing graduate teaching/research assistants (GA's) for the program. In Year 1 each college has agreed to reallocate two GA's to this program from their respective budgets (total of 8 reallocated to the program). In Years 1-5, pending solid enrollment growth in the program, the Provost's office has committed to creating or redirecting funds for new graduate

assistantships as needed. For the purposes of the cost projections of this proposal, solid enrollment growth is assumed. In Year 1, we propose to offer up to four master level graduate assistantships per concentration (two reallocated and two created or redirected from the Provost's office) per year for a total of sixteen for the entire degree program. With increased growth in the program, the number of assistantships will increase over time to eight GA's per concentration per year by Year 5.

In this proposal we estimate that funding assistantships for Year 1 would require an upper bound on the annual stipend of $14,650 per GA. As illustrated in Table 2, reallocated GA funds would total $117,200 in Year 1, and new GA funds would also total $117,200 in Year 1. Based on the discussion above, these amounts would double by Year 5. Also, by Year 5 we anticipate having two GA's supported on research grants, which would amount to $29,300 in stipend.

The A&P salaries and benefits counts a minimum anticipated shift too with rough projection of $30,000 in year 1 and double shift cost for new enrollment growth in year 5.

A minimum cost of $5,000 is projected for marketing purpose and software installation for the year 1, and another $10,000 is projected for possible equipment replacement for year 5.

B. Please explain whether the university intends to operate the program through continuing education, seek approval for market tuition rate, or establish a differentiated graduate-level tuition. Provide a rationale for doing so and a timeline for seeking Board of Governors' approval, if appropriate. Please include the expected rate of tuition that the university plans to charge for this program and use this amount when calculating cost entries in Table 2.

NA

C. If other programs will be impacted by a reallocation of resources for the proposed program, identify the impacted programs and provide a justification for reallocating resources. Specifically address the potential negative impacts that implementation of the proposed program will have on related undergraduate programs (i.e., shift in faculty effort, reallocation of instructional resources, reduced enrollment rates, greater use of adjunct faculty and teaching assistants). Explain what steps will be taken to mitigate any such impacts. Also, discuss the potential positive impacts that the proposed program might have on related undergraduate programs (i.e., increased undergraduate research opportunities, improved quality of instruction associated with cutting-edge research, improved labs and library resources).

No programs are impacted by a reallocation of resources. Undergraduate programs will not be impacted. They will have potential to benefit from the new MS-DSA program for undergraduate research and discovery since the graduate teaching assistants will have more experience with data-driven research and inquiry experience. All graduate courses are being taught by graduate faculty. Opportunities for undergraduate research can be expected to increase as additional graduate students work with faculty in Data Science and Analytics; undergraduates often assist graduate student projects and are trained by them for independent research. Another positive impact is that low enrollment graduate classes offered in Data Learning courses will increase enrollment that will grow over the next five years. Since there are many options among existing graduate courses, this will probably be of small impact across the college, but courses that could not be offered regularly due to low enrollments will meet enrollment targets, while courses that were traditionally run with small numbers of students will increase in size. This program is also likely to increase enrollment in the FAU Big Data Certificate graduate programs and the MS in

Applied Mathematics and Statistics program as well as doctoral programs as students complete the MS degree and move into doctoral programs.

D. Describe other potential impacts on related programs or departments (e.g., increased need for general education or common prerequisite courses, or increased need for required or elective courses outside of the proposed major).

There is only one new core course on Introduction to Data Science for the proposed program. Hence the potential impact, if any, is to the minimum in assignment re-allocation. This core course does not have additional prerequisite, beside the admission requirements to the program.

E. Describe what steps have been taken to obtain information regarding resources (financial and in-kind) available outside the institution (businesses, industrial organizations, governmental entities, etc.). Describe the external resources that appear to be available to support the proposed program.

The program has access to research programs and resources that are sponsored by industrial and governmental collaborators. This includes groups whose focus is cybersecurity, topological data analysis, and a big data lab from engineering etc. The program also has close connection to research programs sponsored by NSF, NIH, NSA, US Department of Commerce, US DOT, and US State Department.

The College of Engineering has a Big Data Training & Research Laboratory which has been established through funding from NSF. Current Big Data research involves state-of-the-art data analytics infrastructure, training, and cross-disciplinary research in collaboration with College of Science, College of Business, and HBOI. Partnership with local industries is a focus of current research enabling applications related to health care and health management problems. A 12-credit Graduate Certificate Program on Big Data Analytics has been launched in Spring 2016 in collaboration with the College of Business. Several courses such as “Big Data Analytics”, “Deep Learning”, “Social Networks and Big Data Analytics”, Data Mining for Bioinformatics,” etc. have been developed. The transportation analytics has become a cornerstone of freight mobility research for efficiently moving people and goods. In South Florida such transportation is of paramount importance, as it is central to the function of our ports, and is critical in case of a hurricane. The College of Engineering has recently received a ten-million dollars from US DOT to establish a Freight Mobility Center. The hub of the Center will be located in Davie and can serve as a potential recruitment tool. The sensor data analytics via one of FAU pillar I-SENSE is also unique.

IV. Projected Benefit of the Program to the University, Local Community, and State

Use information from Tables 1 and 2 in Appendix A, and the supporting narrative for “Need and Demand” to prepare a concise statement that describes the projected benefit to the university, local community, and the state if the program is implemented. The projected benefits can be both quantitative and qualitative in nature, but there needs to be a clear distinction made between the two in the narrative.

In the era of big data and quantum information processing, the timely analysis of streaming or unstructured data is very important. Automating data science for fast data and streaming is the trend for the speedy discovery of knowledge and for timely action in post disaster situations. The pressing demand for skillful data scientists is made evident by the 2017 Hanover Market Analysis and fast growing national and international programs in Data Science, Business

Analytics, Informatics and Management. The internet and social media posts generate non-traditional data which requires modern analytic methods and scalable algorithms to pre-process, integrate and visualize in a timely manner. This provides challenges and opportunities for data scientists and data analysts to help make suggestions and decisions via knowledge discovery in databases. These discoveries will have economic impacts as a result of FAU data scientists' expertise in statistical modeling, data mining and machine learning, fault detection, cybersecurity, criminal justice, informational system and operational management, drug discovery and global environmental/climate change.

V. Access and Articulation – Bachelor's Degrees Only

NA

A. If the total number of credit hours to earn a degree exceeds 120, provide a justification for an exception to the policy of a 120 maximum and submit a separate request to the Board of Governors for an exception along with notification of the program's approval. (See criteria in Board of Governors Regulation 6C-8.014)

B. List program prerequisites and provide assurance that they are the same as the approved common prerequisites for other such degree programs within the SUS (see link to the Common Prerequisite Manual on the resource page for new program proposal). The courses in the Common Prerequisite Counseling Manual are intended to be those that are required of both native and transfer students prior to entrance to the major program, not simply lower-level courses that are required prior to graduation. The common prerequisites and substitute courses are mandatory for all institution programs listed, and must be approved by the Articulation Coordinating Committee (ACC). This requirement includes those programs designated as "limited access."

If the proposed prerequisites are not listed in the Manual, provide a rationale for a request for exception to the policy of common prerequisites. NOTE: Typically, all lower-division courses required for admission into the major will be considered prerequisites. The curriculum can require lower-division courses that are not prerequisites for admission into the major, as long as those courses are built into the curriculum for the upper-level 60 credit hours. If there are already common prerequisites for other degree programs with the same proposed CIP, every effort must be made to utilize the previously approved prerequisites instead of recommending an additional "track" of prerequisites for that CIP. Additional tracks may not be approved by the ACC, thereby holding up the full approval of the degree program. Programs will not be entered into the State University System Inventory until any exceptions to the approved common prerequisites are approved by the ACC.

C. If the university intends to seek formal Limited Access status for the proposed program, provide a rationale that includes an analysis of diversity issues with respect to such a designation. Explain how the university will ensure that Florida College System transfer students are not disadvantaged by the Limited Access status. NOTE: The policy and criteria for Limited Access are identified in Board of Governors Regulation 6C-8.013. Submit the Limited Access Program Request form along with this document.

D. If the proposed program is an AS-to-BS capstone, ensure that it adheres to the guidelines approved by the Articulation Coordinating Committee for such programs, as set forth in Rule 6A-10.024 (see link to the Statewide Articulation Manual on the resource page for new program proposal). List the prerequisites, if any, including the specific AS degrees which may transfer into the program.

INSTITUTIONAL READINESS

VI. Related Institutional Mission and Strength

A. Describe how the goals of the proposed program relate to the institutional mission statement as contained in the SUS Strategic Plan and the University Strategic Plan (see link to the SUS Strategic Plan on the resource page for new program proposal).

The identified mission of the SUS is to "….provide undergraduate, graduate and professional education, research, and public service of the highest quality." The goals of the proposed Masters of Science in Data Science and Analytics degree are to provide graduate students with essential skill sets in analyzing real world data and a broad understanding of data challenges and opportunities, along with the research and inquiry skills necessary to conduct independent research and answer questions within their area of concentration. They will be well prepared with rich hands-on data-driven experience and data analytic skills to enter the high demand workforce in the era of big data and quantum information processing. The new program will thus enhance both graduate education and public service in fields important not only to South Florida but globally by producing graduates well situated to enter the workforce ready to apply their skills to research, management and administrative questions related to data science and analytics. Graduates are expected to enter into higher education, government, private sector consulting positions and non-profit organizations.

The areas of faculty expertise in the new program, from four participating colleges, will support the state universities' mission to:

1) Support students' development of the knowledge, skills, and aptitudes needed for success in the global society and marketplace.
   - The MS-DSA degree will provide cross-disciplinary training with a core curriculum in fundamental data science, introduction to data mining and machine learning, quantitative methods and big data analytics, with additional coursework in areas of specialization in Data Science, Data Mining and Machine Learning, Social Data Science and Business Analytics. Hands-on data learning experience courses, as well as seminar and thesis work, will prepare students for the workplace with practical experience and strong communication skills.

2) Transform and revitalize Florida's economy and society through research, creativity, discovery, and innovation.
   - Participating faculty in the new program are world-renowned in their fields, with strong records of publication, grantsmanship, and discovery.

3) Address the significant challenges and opportunities facing Florida's citizens, communities, regions, the State, and beyond.
   - The MS-DSA program will train students in a variety of areas relevant to citizens of Florida, the Southeastern United States, and worldwide. It directly addresses the global need to increase data scientists, and seeks to prepare data scientists equipped with a diverse and wide-ranging skill set, balancing knowledge in scalable algorithms and computer programming languages with advanced experience in data mining and visualization. The Data Science and Business concentration as well as the Data Science and Society concentration will train students in extracting actionable intelligence from Big Data, facilitating knowledge discovery, data management, and the analysis of the

social implications related to security and privacy. These concentrations will also help prepare students to excel in data curation and its communication within industries and organizations.

- Deliver knowledge to advance the health, welfare, cultural enrichment, and economy through community and business engagement and service.
- All participating FAU Colleges have a strong culture of community and business engagement: FAU's main campus hosts bi-monthly "Frontiers in Science" public lectures. Recently FAU has established the Office of Community Engagement and seeks the Carnegie Foundation's Classification for Community Engagement. The Charles E. Schmidt College of Science has launched alive "Ask a Scientist" radio program and established the Center of Science Learning. FAU students and faculty also speak on national and international professional meetings and participate in life-long learning training programs.
- The MS-DSA Program will also seek to provide public service through student internships with federal, state and local agencies and organizations. The internships would offer opportunities for FAU students to collect data, participate in research and monitoring efforts, learn new skills, obtain experience, and provide various types of support to local partners on research projects related data science and analytics. Thus, the MS-DSA Program, its faculty and students will become a resource for local communities, government agencies, and local businesses in their efforts to find innovative solutions to problems facing coastal Florida.

B. Describe how the proposed program specifically relates to existing institutional strengths, such as programs of emphasis, other academic programs, and/or institutes and centers.

By creating concentrations across all four colleges with a common core on Introduction to Data Science, this program will enhance the graduate offerings across all participating colleges. It contributes to the sophistication of our students' quantitative and analytical skills, and prepares them for employment opportunities in fast growing and in demand fields in ways that more traditional programs do not. Because students in our program will have the ability to use their electives to mesh their primary interest in, say, big data and computer science with coursework in business data analytics, they will enlarge their skillset beyond what they might otherwise enjoy had they only taken a degree program with coursework delivered by the Computer Science department. In short, multi-disciplinary exposure will make our graduates capable of functioning in a wider array of organizations and industries than would otherwise be possible in a more traditionally offered, single-department program.

Such collaboration and multidisciplinary exposure will benefit from existing degree programs such as the MS in Applied Mathematics and Statistics (AMST), MS in Information Technology and Management, and social science MA programs with quantitative foci such as Political Science, Sociology, and Anthropology. The Big Data Analytics Certificate courses will also play an important role. The rich curricular offerings of these already existent programs can help open up additional opportunities for students in the MS in Data Science and Analytics.

The Center for Cryptology and Information Security was recognized as a National Center of Academic Excellence in Information Assurance/Cyber Research. FAU recently received ten-million dollars from the United States Department of Transportation to establish the Freight Mobility Research Institute. The Quantum@FAU is the joint effort among Science, I-SENSE and Engineering which has a physical lab Q-OWLS standing for Quantum Optics with Lasers. Furthermore, FAU has established several core facilities including a Biostatistics Collaborative Core, Water Analysis Lab, Engineering & Technology Core, MRI & Human Imaging and Comparative Medicine core. A Data Science core is under consideration. Graduate students will gain hands-on diverse experience through serving these university level cores. The research interests of all participating faculty range from statistical modeling, machine learning and data mining, business analytics, computing and informatics, cybersecurity and data science for social good.

These areas fit directly into the new FAU Strategic Plan with clear links to the pillars of Biomedical Research with healthcare data-driven and the platform of Economic Development and Big Data platform.

C. Provide a narrative of the planning process leading up to submission of this proposal. Include a chronology in table format of the activities, listing both university personnel directly involved and external individuals who participated in planning. Provide a timetable of events necessary for the implementation of the proposed program.

The initial discussions related to the development of the MS-DSA program took place in the Fall of 2017 between the Senior Associate Provost, the dean of Charles E. Schmidt College of Science, and the Chair of ITOM and Big Data Platform Committee. The pre-proposal was developed by the Chair of ITOM and the Associate Dean of Academic Affairs of CESCOS with input from the Dean of CESCOS and the Senior Associate Provost. It was followed by meetings with the Senior Associate Provost. The pre-proposal was approved on Feb. 6, 2018 CAVP meeting which recommended to form a program steering committee. The program steering committee was formed in March 2018. The Associate Dean of Academic Affairs from the Charles E. Schmidt College of Science was appointed to the lead of the program steering committee and first drafted this proposal. The program steering committee met several times and reached agreement to develop four concentrations for the MS in Data Science and Analytics. These discussions led to the preparation of new syllabi developed specifically for the MS-DSA for the Data Science Concentration housed in the department of mathematical sciences; these syllabi were submitted for approval in December of 2018. A market demand survey for the new program was completed in December 2017.

Planning Process

Date	Participants	Planning Activity
August 2017	Senior Associate Provost, Dean of CESCOS, Chair of ITOM,	Initial plan for a new degree program
September 2017	Senior Associate Provost, Dean and Associate Dean of CESCOS, Chair of ITOM	Follow up the initial plan for a new degree program
October 2017	Associate Dean of CESCOS, Chair of ITOM, Registrar Officer	Teleconference discussing the choice of CIP Code
October 2017	Registrar Officer	Reached out to FIU inquiring suitable CIP Code
December 2017	Pre-proposal developed by the	The pre-proposal was submitted to Senior

	Associate Dean of CESCOS and the Chair of ITOM	Vice Provost, then submitted by Senior Vice Provost for CAVP approval
October to December 2017	Hanover contracted by FAU	Market Survey and Analysis by Hanover completed
Feb. 6, 2018	Senior Vice Provost announced the approved Pre-proposal to Dean of CESCOS and the Chair of ITOM	The MS-DSA program is listed on page 20 of 2018 FAU Accountability plan CESCOS appointed the MS-DSA program committee chair
March, 2018	MS-DSA Program Committee established. Five representatives from the five participating colleges	Initial meeting of Program Committee to reach agreement on program degree requirements
June, 2018	MS-DSA Program Committee, Registrar Officer	More meetings of Program Committee and Registrar to reach the four concentrations for full Proposal
December 2018	Program Committee	Discuss the draft of full proposal
December 2018	Program Committee	Finalize the full proposal
January/February, 2019	Graduate committees/Deans Senior Associate Provost, CoS Associate Dean of Academic Affairs, Chair of Math. Sciences	Approvals Finalizing Appendix A
March, 2019	University GPC	Approval
April, 2019	University Senate	Approval

Events Leading to Implementation

Date	Implementation Activity
February 2018	Approval of pre-proposal by CAVP
October 2018	Colleges submitted sub-proposals and new syllabi
November 2018	The 1st draft of the full proposal submitted to program committee for revision
December 2018	Full proposal revision to final version, collect CVs of all participating faculty, approval of the new common core course
January 2019	Submit for college approvals
February 2019	Draft Catalog file and submit for college graduate committee approval
March 2019	University GPC approval

VII. Program Quality Indicators - Reviews and Accreditation

Identify program reviews, accreditation visits, or internal reviews for any university degree programs related to the proposed program, especially any within the same academic unit. List all recommendations and summarize the institution's progress in implementing the recommendations.

State of Florida requires seven year program review. FAU follows BOG recommendation. Furthermore, all FAU degree programs are required to have annual review on top of the periodic review or accreditation. Internal review is done via the assessment portal at http://www.fau.edu/iea/assessment/index.php. Accreditation differs from department to department as needed.

The Department of Mathematical Sciences

As part of its graduate program, the Department of Mathematical Sciences offers a *Master of Science in Applied Mathematics and Statistics* (AMST) program, whose *Biostatistics Track* and *Cryptology Track* are expected to benefit from this proposal. The department has reviewed the program internally as part of its regular program assessment, and one of strategic goals related to this new program is to build data security and statistical faculty expertise for the AMST program. The current AMST faculty has considerable academic and research experience with

cybersecurity and statistical modeling. However, the relatively small number of AMST faculty has been a limitation to further growth and the ability of the program to build and maintain research relationships with non-university partners. Action plans are as below:

1) Short-term: Efforts have been focused on recruitment and marketing the program and to hire a new faculty at the assistant professor level.
2) Longer-term: Support graduate students via Biostatistics core and Data Science core and partner internship opportunities and outreach to industrial partners.

The Department of Information Technology and Operations Management (ITOM)

The ITOM's strategic goal is to develop competence in information systems, operations management (including quality management) and related decision-sciences disciplines for traditional and nontraditional students across the College of Business; to produce skilled individuals proficient in information technology who are able to contribute effectively to their organizations and communities in an ever-evolving technological environment; to engage in an active partnership with the business community; and to continually innovate and increase the quality of its educational and research activities in a manner that increases education effectiveness and global reach. ITOM offers in conjunction with College of Engineering the Master of Science in Information Technology Management (MSITM). The MSITM program at ITOM, College of Business, is a very different offering from the proposed program. The former has managerial and business focus, while the latter's focus is on Data Science. The MSITM program is fully accredited with AACSB and the learning goals for the Business track are: 1. Students will demonstrate the ability to analyze and articulate the information technology investment strategies that align business strategies and encompass elements of an organization's functional processes, work practices, and human resource capital. 2. Students will demonstrate an ability to understand sourcing issues involving global IT providers and teams to apply this knowledge for selecting and evaluating sourcing partners. 3. Students will demonstrate effective oral and written communication skills necessary to succeed in a business and global environment. Accreditation visits are every 5 years, the last visit being in January 2018. ITOM conducted internal review and submitted assessment. We do not intend recommending the MS-DSA for AACSB accreditation due to the limited amount of Business content in the program. AACSB typically requires a minimum of 50% of the program content to be business related and taught by business faculty.

Items to Address/Specific Recommendations:

1) Since 2012, student enrollments have increased from 7,100 to 8,100 in 2017. While the numbers of full-time faculty have not changed over this period, the College has implemented several technology-based approaches to increase its capacity and efficiency, such as online and lecture capture. For example, lecture capture allows the College to enroll large numbers of students in a course, well beyond the room capacity, while encouraging the students to engage synchronously or asynchronously by viewing the recorded videos. However, even with these efficiencies, it is not clear that this level of growth can be sustained without adding additional faculty.
2) The College needs to address faculty needs in concert with its future enrollment growth.

The Department of Computer and Electrical Engineering and Computer Science (CEECS)

The CEECS department aims to find a balance of adhering to the mathematical and scientific fundamentals of our disciplines while also following their evolution and reflecting them in our offered curriculum and student training. We emphasize critical thinking, problem solving and

teamwork, and stress the significance of lifelong learning. The goals of the College of Engineering and Computer Science are to encourage young people to consider careers in engineering and computer science by introducing them to these fields while in middle and high school; to prepare graduates in ways that provide them a basis for lifelong personal and professional development and that enable them to exercise leadership and make lasting contributions in their disciplines; to continue on new roads of research and discovery in its existing areas of expertise, in emerging disciplines and in related interdisciplinary areas; to provide the educational resources that working professionals need to keep pace with developments in their field; and to magnify its positive impact in serving regional, state, national and global needs by building mutually beneficial linkages with business, industry, state colleges, K-12 programs and schools and other constituencies. The CEECS department offers two programs related to the proposed MS-DSA: MS in Information Technology and Management, and a certificate in Big Data Analytics. Both of these programs are offered jointly with the ITOM department, as described in the previous paragraph. The CEECS department did not have a recent review of the MS in Information Technology and Management program. For review of this program, please refer to the ITOM section.

The Department of Political Science offers undergraduate and graduate courses that contribute to the understanding of American politics, comparative politics, and international relations. The Department embraces the epistemology of social science research and helps students develop skills important to this field, and many others, including written and oral communication and critical thinking. The faculty and staff in the Department strive to help students meet their academic goals. The department is dedicated to advancing the study of political science through research, teaching and scholarship. Our diverse approach is based on teaching critical thinking, and students are encouraged to engage in quantitative and qualitative research by applying the basic principles of scientific methodology. In addition to developing these skills, the Department is dedicated to providing practical experience and advanced research opportunities through, for example, the Honors Program, Campaigning Program, Diplomacy Program, research-oriented upper division courses, directed independent studies, and internships.

VIII. Curriculum

A. Describe the specific expected student learning outcomes associated with the proposed program. If a bachelor's degree program, include a web link to the Academic Learning Compact or include the document itself as an appendix.

The MS-DSA Program will provide the essential skill sets in analyzing big and complex data and equip students with a broad understanding of data challenges and opportunities, along with the research and inquiry skills necessary to independently conduct research and answer questions within their area of concentration. To meet this goal, courses in the MS-DSA Program curriculum are organized around interdisciplinary focal areas in computer science, mathematics and statistics, business analytics and social science. Courses offered within this framework include: traditional lecture-style, e-learning, and lab courses; special topics courses that introduce students to the latest theories, methods, and emerging issues; seminar series; and experiential learning through thesis research, directed independent study (DIS), and internship programs. Through this framework, students will gain proficiency in the application of scientific principles such as, critical thinking, experimental design, data preprocessing and wrangling, data visualization and scalable computing, and advanced data mining and machine learning, as well

as a sense of professional and technical writing, and reporting, responsibility, and integrity.

Both thesis and non-thesis graduate students will demonstrate a broad understanding of the multidisciplinary features of data science and analytics and in-depth knowledge of their area of specialty. They will be able to use scientific research methods, perform analyses of big and complex data and critically evaluate and communicate research findings. They will demonstrate professional skills in data science and analytics, as evidenced by scholarly interactions with professionals in the industry and government, including participation in professional organizations, workshops, and conference participation.

Graduate students enrolled in the thesis option will be able to conduct original research and perform in-depth analysis, as demonstrated by the successful completion of a Master's Thesis. Specifically, students will demonstrate: 1) a current knowledge of their specialties of study and the ability to critically review and interpret scientific literature 2) the ability to develop a hypothesis, design and execute scientific experiments, and draw logical conclusions from data, 3) the ability to analyze big and complex data 4) the ability to write algorithms and software for reproducible research, and 5) the ability to write scientific reports and communicate effectively in scholarly presentations.

Specific Student Learning Outcomes – Master's Program

SLO 1: Content Knowledge and Skills

Students will demonstrate substantial professional skills in data science and analytics, as evidenced by real data analytics via term projects, professional algorithms, and software products from core courses, and be able to deliver oral presentation of the projects in classrooms, meetings and activities such as scholarly presentations, workshop participation, and conference attendance.

Implementing Strategy

Information on student projects will be collected to a repository webpage and participation in professional societies and organizations, scholarly interaction with faculty, and participation in professional workshops and conferences, will be collected by means of an online survey that is to be completed by students each academic year.

Assessment Method

Course projects will be graded by the presentation participants and the instructors based on the target course objectives to reflect the knowledge grasp level. In addition, the analyses and summary of the percentage of students reporting participation in specific professional activities will be reviewed annually by the MS-DSA Program Committee.

SLO 2: Original Thesis Research

Students enrolled in the thesis option will be able to conduct original research and perform in-depth analysis, as demonstrated by successful completion of a Master's Thesis. Specifically, students will demonstrate:

1) Frontier knowledge of data science and analytics and the ability to critically review and interpret new methods and algorithms.
2) the ability to preprocessing, integrating and efficiently visualizing complex data, develop hypothesis, retrieve data, write algorithm, and draw logical conclusions from data.

3) the ability to write scientific reports and communicate same effectively in oral presentations.

Implementing Strategy
Overall evaluation of student thesis work in the MS-DSA Program will be performed by the thesis committee in accordance with the guidelines of the academic department of the faculty advisor. A thesis committee reviews the thesis proposal and thesis defense presentations, which are open to the university at large and to the public. Each member of the Thesis Committee will submit a written evaluation of the thesis proposal and defense to the Program Coordinators, utilizing standard assessment forms that will be established by the MS-DSA Program Committee.

Assessment Method
Assessment of Thesis Proposal: During the first year, each student will write a thesis proposal and present a proposal seminar that is open to all faculty as well as the public. Each member of the Thesis Committee evaluates the proposal by a 5-pt scale (1=below expectation, 3= Meets expectation; and 5 = Exceeds expectation) for the established criteria such as:

1) Scientific Merit of Study
2) Adequacy of literature review
3) Ability to create testable hypothesis and define objectives
4) Soundness of research methods, including procedure for data analysis
5) Oral communication and seminar

Assessment of Thesis Defense: During the last semester of study, each student will submit a final written thesis and present a thesis defense seminar. Each member of the Thesis Committee evaluates the thesis by a 5-pt scale (1=below expectation, 3= Meets expectation; and 5 = Exceeds expectation) for the established criteria such as:

1) Scientific Merit of Study
2) Critical analysis of literature in the field
3) Hypothesis and extent to which objectives are accomplished
4) Scope and quality of data collected and its presentation
5) Intellectual merit of data interpretation and analysis
5) Potential for journal publication from the work

<u>SLO 3: Employment after Graduation</u>
Students will demonstrate the skills required to successfully compete for professional positions in the workforce by gaining employment in a data sciences-related field in the public or private sector.

Implementing Strategy
The MS-DSA Program will maintain contact with students after graduation through faculty advisors and annual email surveys.

Assessment Method
A system for collection and tracking post-graduation placement data (career path after leaving FAU) through email surveys will be developed by faculty and staff.

SLO 4: Critical Thinking and Communication

Students will demonstrate a broad understanding of the multidisciplinary research in data science and analytics and in-depth knowledge of their area of interest. They will be able to perform analyses of scientific data and research methods, critically evaluate research findings, and communicate effectively with colleagues in their field.

Implementing Strategy

All students must take the common core course during their initial fall semester, which will focus on these essential skills. Masters candidates will be evaluated via the Thesis and thesis seminar as above (SLO2); Non-thesis students will be evaluated through the exit exam (see graduation requirements, below)

Assessment Method

Student presentations and thesis seminars will be graded using a rubric that evaluates communication, critical thinking, and synthesis skills (to be established).

B. Describe the admission standards and graduation requirements for the program.

This is a multi-college interdisciplinary program designed to provide students with specialized training in Data Science and Analytics jointly administered by the four participating colleges, mainly through an executive committee. Students are required to take most of the coursework spread across the core subject areas. The exact courses taken are to be determined by students and their advisory committees.

Admissions Requirements

Each concentration will have a common application deadline. In addition to meeting all of the University and College admission requirements for graduate study, each applicant for the MS-DSA program must

- have obtained a Bachelor's degree from an accredited institution and possess a minimal background consisting of MAC 2233 (Method of Calculus) or equivalent, STA 2023 (Introductory Statistics) or equivalent, and computer programming COP 2220, MAD 2502, or equivalent. Knowledge of Python and statistical packages, such as R, as well as coursework in linear algebra are recommended.
- have a minimum of 3.0 GPA (B or better average) on the last 60 hours of undergraduate credits and establish graduate level proficiency.
- provide two letters of recommendation.
- have a minimum GRE score of 151 Verbal and 151 Quantitative for GREs taken after August 2014. GRE scores older than 5 years prior to admission will not accepted. The Data Science and Engineering concentration requires the submission of the GRE score (Verbal and Quantitative sections), but no minimum values are imposed.

Graduation Requirements

Students may graduate with a thesis or non-thesis Master's degree. Students are required to take one common core course, two core courses from the list of core courses, four concentration courses for each concentration, three elective courses from the list of elective

courses for a total of 30 credits for either the thesis or non-thesis option. The exact courses taken are to be determined by the students and their advisory committee.

C. Describe the curricular framework for the proposed program, including number of credit hours and composition of required core courses, restricted electives, unrestricted electives, thesis requirements, and dissertation requirements. Identify the total numbers of semester credit hours for the degree.

The proposed MS-DSA offers both thesis and non-thesis options. It will offer four concentrations. Each concentration will require three core courses (9 credits including the common core CAP 5768: Introduction to Data Science) chosen from a poll of five courses (see details in the next section), four concentration courses (12 credits), and three elective courses (9 credits) for both thesis and non-thesis options for a total of 30 credits. All core courses should be taken at beginning of the graduate program. All core courses are not counted as elective courses, and all courses cannot be double counted. The elective courses should be different from the core courses. Elective courses can be chosen from the courses offered from all colleges. See appendix for the list of elective courses.

D. Provide a sequenced course of study for all majors, concentrations, or areas of emphasis within the proposed program.

The sequenced course of study required by the four concentrations are listed below.

1. **Data Science via Scientific Inquiry, Department of Mathematical Sciences**

The Scientific Inquiry concentration is housed in the Department of Mathematical Sciences. It is naturally divided into four themes as below:

- **Data Fundamentals:** Software tools of the trade, data wrangling, data visualization, examples across disciplines, working with large datasets, and efficiency in data manipulation. Mathematical foundations of machine learning methods, classification and regression approaches, clustering and dimensionality reduction, feature selection, hyper-parameter optimization, model assessment.
- **Statistical Methods:** Modeling distributions, parameter estimation, hypothesis testing, statistical computing, linear and nonlinear regression, time series analysis, survival analysis, longitudinal data analysis and high dimensional data analysis.
- **Cryptology and Data Security:** Protecting data in rest and in motion. Protecting users' privacy and personal information in the data collection and data analysis phases. Protecting big public datasets.
- **Computational Topological Methods**: Mathematical foundations and computational algorithms for measurements of geometric and topological features of data.

In addition to the required common core course CAP 5768 above, all students in this concentration must complete another two core courses and four concentration courses chosen from the list below, plus three elective courses to fulfil 30 credits required.

Two More Core Courses required by Data Science via Scientific Inquiry Concentration:

- CAP 6673 Data Mining and Machine Learning
- One of the following core courses
    - BSC 6459 Biomedical Data and Informatics
    - ISM 6404 Introduction to Business Analytics and Big Data

- POS 6934 Quantitative Methods

Choose Four Concentration Courses from:

Statistics courses:

- STA 5195 Biostatistics
- STA 6106 Statistical Computing
- STA 6177 Survival Analysis
- STA 6236 Regression Analysis
- STA 6326 Mathematical Statistics
- STA 6857 Applied Time Series Analysis

Cryptology and Data Security courses:

- MAD 5474 Introduction to Cryptology and Information Security
- MAD 6478 Cryptanalysis
- CTS 6319 Cyber Security: Measurement and Data Analysis
- CIS 6370 Computer Data Security

Mathematics courses:

- MAP 6196 Mathematical Foundations of Data Science (NEW COURSE)
- MAD 6307 Graph Theory
- MTG 6329 Applied Computational Topology (NEW COURSE)

2. **Data Science and Engineering Concentration, Department of Computer & Electrical Engineering and Computer Science**

The Data Science and Engineering concentration is housed in the Department of Computer Science & Engineering. In addition to the required common core course CAP 5768 above, all students in this concentration must complete another two core courses and four concentration courses chosen from the list below, plus three elective courses to fulfil 30 credits required.

Two More Core Courses required by Concentration:

- CAP 6673 Data Mining and Machine Learning
- One of the following core courses
  - ISM 6404 Introduction to Business Analytics and Big Data
  - POS 6934 Quantitative Methods
  - BSC 6459 Biomedical Data and Informatics

Choose Four Concentration Courses from:

- CAP 5615 Introduction to Neural Networks
- CAP 6315 Social Networks and Big Data Analytics
- CAP 6546 Data Mining for Bioinformatics
- CAP 6618 Machine Learning for Computer Vision
- CAP 6619 Deep Learning
- CAP 6673 Data Mining and Machine Learning
- CAP 6776 Information Retrieval
- CAP 6777 Web Mining
- CAP 6778 Advanced Data Mining and Machine Learning
- CAP 6780 Big Data Analytics with Hadoop
- CAP 6807 Computational Advertising & Real Time Data Analytics

- CEN 6405 Computer Performance Modeling

3. **Data Science in Business Concentration, Department of Information Technology and Operational Management**

The Data Science in Business concentration is housed in the Department of Information Technology and Operations Management (ITOM). In addition to the required common core course CAP 5768 above, all students in this concentration must complete another two core courses and four concentration courses chosen from the list below, plus three elective courses to fulfil 30 credits required.

Two More Core Courses Required by Business Concentration:
- ISM 6404 Introduction to Business Analytics and Big Data
- One from the following core courses from outside the college
    - CAP 6673 Data Mining and Machine Learning
    - POS 6934 Quantitative Methods
    - BSC 6459 Biomedical Data and Informatics

Choose Four Concentration Courses from
Four classes from the following list, or any other data class in the College Business with the approval of the ITOM Chair.
- ISM 6136 Data Mining and Predictive Analytics
- ISM 6217 Database Management Systems
- ISM 6405 Advanced Business Analytics
- ISM 6555 Social Media and Web Analytics
- ISM 6562 Data Management and Analysis with Excel
- QMB 6603 Data Analysis for Managers
- COM 6316 Quantitative Communication Research

4. **Data Science in Society Concentration, Department of Political Science**

The data science and society concentration is housed in the Department of Political Science. In addition to the required common core course CAP 5768 above, all students in this concentration must complete another two core courses and four concentration courses chosen from the list below, plus three elective courses to fulfil 30 credits required.
Two More Core Courses Required by Society Concentration:
- POS 6934 Quantitative Methods
- One from the following core courses from outside the college
    - BSC 6459 Biomedical Data and Informatics
    - ISM 6404 Introduction to Business Analytics and Big Data
    - CAP 6673 Data Mining and Machine Learning

Choose Four Concentration Courses from
Four classes from the following list, or any other data class in the College of Arts and Letters with the approval of the social data science concentration director.
- POS 6736 Research Design in Political Science
- POS 6208 Seminar in Political Behavior

- ANG 6092 Advanced Anthropological Research 2
- ANG 6486 Quantitative Reasoning in Anthropological Research
- COM 6316 Quantitative Communication Research
- SYA 6305 Seminar in Advanced Research Methods
- ISM 6555 Social Media and Web Analytics
- CAP 6315 Social Networks and Big Data Analytics

The List of Elective Courses for All Concentrations

All students are required to choose three elective courses, other than the three core and four concentration courses for their program, from the list below or other data classes at FAU approved by the concentration director of each concentration of MS in Data Science and Analytics.

Statistics and Data Applications
- STA 5195 Biostatistics
- STA 6106 Statistical Computing
- STA 6177 Survival Analysis
- STA 6197 Biostatistics -Longitudinal Data Analysis
- STA 6207 Applied Statistical Methods
- STA 6236 Regression Analysis
- STA 6326 Mathematical Statistics
- STA 6857 Applied Time Series Analysis
- BSC 6459 Biomedical Data and Informatics
- MTG 6328 Applied Computational Topology

Data Mining and Machine Learning
- CAP 5615 Introduction to Neural Networks
- CAP 6315 Social Networks and Big Data Analytics
- CAP 6546 Data Mining for Bioinformatics
- CAP 6618 Machine Learning for Computer Vision
- CAP 6619 Deep Learning
- CAP 6673 Data Mining and Machine Learning
- CAP 6778 Advanced Data Mining and Machine Learning
- CAP 6780 Big Data Analytics with Hadoop
- CAP 6807 Computational Advertising & Real Time Data Analytics
- CAP 6546 Data Mining for Bioinformatics
- CAP 6776 Information Retrieval
- CAP 6777 Web Mining
- CEN 6405 Computer Performance Modeling
- ISM 6136 Data Mining and Predictive Analytics

Data Security and Privacy
- CIS 6370 Computer Data Security
- CTS 6319: Cyber Security: Measurement and Data Analysis

- ISM 6328 Management of Information Assurance and Security
- MAD 5474 Introduction to Cryptology and Information Security
- MAD 6478 Cryptanalysis
- PHY 6646 Quantum Mechanics/Computing 2

Database and Cloud Computing
- CDA 6132 Multiprocessor Architecture
- COP 6726 New Directions in Database Systems
- COP 6731 Theory and implementation of Database Systems
- CEN 5086 Cloud Computing
- ISM 6217 Database Management Systems

Social Data Science from Arts and Letters
- POS 6934 Quantitative Methods
- POS 6736 Research Design in Political Science
- ANG 6090 Advanced Anthropological Research 1
- ANG 6092 Advanced Anthropological Research 2
- ANG 6486 Quantitative Reasoning in Anthropological Research
- COM 6316 Quantitative Communication Research
- SYA 6305 Seminar in Advanced Research Methods
- CAP 6315 Social Networks and Big Data Analytics

Business Analytics
- ISM 6136 Data Mining and Predictive Analytics
- ISM 6217 Database Management Systems
- ISM 6404 Introduction to Business Analytics and Big Data
- ISM 6405 Advanced Business Analytics
- ISM 6555 Social Media and Web Analytics
- ISM 6562 - Data Management and Analysis with Excel
- QMB 6603 Data Analysis for Managers

Scientific Applications and Modeling
- AST 6765 Astro-statistics and Machine Learning
- GIS 6306 Spatial Data Analysis
- GIS 6112C Geospatial Databases
- GIS 6061C Web GIS
- GIS 6127 Hyperspectral Remote Sensing
- GIS 6028C Photogrammetry and Aerial Photography Interpretation
- GIS 6032C LiDAR Remote Sensing and Applications
- PHY 6938 Quantum Information Processing
- PHY 6936 Deep Learning and Data Analysis
- PHZ 5156 Computational Physics
- PHZ 7609 Numerical Relativity

E. Provide a one- or two-sentence description of each required or elective course.

Required Core Courses:

BSC 6459 Biomedical Data and Informatics

This course teaches essential concepts and methodology for biomedical data acquisition and analysis with an emphasis on the analysis of massive data. The course sets up the foundation for students' careers in biomedical informatics in a wide range of fields including biomedical academia, pharmaceutical and biotechnology industries.

CAP 5768 Introduction to Data Science

This course will survey foundational topics in data science and reinforce practical programming skills in the context of data analytics. Students will learn fundamentals of computational data analysis using statistics and machine learning and gain experience working with data sets from a variety of domains.

CAP 6673 Data Mining and Machine Learning

This course deals with the principles of data mining. Topics covered include machine learning methods, knowledge discovery and representation, classification and prediction models.

ISM 6404 Introduction to Business Analytics and Big Data

This course provides an understanding of the business intelligence and business analytics processes and techniques used in transforming data to knowledge and value in organizations. Students also develop skills in analyzing data using generally available tools, e.g., Excel.

POS 6934 Quantitative Methods

This course discusses these issues and others and then move to interpret, implement, and employ basic research tools and methods. It is an applied course, but for applications to be performed there is a fundamental level of theoretical knowledge required. Many mistakes are made by those who only know to interpret findings and use 'canned' computer packages.

Concentration Elective Courses:

AST 6765 Astro-statistics and Machine Learning

A course on big data analysis in astronomy with applications.

CAP 5615 Introduction to Neural Networks, 3 credits

Brief introduction to biological neural systems. Models of neural mechanisms of learning and memory. Neural net applications to image processing, pattern recognition, machine learning, optimization problems, and robotics. Hardware implementation issues.

CAP 6315 Social Networks and Big Data Analytics, 3 credits

This course teaches students basic concepts of Big Data Analytics with focus on social network analysis and modeling. The class covers three major topics: graphs and social network models, Big Data Analytics platform and MapReduce (Hadoop) programming, and social network analytics and mining algorithms.

CAP 6546 Data Mining for Bioinformatics, 3 credits

Course focuses on the principles of data mining as it relates to bioinformatics. Topics covered include gene selection, class imbalance, classification, biomarker discovery and prediction models. No prior knowledge of biology is required.

CAP 6618 Machine Learning for Computer Vision, 3 credits

Introduction to machine learning techniques and their application in computer vision problems. Discusses image processing principles, techniques and algorithms. Use of MATLAB for lab assignments and projects.

CAP 6619 Deep Learning, 3 credits

This course teaches students basic concepts of deep learning with applications in computer science, engineering, business and other areas. The class covers major topics including math preliminaries, machine learning basics, deep forward networks, convolution networks, autoencoders, representation learning networks and their implementations and applications.

CAP 6776 Information Retrieval, 3 credits

This course teaches concepts, techniques and popular tools and applications in information retrieval (IR), which aims to obtain relevant information from a collection of resources. The class covers efficient text indexing, text processing, web search and text mining. New applications are also introduced.

CAP 6777 Web Mining, 3 credits

Course covers the techniques used to model, analyze, and understand the Internet and the web, especially the web graph and hypertext data.

CAP 6778 Advanced Data Mining and Machine Learning, 3 credits

The study of advanced topics in data mining and machine learning. Current research issues in data mining and its application in bioinformatics, computer network security, computer science, and software engineering.

CAP 6780 Big Data Analytics with Hadoop, 3 credits

Course covers data mining and machine learning in relation to Big Data. Big Data challenges such as high dimensionality, class imbalance and quality of data are examined. Offers hands-on experience with Big Data analysis in Hadoop using a high performance computing cluster.

CEN 6405 Computer Performance Modeling, 3 credits

Use of statistical software packages such as SAS for data validation, description and analysis of statistical models used in computer science and software engineering.

CAP 6807 Computational Advertising & Real Time Data Analytics, 3 credits

This course teaches students basic concepts of computational advertising with a focus on real-time data analytics for displaying advertisement. The class introduces different key aspects of building platforms for online advertising, the computational requirement, tools and solutions.

CEN 5086 Cloud Computing

Cloud computing is concerned with the use and architecture of this model of computation. We study the services provided by clouds, their internal structure, and their possibilities and limitations. We use UML as a language to describe architectures and patterns to help the design of software applications using clouds and to describe cloud architectures.

CIS 6370 Computer Data Security

Overview of technical aspects of data security with emphasis on the Internet and the design of secure systems. Security is a fundamental issue in current systems and there is a strong demand for software engineers who can develop secure software and maintain secure systems. This course exposes the required concepts and points the directions for further specialization. We use security patterns and UML models to describe designs. Emphasis on a holistic approach to security, as opposed to details of security mechanisms. The course is updated yearly to reflect the latest advances in this topic. Its orientation is strongly practical with emphasis on systems design and evaluation.

CTS 6319 Cyber Security: Measurement and Data Analysis

This course explores techniques and considerations for conducting cyber security research rooted in empirical observation. Topics include Internet measurement methodologies and data analytics and characterizing cyber-attacks. The ultimate goal of this course is to foster analysis of empirical data that is both sound and insightful.

GIS 6306 Spatial Data Analysis

Introduces a range of spatial statistical methods commonly used in the analysis of geo-spatial data in GISciences. Emphasis on gaining insight into the overall framework for analysis and developing an understanding of various concepts with in-depth treatment of select techniques. Methods are mainly discussed within the context of GIS technology.

GIS 6112C Geospatial Databases

Geospatial databases provide the functions of storing, managing and querying geospatial data and are an essential component of geographical information systems (GIS). This course covers the fundamental principles, techniques and methodologies for designing and implementing a geospatial database and querying and geoprocessing in geospatial databases. Students receive hands-on experience via labs and projects.

GIS 6061C Web GIS

This course provides students with a comprehensive and up-to-date overview of Web GIS, including the basic concepts, principles, related fields and frontiers. It also provides state-of-the-art technical skills to build Web GIS applications and the knowledge needed to choose from various Web GIS development options.

GIS 6127 Hyperspectral Remote Sensing

Course introduces state-of-the-art techniques for the processing and interpretation of hyper- and ultraspectral data with a focus on thematic information extraction from airborne and satellite-based hyperspectral sensors. Course covers the full hyperspectral remote sensing processing chain from data acquisition and calibration to image processing and thematic mapping.

GIS 6028C Photogrammetry and Aerial Photography Interpretation

This course introduces concepts, theories and applications of photogrammetry. It covers history, principle, geometry, stereoscopy of aerial photography and fundamentals of analytical photogrammetry.

GIS 6032C LiDAR Remote Sensing and Applications

Introduces LiDAR principles, sensors and platforms, data processing and analysis and applications. Students master basic skills of LiDAR needed to leverage the commercial LiDAR sources and information products in a broad range of applications.

ISM 6136 Data Mining and Predictive Analytics

This course introduces the core concepts of data mining (DM) and its techniques, implementation and benefits. Course also identifies industry branches that most benefit from DM, such as retail, target marketing, fraud protection, health care and science, and web and e-commerce. Detailed case studies and using leading mining tools on real data are presented.

ISM 6217 Database Management Systems

Development of well-formed databases to manage data from initial database design to implementation and query. Applies database management tools and techniques such as data security for use in businesses and government. Available only to graduate students lacking an undergraduate course in database management systems.

ISM 6328 - Management of Information Assurance and Security

An introduction to the various technical and administrative aspects of information security. Emphasis is on the management of information security efforts.

ISM 6404 Introduction to Business Analytics and Big Data

This course provides an understanding of the business intelligence and business analytics processes and techniques used in transforming data to knowledge and value in organizations. Students also develop skills in analyzing data using generally available tools, e.g., Excel.

ISM 6405 Advanced Business Analytics

An in-depth examination of business analytics methods of visualization, data mining, text mining and web mining, using various analytical tools. In a laboratory setting, investigates applications for smaller firms.

ISM 6555 Social Media and Web Analytics

This course covers concepts and techniques for retrieving, exploring, visualizing and analyzing social network and social media data, website usage and clickstream data. Students learn to use key metrics to assess goals and return on investment and perform social network analysis to identify important social actors, subgroups and network properties in social media.

ISM 6562 - Data Management and Analysis with Excel

Graduate students from all disciplines will solve research and business problems by leveraging the most powerful productivity tool, Excel. Curation, management, analysis, and visualization of information and data are covered by using PowerView, Vlookup, charts, pivot tables, scenarios, functions, macro programming etc.

QMB 6603 Data Analysis for Managers

Introduction to statistical analysis of data using interactive computing, including topics such as randomness, cross-sectional regression, auto-regression, experiments versus observational studies, causal inference, and analysis of univariate and multiple time series.

MAD 5474 Introduction to Cryptology and Information Security

Classical ciphers and their analysis; unconditional versus computational security; basic constructions for stream ciphers; examples and modes of operation of block ciphers; cryptographic hash functions; public key encryption with ElGamal and RSA; digital signature schemes; Diffie-Hellman key exchange.

MAD 6307 Graph Theory

A first graduate course in theory and applications of graphs, including basic properties, algorithms, matchings, network flows, connectivity, colorings, planarity, vector spaces, and polynomials associated with a graph.

MAD 6478 Cryptanalysis

Entropy, probabilistic attacks. Passive and active attacks. Ciphertext-only, known-plaintext, chosen-plaintext, chosen-ciphertext attacks, adaptive attacks. Types of security. Know attacks on computationally secure systems. Meet in the middle attacks. Differential and linear cryptanalysis. Random number generators, tests, analysis and weakness.

MAP 6196 Mathematical Foundations of Data Science (New Course)

This course covers the mathematical underpinnings of a variety of methods of modern data science and machine learning while buttressing understanding of the theory through implementation and experimentation using the Python programming language and example datasets.

MTG 6329 Applied Computational Topology (New Course)

An introduction to the computational methods of topology, focusing on topological data analysis, persistence homology, and applications.

PHY 4605 & PHY 6646 Quantum Mechanics 2

Advanced concepts of quantum mechanics, many-particle theory and the local density approximation, introduction to relativistic and quasi-relativistic quantum theory, time-dependent perturbation theory and the interaction of particles with radiation.

PHY 6938 Quantum Information Processing

A course on foundations and contemporary applications of quantum information theory and quantum computing, with applications.

PHY 6936 Deep Learning and Data Analysis

A course on the foundations of deep learning from a statistical physics perspective, with applications to physics problems.

PHZ 5156 Computational Physics

Introduction to the use of numerical methods to solve realistic physics problems. Emphasis on good programming techniques and on obtaining insight into the problem rather than just numerical answers. Discussion of recent developments such as distributed and symbolic computing.

PHZ 7609 Numerical Relativity

The course offers an introduction to the mathematical formalisms employed to solve the Einstein equations numerically.

STA 5195 Biostatistics

An introduction to statistical tools used routinely for inference and data analysis in the health sciences. Topics include biostatistical design of medical studies, measure of disease occurrence and association, methods for rates and proportions, ROC analysis for screening and diagnosis, discrimination and classification, principal component analysis and factor analysis, log-linear models and survival analysis.

STA 6106 Statistical Computing

Algorithms in statistical computing: Random number generation, generating other distributions, random sampling and permutations. Matrix computations in linear models. Non-linear optimization with applications to statistical procedures. Other topics of current interest, such as issues of efficiency and use of graphics.

STA 6177 Survival Analysis

Introduces basic concepts of clinical trials, then the principles and methods of statistical inference that are commonly used for epidemiologic analysis of survival data. The major topics covered are: Basic concepts in survival analysis, types of censoring, life table and Kaplan-Meier, log-rank method and Cox proportional model. Software package R language is utilized.

STA 6197 Biostatistics -Longitudinal Data Analysis

Course covers techniques for analyzing longitudinal or repeated measured data, including derivation and estimation of model parameters. Also covers univariate and multivariate analysis of variance for repeated measures, random or mixed-effect models, covariate pattern models, generalized estimating equations models, mixed-effect logistic regression models, and missing data in longitudinal studies.

STA 6207 Applied Statistical Methods

Overviews of normal theory inference and categorical data methods; basic concepts of experimental design; analysis of variance and covariance; introduction to regression models and selection procedures. Statistical software Minitab and R are used for data analysis.

STA 6236 Regression Analysis

This course provides basic theory, methods and applications of regression analysis. Topics covered include simple regression (least squares method), multiple regression, transformation, inference and correlation analysis, categorical variables, residual diagnostics, model building and multicollinearity.

STA 6326 Mathematical Statistics

Theory of inference, regression, ANOVA, robust procedures, or other selected topics.

STA 6857 Applied Time Series Analysis

This course introduces fundamental concepts and some common models for time series data. Topics include stationarity, autocovariance function and spectrum, integral representation of a stationary time series and interpretation, ARMA, ARIMA and GARCH models, estimation and forecasting, multivariate time series, using R for the analysis of time series, and applications of time series.

F. For degree programs in the science and technology disciplines, discuss how industry-driven competencies were identified and incorporated into the curriculum and indicate whether any industry advisory council exists to provide input for curriculum development and student assessment.

As indicated above the program has close ties to end users in both industrial and governmental sectors. The Program includes cross-disciplinary courses in mathematics and statistics, computer science, information technology and operational management, political science that meet the needs of the industry. Though an industry advisory council is not being formed; we do have few MOUs in place to get input from industrial sponsors if it is needed for relevant courses.

G. For all programs, list the specialized accreditation agencies and learned societies that would be concerned with the proposed program. Will the university seek accreditation for the program if it is available? If not, why? Provide a brief timeline for seeking accreditation, if appropriate.

At this time we are not seeking additional accreditation for the Masters in Data Science and Analytics as this is not a professional development program.

H. For doctoral programs, list the accreditation agencies and learned societies that would be concerned with corresponding bachelor's or master's programs associated with the proposed program. Are the programs accredited? If not, why?

NA

I. Briefly describe the anticipated delivery system for the proposed program (e.g., traditional delivery on main campus; traditional delivery at branch campuses or centers; or nontraditional delivery such as distance or distributed learning, self-paced instruction, or external degree programs). If the proposed delivery system will require specialized services or greater than normal financial support, include projected costs in Table 2 in Appendix A. Provide a narrative describing the feasibility of delivering the proposed program through collaboration with other universities, both public and private. Cite specific queries made of other institutions with respect to shared courses, distance/distributed learning technologies, and joint-use facilities for research or internships.

Courses will be delivered through distance learning, purely online, traditional classroom and laboratory work; many of the courses have significant data components using software packages such as R, Python, and excel etc. The strength of the program is that the remaining courses are research intensive due to real big and complex data. There is not a perceived need to look outside the university. What is more important is an assessment and monitoring of the effectiveness of the courses offered, and a reevaluation each year based on the assessment goals established in conjunction with the college assessment officer. We expect that the majority of the students will be performing research towards their Master's thesis, DIS opportunities are available to all students and, when possible, Research Assistantships will be available for the students working on sponsored programs within the research labs.

IX. Faculty Participation

A. Use Table 4 in Appendix A to identify existing and anticipated full-time (not visiting or adjunct) faculty who will participate in the proposed program through Year 5. Include (a) faculty code associated with the source of funding for the position; (b) name; (c) highest degree held; (d) academic discipline or specialization; (e) contract status (tenure, tenure-earning, or multi-year annual [MYA]); (f) contract length in months; and (g) percent of annual effort that will be directed toward the proposed program (instruction, advising, supervising internships and practica, and supervising thesis or dissertation hours).

Table 4 in Appendix A lists all full time faculty associated with the program in Year 1 through Year 5 of

the program. The following scale is used for estimation in Table 4:

- One faculty teaching one course purely for the program, such as teaching the core course CAP5768 (Introduction to Data Science), is projected to be 12.5% annual effort.
- One faculty teaching one existing course with reallocation seats from other programs to the proposed program, is projected to be 6.25% annual effort.
- One faculty supervising one Master's thesis or GRA is projected to be 3.75% annual effort.
- One faculty administrating a concentration in the program is projected to be 1% annual effort.

B. Use Table 2 in Appendix A to display the costs and associated funding resources for existing and anticipated full-time faculty (as identified in Table 4 in Appendix A). Costs for visiting and adjunct faculty should be included in the category of Other Personnel Services (OPS). Provide a narrative summarizing projected costs and funding sources.

The total cost in Year 1 from Table 2 is estimated to be $780,495 of which $545,095 is reallocation of current funds. New recurring E&G funds of $235,400 are estimated for new GA positions. The total cost in Year 5 is estimated to be $1,588,772 of which $734,457 are new funds based on enrollment growth and $73,820 are projected GRA's funded from external grants.

C. Provide in the appendices the abbreviated curriculum vitae (CV) for each existing faculty member (do not include information for visiting or adjunct faculty).

See the appendices for all abbreviated CVs in Appendix D. Brief research interests of the faculty are given below.

The Department of Mathematical Sciences

Dr. Lianfen Qian: Interests: Structural change detection and estimation, survival analysis, longitudinal data analysis, genome-wide association and drug discovery, undergraduate and graduate research mentor.

Dr. Rainer Steinwandt: Interests: cryptography and data security, quantum information science.

Dr. William Kalies: computational topology, computational dynamical systems, and analysis of dynamics from data.

Dr. Francis Motta: Interests: Topological data analysis, applied dynamical systems, machine learning, quantitative and systems biology, research mentoring.

Dr. Lun-ching Chang: Statistical Genetics, Bioinformatics, Computational Biology, Biostatistics and Next Generation Sequence (NGS) analysis.

Dr. Hongwei Long: Interests: Stochastic analysis, stochastic partial differential equations and their numerical solutions, nonlinear filtering theory and its applications, parameter estimation and mathematical finance.

Dr. Dragan Radulovic: data mining and applied mathematical techniques commonly encountered in modern business environments.

Dr. Koray Karabina: Interests: Design and implementation of algorithms in classical and post-quantum cryptography: Elliptic curve cryptography; isogeny based cryptography; biometric template protection; efficient arithmetic; scalar multiplication; pairing based cryptography; discrete logarithm problem. Design and analysis of cryptographic protocols: Biometric authentication and template security; privacy preserving primitives; secure multi-party computation; side channel protection.

Dr. William Hahn: Interests: artificial intelligence and immune systems, Sparse Coding and Compressed Sensing, Convolutional Neural Networks, deep learning, Saliency map classification.

The Department of Information Technology and Operational Management (ITOM)

Dr. Tamara Dinev, Department Chair and Professor, Dean's Research Fellow. Research Interests: Information Privacy and Information Privacy Concerns, Cross-cultural Research in Information Systems and Internet Use, Information Security and Management of Information Security, Information Technology Adoption and Diffusion, Quantitative Research Methods

Dr. Jahyun Goo, Associate Professor. Research Interests: Global Sourcing and Virtual teams, Information Security and Management of Information Security, Information Technology Adoption and Diffusion, Quantitative Research Methods

Dr. Bharti Sharma, Instructor. Teaching and Research Interests: Data Mining and Data Warehousing, Social Media and Web Analytics, Database Management

The Department of Computer and Electrical Engineering & Computer Science (CEECS)
Dr. Taghi M. Khoshgoftaar is Motorola Endowed Chair professor of the Department of Computer and Electrical Engineering and Computer Science, Florida Atlantic University and the Director of NSF Big Data Training and Research Laboratory. His research interests are in big data analytics, data mining and machine learning, health informatics and bioinformatics, social network mining, fraud detection, and software engineering. He has published more than 700 refereed journal and conference papers in these areas. He is the conference chair of the IEEE International Conference on Machine Learning and Applications (ICMLA 2019). He is the Co-Editor-in Chief of the journal of Big Data. He has served on organizing and technical program committees of various international conferences, symposia, and workshops.
Dr. Xingquan (Hill) Zhu is a professor in the Department of Computer and Electrical Engineering and Computer Science at FAU. Dr. Zhu's research interests are data mining, machine learning, multimedia systems, and bioinformatics.
Dr. Dingding Wang's primary research interest lies in data mining, information retrieval, and machine learning for improving document understanding. In particular, her research goal is to help users to better understand and utilize large real document data sets via document clustering, summarization, and storyline generation. She also works on research topics related to social network analytics, bioinformatics, music information retrieval, recommendation systems, and malware detection.

The Department of Political Science, College of Arts and Letters
Dr. Kevin Michael Wagner's research interests include judicial politics, political behavior, legislative behavior, American political development, media and politics, and American political thought. The main theme animating his research is an interest in understanding political change in democratic systems including the shifts caused by technology such as the Internet.
Dr. Mehmet Gurses' research interests include ethnic and religious conflict, post-civil war peace building, post-civil war democratization, Kurdish politics, and the emergence and evolution of the Islamist parties in the Middle East.
Dr. Dukhong Kim's main research and teaching areas include political behavior, public opinion, minority politics, the presidency, political psychology, and methods. He co-authored and published an article in the American Political Science Review.
Dr. Eric Prier's main research interests include Public Procurement, Political Economy and Public Policy.

D. Provide evidence that the academic unit(s) associated with this new degree have been productive in teaching, research, and service. Such evidence may include trends over time for average course load, FTE productivity, student HC in major or service courses, degrees granted, external funding attracted, as well as qualitative indicators of excellence.

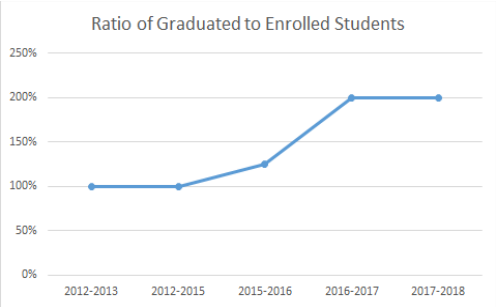
The Department of Mathematical Sciences is home to two major international journals -- de Gruyter's Journal of Mathematical Cryptology (two of three managing editors are with the department) and Forum Geometricorum (the editor-in-chief is with the department). From Fiscal Year 2015 to Fiscal Year 2018, the award amount received by the department (in USD) increased by more than a factor 2.5. Currently faculty at the department is funded through the Army Research Laboratory, DARPA, Cyber Florida, the German Federal Office for Information Security, NATO SPS, NIST, NSF, and NSA. In addition to publishing research papers, faculty is active in writing textbooks --- in 2015 a textbook in cryptography (CRC Press) appeared, in 2017 in algebra (AMS), and in 2018 in analysis (AMS).

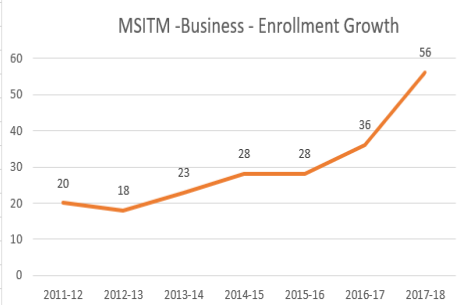
Through its cryptography group, the department is actively involved in a federal standardization process in the area of data security --- 3 of 26 Round 2 candidates in NIST's ongoing post-quantum standardization effort are co-authored by a department member. For a research project in the area of data security, one of the faculty members received the 2018 NATO Science for Peace and Security Partnership Prize. In addition to workshops in the area of Statistics and Data Science in conjunction with eCOTS, the department routinely hosts large international scientific meetings in various areas, including,

e.g., the 9th International Conference on Post-Quantum Cryptography in 2018 and -- this year for the 50th time -- the Southeastern International Conference on Combinatorics, Graph Theory and Computing.

Through its service courses, the department serves more than 13,000 students per year. For its own majors, undergraduate as well as graduate degrees are offered, including a Ph.D. program, which in 2018 graduated six students, moving on to academia, government, and industry. For incoming students, the department offers support through various student chapters of professional organizations (AMS, AWM, SIAM) -- the AWM student chapter received in 2018 the Association of Women in Mathematics' Fundraising and Sustainability Award.

The AMST program from the Department of Mathematical Sciences has seen significant improvement in the ratio of graduated to enrolled (see figure below blue colored one). This could be the results of departmental efforts in the past two years by various methods including encouraging students to get the degree along the way to a PhD.





The enrollments of the MSITM graduate program offered by the **ITOM department** have seen substantial growth. Above (orange colored one) is the enrollment data since 2011. Accordingly, individual course loads have grown from 10 enrollments on average to 22 on average.

The ITOM Department has over 250 undergraduate, and 60 M.S. students. Its programs, BBA/BS in MIS and MS in ITM, are all accredited by the AACSB and Southern Association of Colleges and Schools (SACS). The 5-year trend of degrees awarded are shown the table below.

	2013-14	**2014-15**	**2015-16**	**2016-17**	**2017-18**
Bachelor's	62	83	88	102	111
Master's	11	8	11	10	24
Total	**73**	**91**	**99**	**112**	**135**

In the AY 2017-18, the ITOM Department faculty have published 2 books, 21 peer reviewed publications, 16 conference presentations.

The CEECS Department has over 800 undergraduate, 200 M.S. and 75 Ph.D. students. Its three programs (Electrical Engineering, Computer Engineering and Computer Science) are all accredited by the American Board of Engineering Training (ABET) and Southern Association of Colleges and Schools (SACS). The 5-year trend of degrees awarded and 6-year trend of research expenditures are shown in the tables below.

	2013-14	**2014-15**	**2015-16**	**2016-17**	**2017-18**
Bachelor's	190	171	226	225	232
Master's	71	59	41	54	85
PhD	10	16	5	7	14
Total	**271**	**246**	**272**	**286**	**331**

Total Departmental Research Expenditure

FY2012-13	FY2013-14	FY2014-15	FY2015-16	FY2016-17	FY2017-18
1,021,174	867,727	850,795	1,457,057	2,370,294	2,463,447

The CEECS Department is home to two NSF IUCRC (Industry – University Cooperative Research Centers), two named laboratories (Bidtellect and Tecore). In AY 2017-18, CEECS faculty have published 9 books, 220 peer reviewed publications, 142 conference presentations and submitted 56 grant proposals.

The Political Science department currently serves over 500 undergraduate majors and 22 M.A students. In addition, it is a key department in the launch of the new Culture, Society and Politics track of the College of Arts and Letters PhD program in Comparative Studies. As such, it is in the process of matriculating its first 6 incoming PhD students whose primary area of interest, and thus coursework, is in political science. In addition to this, the Political Science department offers two key courses within the university's Intellectual Foundations Program, INR 2002 World Politics and POS 2041 Government of the United States, and delivers these to roughly 1400 students a year. Between 2014 and 2017 the department produced 6 monographs, 42 journal articles, 27 other scholarly publications, and 97 conference presentations. The 5 year degree trends for the department are shown in the table below.

	2013-14	2014-15	2015-16	2016-17	2017-18
Bachelor's	126	138	121	120	124
Master's	13	11	10	9	12
Total	**139**	**149**	**131**	**129**	**136**

X. Non-Faculty Resources

A. Describe library resources currently available to implement and/or sustain the proposed program through Year 5. Provide the total number of volumes and serials available in this discipline and related fields. List major journals that are available to the university's students. Include a signed statement from the Library Director that this subsection and subsection B have been reviewed and approved.

All FAU campuses have onsite libraries, with extensive physical and electronic collections.
The print volume count for books that could be categorized as Data Science and Analytics totals 18,483 plus an additional 6,217 unique e-book titles. The number of print and electronic serials subscribed includes 0 print journals and 813 unique electronic journals.

The libraries also have access to a number of journal titles through aggregator databases such as JSTOR, ProQuest or Academic Search Premier. A list of journal titles related to Data Science and Analytics in excel file (DataRelatedJournals.xls) and a list of aggregator databases such as JSTOR, ProQuest or Academic Search Premier in excel file (RelatedDatabases.xls) are attached. (Please see second attached file.)

B. Describe additional library resources that are needed to implement and/or sustain the program through Year 5. Include projected costs of additional library resources in Table 2 in Appendix A. Please include the signature of the Library Director in Appendix B.

No additional resources are being requested. This type of research has been done under other degree programs for many years at FAU, so the needed materials are already in place.

C. Describe classroom, teaching laboratory, research laboratory, office, and other types of space that are necessary and currently available to implement the proposed program through Year 5.

The existing space at each of the sites participating in the program is sufficient to meet the needs of both teaching and research opportunities. Facilities and research areas are described below.

Center for Cryptology and Information Security (CCIS)
The CCIS was established in the Fall of 2003 as a FAU College of Science center with funding provided by a Federal Earmark, and is by now founded on the unique strengths of cryptology and information security specialists in four different colleges of FAU, three of which are part of this proposal. The center seeks and promotes collaboration with information technology industries of our region, and with federal and state government departments in the areas of information security. In July 2016, FAU and the Airforce Research Laboratory, Information Directorate, Rome, New York, US (AFRL/RI) have entered into an Education Partnership Agreement for a period of 5 years. AFRL/RI is recognized as a national asset and leader in Communications, Computing, Cyber, and Intelligence technologies. This agreement will provide a unique opportunity for collaborative research and development. CCIS enabled FAU to be recognized as a National Center of Academic Excellence in Information Assurance/Cyber Defense Research (CAE-R) for academic years 2014-2019.

The mission of the Center is to promote and advance the state of knowledge, methodology, and training in information security. This faculty will bring the required expertise in securing data in rest and motion to the proposed degree program.

NSF Big Data Lab
This lab, procuring and acquiring a large computing cluster appropriate for Big Data research, aims to enable research in a number of fields of national concern such as bioinformatics, ocean energy, social media mining, environmental and climate modeling, image processing and analysis emergency response, health and medical informatics, national security, infrastructure maintenance and reliability, law enforcement, commerce, and manufacturing. All these demand the advanced computation resources under this acquisition. The study of Big Data encompasses the analysis of extremely large datasets, building models which are able to incorporate vast numbers of instances and features in order to make reliable predictions and connections.
Maintaining and promoting the growth of Big Data has become an essential activity to ensure that the problems that now seem insurmountable may be solved tomorrow. Two aspects of this growth are developing and providing courses for students focused on the tools and techniques necessary for Big Data research, and more focused training in these tools for existing researchers whose area of expertise lies in other aspects of research. Best practices will be followed for cultural diversity, involving students and researchers from underrepresented groups.

Participating Department Showcase at FAU:

The Department of Mathematical Sciences is home to 30 tenure-track or tenured faculty members and 18 faculty members in non-tenure-track positions. Research in the department that is relevant to this proposal ranges from machine learning, statistics, and topological data analysis to data security in the era of quantum information processing. The department is regularly home to major international research conferences, and departmental research is currently funded through various national and international organizations, including ARL, NIST, NSF, DARPA, and NATO. An international (cybersecurity) research project involving the department just recently received the 2018 NATO Science for Peace and Security Partnership Prize.

On the educational side, the department offers a full range of degree programs, ranging from the BA and BS to the MS and PhD level. Recent graduates of the department have placed successfully in academia, industry and government. Through its service courses, including in particular the foundational STA 2023 Introductory Statistics course, the department serves each semester thousands of FAU students. The department's commitment to student success is illustrated by a diverse and continually evolving portfolio of teaching methodologies. Next to traditional lecture-discussion style courses, this includes active learning with group work and learning assistants in the classroom, a math emporium, as well as courses taught mostly or fully online.

A Math Club and multiple student chapters (AMS, AWM, SIAM) are available to support students. The student chapter of the Association for Women in Mathematics (AWM) received in 2018 the AWM student chapter award in the Fundraising/Sustainability Category. This beautifully evidences the departmental commitment to tackle the challenge of underrepresentation of women in the Mathematical Sciences.

The Department of Computer and Electrical Engineering & Computer Science

Big Data Training and Research Laboratory (Director: Dr. Taghi Koshgoftaar)

NSF Big Data Training and Research Laboratory project consisted of procurement and deployment of a large computing cluster appropriate for Big Data research and led to the developed large-scale computational resources capable of solving Big Data challenges at Florida Atlantic University (FAU). The tools and resources provided by this project include a high performance computer cluster and advanced databases and facilities to store, maintain, and secure large quantities of data.

The computational facilities constructed as a part of this project provide student and faculty researchers with access to state-of-the-art hardware and software required to work with Big Data. Researchers have access to multiple distributed file systems including Hadoop and Lustre, and can leverage GPU accelerated nodes for training deep artificial neural networks and for use in other highly parallel tasks. Since the facility's inception, its resources have been used in over 100 published peer reviewed journal and conference papers and continue to be used in many ongoing research projects in a number of Big Data and/or Deep Learning application domains, including anomaly detection, fraud detection, sports medicine, network security, transfer learning, facial recognition, social media mining, fake review detection, and text mining. six PhD and three Masters Students have utilized these facilities to complete their dissertation or thesis and graduate since 2015, with many more set to graduate in the near future.

Additionally, the resources and tools acquired through this project have led to the development of new educational courses for graduate students and advanced undergraduates specifically focused on the tools and techniques necessary for Big Data research, such as using the Hadoop distributed file system for machine learning, and Deep learning.

Bidtellect Laboratory (Director: Dr. Hill Zhu)

The Bidtellect Laboratory is an incubator to support big data analytics and digital advertising research, as well as serve as an educational platform. Bidtellect's proprietary state of the art technology allows native ad planning, buying, selling and overall management on a single platform. By utilizing Bidtellect's Native DSP (nDSP), Native SSP (nSSP) and openRTB 2.3 Native Exchange, advertisers and publishers can now implement effective Native campaigns at scale with maximum optimization and ROI.

The ITOM Department

Classroom and teaching laboratory space are located in the Fleming Hall and Business BU building, with

state of the art Trading Room and Lecture Capture rooms permitting distance learning between FAU campuses from some classrooms. No additional teaching space is required to implement the proposed MS-DSA degree program- Data Science and Business Concentration. Major research areas of ITOM include Information Security, Social Media and Big Data, Global Sourcing and Virtual Teams, Privacy and Social implications of information security and Big Data, Healthcare analytics, Supply Chain Management, Supply chain security and analytics, Operations Management, Information technology adoption by individuals and organizations, IT organizational policies and practices.

The Political Science Department

The College of Arts and Letters boast an Advanced Media Production lab that includes an array of computer equipment that we anticipate using to support this initiative. As a teaching space with embedded technology capable of being used to support the program goals, we anticipate that this will be a primary space for delivery of curriculum by Arts and Letters faculty as it relates to the M.S in Data Science and Analytics degree. In addition, the college is currently seeking external grant funding in order to expand the Advanced Media Production labs capacities, transforming it into a Digital Humanities Lab that will include even more instructional and technological capacity than is currently enjoyed in the existing lab. If we are successful in securing external funding for the expanded lab, we will use this space to deliver instruction, as well.

D. Describe additional classroom, teaching laboratory, research laboratory, office, and other space needed to implement and/or maintain the proposed program through Year 5. Include any projected Instruction and Research (I&R) costs of additional space in Table 2 in Appendix A. Do not include costs for new construction because that information should be provided in response to X (E) below.

NA

E. If a new capital expenditure for instructional or research space is required, indicate where this item appears on the university's fixed capital outlay priority list. Table 2 in Appendix A includes only Instruction and Research (I&R) costs. If non-I&R costs, such as indirect costs affecting libraries and student services, are expected to increase as a result of the program, describe and estimate those expenses in narrative form below. It is expected that high enrollment programs in particular would necessitate increased costs in non-I&R activities.

NA

F. Describe specialized equipment that is currently available to implement the proposed program through Year 5. Focus primarily on instructional and research requirements.

This would be a very extensive list as there are many labs involved as described in the previous section. However, there are no new requests for additional equipment and all the courses that exist or have been developed have considered the impact of additional students. As the students will be spread across a number of areas, the impacts will be minimal and they will likely increase the probability that some low enrollment courses will be offered.

G. Describe additional specialized equipment that will be needed to implement and/or sustain the proposed program through Year 5. Include projected costs of additional equipment in Table 2 in Appendix A.

We anticipate only some expenses on marketing the new program, software renewals and replacement of equipment over the time as the program is modeled on existing master degree programs in all participating departments. Hence we budget at $5,000 on the first year and with new enrollment growth expenses of $10,000 by the year 5.

H. Describe any additional special categories of resources needed to implement the program through Year 5 (access to proprietary research facilities, specialized services, extended travel, etc.). Include projected costs of special resources in Table 2 in Appendix A.

Given the large diversity of existing facilities, courses and research labs, the primary focus in the early years will be to review the curriculum and identify the long term program needs once it is understood in which facility the students and consultation with advising board will concentrate, and where specifically our students will fit into the workforce in Florida.

I. Describe fellowships, scholarships, and graduate assistantships to be allocated to the proposed program through Year 5. Include the projected costs in Table 2 in Appendix A.

Eight new TA stipends and associated tuition waivers are needed for the first year. The provost office will fund the TA stipends. Four additional new TA stipends and associated tuition waivers are needed for the second year through year 4. This will attract high achieving students to the program in the first two years. The TAship assignments will be allocated across the colleges and will be budgeted by the Provost office. As FAU faculty engage increasingly research and inquiry among undergraduates, it is possible to plan to develop and deliver undergraduate curriculum in specialized areas such as Research Intensive introduction to data science, research intensive statistical learning, research intensive statistical computing and data mining. These TA positions would greatly facilitate the development of the new courses and certificates, creating the seed concentration areas for curriculum growth at the undergraduate and graduate level.

J. Describe currently available sites for internship and practicum experiences, if appropriate to the program. Describe plans to seek additional sites in Years 1 through 5.

Currently we have internships with NCCI, JM Family, Citrix, Goldman Sachs, American Express, Nexis and Lexis, Oak Ridge National Lab and Office Depot. The departments plan to seek addition sites via joint collaboration and hold local conferences such FAU-eCOTs Florida Southern Regional Conference (http://math.fau.edu/qian/2018Program.pdf) and the Inaugural Big Data Conference (http://www.math.fau.edu/big_data_science/) to attract local industry partners.

APPENDIX A

Enrollment, Faculty and A&P effort and budget projections. Pending for provost and budget approval.

APPENDIX B

Please include the signature of the Equal Opportunity Officer and the Library Director.

Signature of Equal Opportunity Officer	**Date**
Signature of Library Director	**Date**

This appendix was created to facilitate the collection of signatures in support of the proposal. Signatures in this section illustrate that the Equal Opportunity Officer has reviewed section II.E of the proposal and the Library Director has reviewed sections X.A and X.B.

APPENDIX C

The brief CVs of participating full time faculty.

APPENDIX D

Market Analysis by Hanover, a survey company contracted by FAU.

APPENDIX E

FAU library journal titles and volumes related to the proposed MS-DSA program.

APPENDIX F

New Program Catalog Change Request

APPENDIX G

The CoS Departmental Chair/Director' support email messages.

APPENDIX H

The New Degree Program Routing Form Signed by Deans

APPENDIX I

Support Letter from UCF

Master of Science with Major in Data Science and Analytics

The Master of Science with Major in Data Science and Analytics (MSDSA) is a multi-college interdisciplinary program jointly administered by the Department of Mathematical Sciences in the Charles E. Schmidt College of Science, the Department of Computer & Electrical Engineering and Computer Science (CEECS) in the College of Engineering and Computer Science, the Department of Information Technology and Operations Management (ITOM) in the College of Business, and the Department of Political Science in the Dorothy F. Schmidt College of Arts and Letters. The program aims to prepare students with the essential skill sets needed to analyze small, fast, big, massive and complex data. To allow for maximum flexibility in career aspirations, students can select from four concentrations:

- Data Science via Scientific Inquiry Concentration, Department of Mathematical Sciences
- Data Science and Engineering Concentration, Department of Computer & Electrical Engineering and Computer Science
- Data Analytics in Business Concentration, Department of Information Technology and Operational Management
- Data Science in Society Concentration, Department of Political Science.

Admission Requirements
To be admitted to the MSDSA program applicants must:

1. Have obtained a Bachelor's degree from an accredited institution and possess a minimal background consisting of MAC 2233 (Method of Calculus) or equivalent, STA 2023 (Introductory Statistics) or equivalent, and computer programming COP 2220, MAD 2502, or equivalent. Knowledge of Python and statistical packages, such as R, as well as coursework in linear algebra are recommended.

2. Have an undergraduate GPA of 3.0 or higher in the last 60 hours of undergraduate credits;

3. Submit two letters of recommendation;

4. Have obtained scores of at least 151 (verbal) and 151 (quantitative) on the Graduate Record Examination (GRE). GRE scores more than five years old are normally not acceptable. The Data Science and Engineering concentration requires the submission of the GRE score (Verbal and Quantitative sections), but no minimum values are required.

5. International students from non-English-speaking countries must be proficient in written and spoken English as evidenced by a score of at least 500 (paper-based test) or 213 (computer-based test) or 79 (Internet-based test) on the Test of English as a Foreign Language (TOEFL) or a score of at least 6.0 on the International English Language Testing System (IELTS); and

6. Meet other requirements of the FAU Graduate College.

Curriculum Requirements
MSDSA program offers both thesis and non-thesis options. Both options require a minimum of 30 credits. Students are required to take one common core course, two additional core courses, four concentration courses, and three elective courses for a total of 30 credits. The exact courses taken are to be determined by the students and their advisory committee. The thesis option requires only one elective course and 6 thesis credits. Students electing the thesis option must successfully complete and defend a written thesis.

Data Science via Scientific Inquiry Concentration

Students are required to take the common core course:	
Introduction to Data Science	CAP 5768
Take two additional core courses:	
Data Mining and Machine Learning	CAP 6673

Introduction to Business Analytics and Big Data	ISM 6404 **or**
Quantitative Methods	POS 6934 **or**
Biomedical Data and Informatics	BSC 6459
In addition, students need to take four concentration courses from the following:	
Biostatistics	STA 5195
Statistical Computing	STA 6106
Survival Analysis	STA 6177
Regression Analysis	STA 6236
Mathematical Statistics	STA 6326
Applied Time Series Analysis	STA 6857
Introduction to Cryptology and Information Security	MAD 5474
Cryptanalysis	MAD 6478
Cyber Security: Measurement and Data Analysis	CTS 6319
Computer Data Security	CIS 6370
Mathematical Foundations of Data Science	MAP 6196
Graph Theory	MAD 6307
Applied Computational Topology	MTG 6329
Lastly, students need to take three elective courses from the Table 1. Thesis option requires only one elective course and 6 thesis credits.	

Data Science and Engineering Concentration

Students are required to take the common core course:	
Introduction to Data Science	CAP 5768
Take two additional core courses:	
Data Mining and Machine Learning	CAP 6673
Introduction to Business Analytics and Big Data	ISM 6404 **or**
Quantitative Methods	POS 6934 **or**
Biomedical Data and Informatics	BSC 6459
In addition, students need to take four concentration courses from the following:	
Introduction to Neural Networks	CAP 5615
Social Networks and Big Data Analytics	CAP 6315

Data Mining for Bioinformatics	CAP 6546
Machine Learning for Computer Vision	CAP 6618
Deep Learning	CAP 6619
Information Retrieval	CAP 6776
Web Mining	CAP 6777
Advanced Data Mining and Machine Learning	CAP 6778
Big Data Analytics with Hadoop	CAP 6780
Computational Advertising & Real Time Data Analytics	CAP 6807
Computer Performance Modeling	CEN 6405
Lastly, students need to take three elective courses from the Table 1. Thesis option requires only one elective course and 6 thesis credits.	

Data Analytics in Business Concentration

Students are required to take the common core course:	
Introduction to Data Science	CAP 5768
Take two additional core courses:	
Introduction to Business Analytics and Big Data	ISM 6404
Data Mining and Machine Learning	CAP 6673 **or**
Quantitative Methods	POS 6934 **or**
Biomedical Data and Informatics	BSC 6459
In addition, students need to take four concentration courses from the following:	
Data Mining and Predictive Analytics	ISM 6136
Database Management Systems	ISM 6217
Advanced Business Analytics	ISM 6405
Social Media and Web Analytics	ISM 6555
Data Management and Analysis with Excel	ISM 6562
Data Analysis for Managers	QMB 6603
Quantitative Communication Research	COM 6316
Lastly, students need to take three elective courses from the Table 1. Thesis option requires only one elective course and 6 thesis credits.	

Data Science in Society Concentration

Students are required to take the common core course:	
Introduction to Data Science	CAP 5768
Take two additional core courses:	
Quantitative Methods	POS 6934
Introduction to Business Analytics and Big Data	ISM 6404 **or**
Data Mining and Machine Learning	CAP 6673 **or**
Biomedical Data and Informatics	BSC 6459
In addition, students need to take four concentration courses from the following:	
Research Design in Political Science	POS 6736
Seminar in Political Behavior	POS 6208
Advanced Anthropological Research 2	ANG 6092
Quantitative Reasoning in Anthropological Research	ANG 6486
Quantitative Communication Research	COM 6316
Seminar in Advanced Research Methods	SYA 6305
Social Media and Web Analytics	ISM 6555
Social Networks and Big Data Analytics	CAP 6315
Lastly, students need to take three elective courses from the Table 1. Thesis option requires only one elective course and 6 thesis credits.	

Table 1 (Elective courses)

Statistics and Data Applications	
Biomedical Data and Informatics	BSC 6459
Applied Computational Topology	MTG 6328
Biostatistics	STA 5195
Statistical Computing	STA 6106

Survival Analysis	STA 6177
Biostatistics -Longitudinal Data Analysis	STA 6197
Applied Statistical Methods	STA 6207
Regression Analysis	STA 6208
Mathematical Statistics	STA 6326
Applied Time Series Analysis	STA 6857
Data Mining and Machine Learning	
Introduction to Neural Networks	CAP 5615
Social Networks and Big Data Analytics	CAP 6315
Data Mining for Bioinformatics	CAP 6546
Machine Learning for Computer Vision	CAP 6618
Deep Learning	CAP 6619
Data Mining and Machine Learning	CAP 6673
Advanced Data Mining and Machine Learning	CAP 6778
Big Data Analytics with Hadoop	CAP 6780
Computational Advertising & Real Time Data Analytics	CAP 6807
Data Mining for Bioinformatics	CAP 6546
Information Retrieval	CAP 6776
Web Mining	CAP 6777
Computer Performance Modeling	CEN 6405
Data Mining and Predictive Analytics	ISM 6136
Data Security and Privacy	
Computer Data Security	CIS 6370
Cyber Security: Measurement and Data Analysis	CTS 6319
Management of Information Assurance and Security	ISM 6328
Introduction to Cryptology and Information Security	MAD 5474
Cryptanalysis	MAD 6478
Quantum Mechanics/Computing 2	PHY 6646
Database and Cloud Computing	
Multiprocessor Architecture	CDA 6132
New Directions in Database Systems	COP 6726
Theory and implementation of Database Systems	COP 6731
Cloud Computing	CEN 5086
Database Management Systems	ISM 6217
Social Data Science from Arts and Letters	

Quantitative Methods	POS 6934
Research Design in Political Science	POS 6736
Advanced Anthropological Research 1	ANG 6090
Advanced Anthropological Research 2	ANG 6092
Quantitative Reasoning in Anthropological Research	ANG 6486
Quantitative Communication Research	COM 6316
Seminar in Advanced Research Methods	SYA 6305
Social Networks and Big Data Analytics	CAP 6315
Business Analytics	
Data Mining and Predictive Analytics	ISM 6136
Database Management Systems	ISM 6217
Introduction to Business Analytics and Big Data	ISM 6404
Advanced Business Analytics	ISM 6405
Social Media and Web Analytics	ISM 6555
Data Management and Analysis with Excel	ISM 6562
Data Analysis for Managers	QMB 6603
Scientific Applications and Modeling	
Astro-statistics and Machine Learning	AST 6765
Spatial Data Analysis	GIS 6306
Geospatial Databases	GIS 6112C
Web GIS	GIS 6061C
Hyperspectral Remote Sensing	GIS 6127
Photogrammetry and Aerial Photography Interpretation	GIS 6028C
LiDAR Remote Sensing and Applications	GIS 6032C
Quantum Information Processing	PHY 6938
Deep Learning and Data Analysis	PHY 6936
Computational Physics	PHZ 5156
Numerical Relativity	PHZ 7609

APPENDIX A

TABLE 1-A (DRAFT)
PROJECTED HEADCOUNT FROM POTENTIAL SOURCES
(Baccalaureate Degree Program)

Source of Students (Non-duplicated headcount in any given year)*	Year 1		Year 2		Year 3		Year 4		Year 5	
	HC	FTE	HC	FTE	HC	FTE	HC	FTE	HC	FTE
Upper-level students who are transferring from other majors within the university**	0	0	0	0	0	0	0	0	0	0
Students who initially entered the university as FTIC students and who are progressing from the lower to the upper level***	0	0	0	0	0	0	0	0	0	0
Florida College System transfers to the upper level***	0	0	0	0	0	0	0	0	0	0
Transfers to the upper level from other Florida colleges and universities***	0	0	0	0	0	0	0	0	0	0
Transfers from out of state colleges and universities***	0	0	0	0	0	0	0	0	0	0
Other (Explain)***	0	0	0	0	0	0	0	0	0	0
Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

* List projected annual headcount of students enrolled in the degree program. List projected yearly cumulative ENROLLMENTS instead of admissions.
** If numbers appear in this category, they should go DOWN in later years.
*** Do not include individuals counted in any PRIOR CATEGORY in a given COLUMN.

TABLE 1-B
PROJECTED HEADCOUNT FROM POTENTIAL SOURCES
(Graduate Degree Program)

Source of Students (Non-duplicated headcount in any given year)*	Year 1		Year 2		Year 3		Year 4		Year 5	
	HC	FTE	HC	FTE	HC	FTE	HC	FTE	HC	FTE
Individuals drawn from agencies/industries in your service area (e.g., older returning students)	5	100	8	160	12	240	15	300	20	400
Students who transfer from other graduate programs within the university**	4	80	2	40	0	0	0	0	0	0
Individuals who have recently graduated from preceding degree programs at this university	5	100	8	160	10	200	10	200	12	240
Individuals who graduated from preceding degree programs at other Florida public universities	3	60	5	100	8	160	8	160	10	200
Individuals who graduated from preceding degree programs at non-public Florida institutions	2	40	4	80	4	80	6	120	6	120
Additional in-state residents***	1	20	3	60	5	100	8	160	8	160
Additional out-of-state residents***	0	0	0	0	1	20	3	60	3	60
Additional foreign residents***	0	0	0	0	0	0	0	0	1	20
Other (Explain)***	0	0	0	0	0	0	0	0	0	0
Totals	20	400	30	600	40	800	50	1000	60	1200

* List projected annual headcount of students enrolled in the degree program. List projected yearly cumulative ENROLLMENTS instead of admissions.

** If numbers appear in this category, they should go DOWN in later years.

*** Do not include individuals counted in any PRIOR category in a given COLUMN.

APPENDIX A

TABLE 2
PROJECTED COSTS AND FUNDING SOURCES

Instruction & Research Costs (non-cumulative)	Year 1 Funding Source						Year 1 Subtotal E&G, Auxiliary, and C&G	Year 5 Funding Source					Year 5 Subtotal E&G, Auxiliary, and C&G
	Reallocated Base* (E&G)	Enrollment Growth (E&G)	Other New Recurring (E&G)	New Non-Recurring (E&G)	Contracts & Grants (C&G)	Auxiliary Funds		Continuing Base** (E&G)	New Enrollment Growth (E&G)	Other*** (E&G)	Contracts & Grants (C&G)	Auxiliary Funds	
Faculty Salaries and Benefits	274,695.24	0	0	0	0	0	**$274,695**	274,695	193,657	0	0	0	**$468,352**
A & P Salaries and Benefits	30,000	0	0	0	0	0	**$30,000**	30,000	60,000	0	0	0	**$90,000**
USPS Salaries and Benefits	0	0	0	0	0	0	**$0**	0	0	0	0	0	**$0**
Other Personal Services	0	0	0	0	0	0	**$0**	0	0	0	0	0	**$0**
Assistantships & Fellowships	117,200	0	117,200	0	0	0	**$234,400**	234,400	234,400	0	29,300	0	**$498,100**
Library	0	0	0	0	0	0	**$0**	0	0	0	0	0	**$0**
Expenses	5,000	0	0	0	0	0	**$5,000**	5,000	10,000	0	0	0	**$15,000**
Operating Capital Outlay	0	0	0	0	0	0	**$0**	0	0	0	0	0	**$0**
Special Categories	0	0	0	0	0	0	**$0**	0	0	0	0	0	**$0**
Total Costs	**$426,895**	**$0**	**$117,200**	**$0**	**$0**	**$0**	**$544,095**	**$544,095**	**$498,057**	**$0**	**$29,300**	**$0**	**$1,071,452**

*Identify reallocation sources in Table 3.

**Includes recurring E&G funded costs ("reallocated base," "enrollment growth," and "other new recurring") from Years 1-4 that continue into Year 5.

***Identify if non-recurring.

Faculty and Staff Summary		
Total Positions	Year 1	Year 5
Faculty (person-years)	1.81	3.37
A & P (FTE)	0.25	0.7
USPS (FTE)	0	0

Calculated Cost per Student FTE		
	Year 1	Year 5
Total E&G Funding	$544,095	$1,042,152
Annual Student FTE	16.7	50
E&G Cost per FTE	$32,581	$20,843

APPENDIX A

TABLE 3 (DRAFT)
ANTICIPATED REALLOCATION OF EDUCATION & GENERAL FUNDS*

Program and/or E&G account from which current funds will be reallocated during Year 1	Base before reallocation	Amount to be reallocated	Base after reallocation
Mathematical Sciences faculty, staff, and expense in this program	1,149,992.24	92,232.06	**$1,057,760**
Computer Science faculty, staff, and expense in this program	435,128.15	79,898.40	**$355,230**
ITOM faculty in this program	563,533.09	81,479.89	**$482,053**
Political Sciencefaculty, staff, and expense in this program	463,858.97	56,084.89	**$407,774**
Science GTA	29,300.00	29,300.00	**$0**
Engineering GTA	29,300.00	29,300.00	**$0**
Business GTA	29,300.00	29,300.00	**$0**
Arts & Letter GTA	29,300.00	29,300.00	**$0**
Totals	$2,729,712	$426,895	**$2,302,817**

*** If not reallocating funds, please submit a zeroed Table 3**

APPENDIX A

TABLE 4 (DRAFT)
ANTICIPATED FACULTY PARTICIPATION

Faculty Code	Faculty Name or "New Hire" Highest Degree Held Academic Discipline or Speciality	Rank	Contract Status	Initial Date for Participation in Program	Mos. Contract Year 1	FTE Year 1	% Effort for Prg. Year 1	PY Year 1	Mos. Contract Year 5	FTE Year 5	% Effort for Prg. Year 5	PY Year 5
A	Lianfen Qian, Ph.D.	Prof	Tenured	Fall 2019	12	1.00	0.06	0.06	12	1.00	0.13	0.13
	Statistics											
A	Dragan Radulovic, Ph.D.	Prof	Tenured	Spring 2020	9	0.75	0.06	0.05	9	0.75	0.19	0.14
	Probability											
A	Lun-ching Chang, Ph.D.	Assoc. Prof	Tenure-earning	Fall 2019	9	0.75	0.19	0.14	9	0.75	0.45	0.34
	Biostatistics											
A	William Kalies, Ph.D.	Prof	Tenured	Fall 2019	9	0.75	0.16	0.12	9	0.75	0.16	0.12
	Mathematics											
A	Rainer Steinwandt, Ph.D.	Prof	Tenured	Fall 2019	12	1.00	0.06	0.06	12	1.00	0.06	0.06
	Mathematics											
A	Stephen Locke, Ph.D.	Prof	Tenured	Spring 2020	12	1.00	0.06	0.06	12	1.00	0.06	0.06
	Mathematics											
A	Koray Karabina, Ph.D.	Assoc. Prof	Tenured	Spring 2020	9	0.75	0.06	0.05	9	0.75	0.16	0.12
	Mathematics											
A	William Hahn, Ph.D.	Assoc. Prof	Tenure-earning	Fall 2019	9	0.75	0.10	0.08	9	0.75	0.26	0.20
	Data Science											
A	Francis Motta, Ph.D.	Assoc. Prof	Tenure-earning	Fall 2019	9	0.75	0.10	0.08	9	0.75	0.26	0.20
	Mathematics											
A	Taghi Koshgoftaar, Ph.D.	Prof	Tenured	Fall 2019	9	0.75	0.33	0.25	9	0.75	0.59	0.44
	Computer Science											
A	Hill Zhu, Ph.D.	Prof	Tenure	Spring 2020	9	0.75	0.16	0.12	9	0.75	0.26	0.20
	Computer Science											
A	Dingding Wang, Ph.D.	Assoc. Prof	Tenure-earning	Spring 2020	9	0.75	0.13	0.10	9	0.75	0.26	0.20
	Computer Science											
A	Tamara Dinev, Ph.D.	Prof	Tenured	Spring 2020	12	1.00	0.16	0.16	12	1.00	0.20	0.20
	ITOM										0.18	
A	Jahyun Goo, Ph.D.	Assoc. Prof	Tenured	Fall 2019	9	0.75	0.16	0.12	9	0.75	0.26	0.20
	ITOM											
A	Bharti Sharma, Ph.D.	Senior Instructor	NA	Spring 2020	9	0.75	0.06	0.05	9	0.75	0.13	0.10
	ITOM											
A	Kevin M. Wagner, Ph.D.	Prof	Ternured	Fall 2019	12	1.00	0.20	0.20	12	1.00	0.20	0.20
	Political Science											
A	Mehmet Gurses, Ph.D.	Assoc. Prof	Tenured	Fall 2019	9	0.75	0.06	0.05	9	0.75	0.23	0.17
	Political Science											
A	Dukhong Kim, Ph.D.	Assoc. Prof	Tenured	Spring 2020	9	0.75	0.06	0.05	9	0.75	0.23	0.17
	Political Science											
A	Eric Prier, Ph.D.	Prof	Tenured	Spring 2020	9	0.75	0.06	0.05	9	0.75	0.19	0.14
	Political Science											
	Total Person-Years (PY)						**2.23**	**1.81**			**4.46**	**3.37**

Faculty Code		Source of Funding	PY Workload by Budget Classsification Year 1	Year 5
A	Existing faculty on a regular line	Current Education & General Revenue	1.81	3.37
B	New faculty to be hired on a vacant line	Current Education & General Revenue	0.00	0.00
C	New faculty to be hired on a new line	New Education & General Revenue	0.00	0.00
D	Existing faculty hired on contracts/grants	Contracts/Grants	0.00	0.00
E	New faculty to be hired on contracts/grants	Contracts/Grants	0.00	0.00
		Overall Totals for	**Year 1** 1.81	**Year 5** 3.37

Salary	Benefits	Salary + Benefits	PY Year 1 Budget	PY Year 5 Budget
135,389.43	37,909.04	173,298.47	10,397.91	22,528.80
	0.00			
96,392.68	26,989.95	123,382.63	5,552.22	17,582.02
	0.00			
76,500.00	21,420.00	97,920.00	13,953.60	33,048.00
	0.00			
97,137.97	27,198.63	124,336.60	14,920.39	14,920.39
	0.00			
151,781.70	42,498.88	194,280.58	11,656.83	11,656.83
102,618.66	28,733.22	131,351.88	7,881.11	7,881.11
98,611.00	27,611.08	126,222.08	5,679.99	15,146.65
				0.00
65,000.00	18,200.00	83,200.00	6,240.00	16,224.00
75,000.00	21,000.00	96,000.00	7,200.00	18,720.00
132,580.79	37,122.62	169,703.41	42,001.59	75,093.76
113,468.61	31,771.21	145,239.82	17,428.78	28,321.77
93,894.47	26,290.45	120,184.92	11,718.03	23,436.06
233,600.00	65,408.00	299,008.00	47,841.28	59,801.60
135,260.23	37,872.86	173,133.09	20,775.97	33,760.95
71,400.00	19,992.00	91,392.00	4,112.64	8,910.72
133,373.16	37,344.48	170,717.64	34,143.53	34,143.53
70,180.83	19,650.63	89,831.46	4,042.42	15,495.93
70,529.62	19,748.29	90,277.91	4,062.51	15,572.94
88,306.21	24,725.74	113,031.95	5,086.44	16,107.05
2,041,025.36	**571,487.10**	**2,612,512.46**	**274,695.24**	**468,352.12**

APPENDIX B

Please include the signature of the Equal Opportunity Officer and the Library Director.

Signature of Equal Opportunity Officer	**Date**
	March 29, 2019
Signature of Library Director	**Date**

This appendix was created to facilitate the collection of signatures in support of the proposal. Signatures in this section illustrate that the Equal Opportunity Officer has reviewed section II.E of the proposal and the Library Director has reviewed sections X.A and X.B.

PPENDIX G

The CoS Departmental Chair/Director' support email messages.

Reply Reply All Forward

Fri 2/8/2019 11:16 AM

Gregg Fields

Re: Request for Feedback -> Degree Proposal -> MS Data Science and Data Analytics

To Rainer Steinwandt

Cc Lianfen Qian

Bing Maps + Get more app

Hi Rainer,

This looks okay from the Department of Chemistry & Biochemistry's standpoint.

Regards,

Gregg

Gregg B. Fields, Ph.D., FNAI
Professor and Chair, Department of Chemistry & Biochemistry
Director, Center for Molecular Biology & Biotechnology
Florida Atlantic University
5353 Parkside Drive
Building MC17, Room 211
Jupiter, FL 33458
561-799-8577

From: Rainer Steinwandt <RSTEINWA@fau.edu>
Date: Thursday, February 7, 2019 at 6:16 PM
To: Steven Bressler <bressler@fau.edu>, Office 2004 Test Drive User <fieldsg@fau.edu>, Rodney Murphey <RMURPHEY@fau.edu>, Teresa Wilcox <wilcoxt@fau.edu>, Luc Wille <willel@fau.edu>, Zhixiao Xie <xie@fau.edu>
Cc: Kenneth Dawson Scully <kdawsons@fau.edu>, Lianfen Qian <lqian@fau.edu>, Ata Sarajedini <asarajedini@fau.edu>
Subject: Request for Feedback -> Degree Proposal -> MS Data Science and Data Analytics

Hello,

Most of you have probably heard back from your College Graduate Committee's representative(s) on yesterday's meeting, which had the proposed MS degree in Data Science & Analytics on the agenda.

Attached is the current status of the proposal, which I received from Lianfen earlier today. Appendix A is still undergoing revisions, but the core piece of interest is perhaps the proposed curriculum. Can you please share this proposal with the appropriate colleagues in your department and communicate changes you'd like to see in the proposal -- or indicate your approval of the current structure. When proposing changes, please try to keep in mind that ultimately we need to build consensus among all involved Colleges.

- One of the sore spots, I take, is the name of the track in our College. One suggestion that I received was to name our track "Scientific Inquiry," which I kind of like -- it is inclusive, avoids awkward wording like "Data Science in Science," and it seems to have a chance to be acceptable to other Colleges.
- If you would like to have courses added to the elective list, please share. That should be straightforward to implement.

To be able to launch this degree by Fall 2019 (which I think is still the goal of all involved Colleges), it would be most helpful to get your feedback within a couple of days. Please do cc Lianfen on your input, as she coordinates this effort across Colleges.

Thanks for your help with this,
Rainer

Reply Reply All Forward

Mon 2/11/2019 10:36 AM

Zhixiao Xie

RE: Request for Feedback -> Degree Proposal -> MS Data Science and Data Analytics

To Rainer Steinwandt

Cc Tobin Hindle; Lianfen Qian

Good Morning Rainer,
I talked to our faculty on this. We support the degree proposal with the recommendation that a few Geosciences courses be included as electives. However, if the revision may cause serious delay to the proposal, we agree to have the proposal move forward and have the revision done after the degree is approved.

Thank You,
Zhixiao

Dr. Zhixiao Xie
Professor and Chair
Geosciences Department
Florida Atlantic University
Tel: 561-297-2852

From: Rainer Steinwandt
Sent: Thursday, February 7, 2019 6:16 PM
To: Steven Bressler <bressler@fau.edu>; Gregg Fields <fieldsg@fau.edu>; Rodney Murphey <RMURPHEY@fau.edu>; Teresa Wilcox <wilcoxt@fau.edu>; Luc Wille <willel@fau.edu>; Zhixiao Xie <xie@fau.edu>
Cc: Kenneth Dawson Scully <kdawsons@fau.edu>; Lianfen Qian <lqian@fau.edu>; Ata Sarajedini <asarajedini@fau.edu>
Subject: Request for Feedback -> Degree Proposal -> MS Data Science and Data Analytics

Reply Reply All Forward

Thu 2/14/2019 3:02 PM

Teresa Wilcox

Re: Request for Feedback -> Degree Proposal -> MS Data Science and Data Analytics

To Rainer Steinwandt; Steven Bressler; Gregg Fields; Rodney Murphey; Luc Wille; Zhixiao Xie

Cc Kenneth Dawson Scully; Lianfen Qian; Ata Sarajedini; David Wolgin

Bing Maps + Get more apps

Rainer,

I approve the current structure of this degree program. In the interest of time, I am satisfied with this moving forward. However, I would like to give psychology faculty a chance to consider whether the department might have courses that would be appropriate to add as electives. If so, might we add these at a later date?

Best,

Teresa

Teresa Wilcox, Ph.D.
Chair and Professor
Department of Psychology
College of Science
Florida Atlantic University
BS 12, Room 101

Reply Reply All Forward

Thu 2/14/2019 3:21 PM

Steven Bressler <bressler.stevenl@gmail.com>

Re: Request for Feedback -> Degree Proposal -> MS Data Science and Data Analytics

To Teresa Wilcox

Cc Rainer Steinwandt; Steven Bressler; Gregg Fields; Rodney Murphey; Luc Wille; Zhixiao Xie; Kenneth Dawson Scully; Lianfen Qian; Ata Sarajedini; David Wolg

Dear Rainer,

I would also like to lend my support to your proposal for a new MS degree in data science & analytics. Can we suggest electives to you at a later time?

Best, Steve

Steven L Bressler, PhD
Professor
Center for Complex Systems & Brain Sciences
Florida Atlantic University
Tel: +1-561-297-2227

MC

Michelle Cavallo
Mon 2/18, 10:36 AM
Lianfen Qian; Rainer Steinwandt; Rodney Murphey

Reply all

Inbox

You replied on 2/18/2019 11:20 AM.

Dear Lianfen and Rainer,

The faculty of the department of biology have reviewed the Data Science MS proposal and find no conflicts. We wish you smooth sailing through the rest of the process.

All the best,

Michelle Cavallo
On behalf of Rod Murphey, Professor and Chairman

Michelle Cavallo
Director of Academic Programs and Support Services
Department of Biological Sciences

MSDS

Luc Wille
Mon 2/18, 10:46 AM
Rainer Steinwandt; Lianfen Qian; Ken Dawson-Scully <dawsonscully@gmail.com>; Christopher Beetle

Inbox

Dear Lianfen and Rainer:

The physics faculty met this past Friday to discuss the proposed Master's in Data Science.

The department would like to add the following five courses as electives:

Computational Physics PHZ 5156
Numerical Relativity PHZ 7609
Quantum Information Processing PHY 6xxx (1)
Astrostastistics and Machine Learning PHx xxxx (2)
Deep Learning and Data Analysis PHx xxxx (3)

With these courses added as electives the department approves the proposal. The first two are existing courses, we can provide you with syllabi for the new courses at a later date.

Please let me know if you have any questions or comments.

Thank you, --Luc

FAU
FLORIDA ATLANTIC UNIVERSITY

Division of Academic Affairs
New Degree Program Approval
Routing and Signature Form

Proposed Program Title: Data Science and Analytics **CIP:** 30.0601

Degree Level: Master of Science

Department: Mathematical Sciences _____ 1-8-19
Chair/Director's Signature Date

College: Charles E. Schmidt College of Science _____ 1/8/19
Dean's Signature Date

Academic Affairs: _____ _____
Associate Provost for Programs and Assessment's Signature Date

_____ _____
Associate Provost for Planning and Budget's Signature Date

Team for Assurance of Student Learning (TASL): _____ _____
Committee Chair's Signature Date

Undergraduate Studies: _____ _____
Dean's Signature (For Undergraduate Degree) Date

Graduate College: _____ _____
Dean's Signature (For Graduate Degree) Date

UFS – GPC or UPC [circle one]: _____ _____
Chair's Signature Date

UFS – Academic Planning and Budget: _____ _____
Chair's Signature Date

University Faculty Senate: _____ _____
UFS President's Signature Date

Provost: _____ _____
Provost's Signature Date

FAU
FLORIDA ATLANTIC UNIVERSITY

Division of Academic Affairs
New Degree Program Approval
Routing and Signature Form

Proposed Program Title: MS in Data Science and Analytics **CIP:** 30.0601

Degree Level: Graduate Degree

Department: Computer and ElctricalEng & Comp. Sci. _____ 01/9/2019
Chair/Director's Signature Date

College: Engineering and Computer Science _____ 1/14/2019
Dean's Signature Date

Academic Affairs: _____ _____
Associate Provost for Programs and Assessment's Signature Date

_____ _____
Associate Provost for Planning and Budget's Signature Date

Team for Assurance of Student Learning (TASL): _____ _____
Committee Chair's Signature Date

Undergraduate Studies: _____ _____
Dean's Signature (For Undergraduate Degree) Date

Graduate College: _____ _____
Dean's Signature (For Graduate Degree) Date

UFS – GPC or UPC [circle one]: _____ _____
Chair's Signature Date

UFS – Academic Planning and Budget: _____ _____
Chair's Signature Date

University Faculty Senate: _____ _____
UFS President's Signature Date

Provost: _____ _____
Provost's Signature Date

FLORIDA ATLANTIC UNIVERSITY

NEW/CHANGE PROGRAM REQUEST
Graduate Programs

UGPC Approval _____
UFS Approval _____
Banner Posted _____
Catalog _____

Department

College Dorothy F. Schmidt College of Arts and Letters

Program Name
Data Science and Analytics (Data Science in Society)

☑ **New Program**
☐ **Change Program**

Effective Date
(TERM & YEAR)

Please explain the requested change(s) and offer rationale below or on an attachment

See attached.

Faculty Contact/Email/Phone
abradfo5@fau.edu

Consult and list departments that may be affected by the change(s) and attach documentation

Approved by	***Date***
Department Chair	1/19/2019
College Curriculum Chair	1/19/2019
College Dean	1/19/2019
UGPC Chair	
UGC Chair	
Graduate College Dean	
UFS President	
Provost	

Email this form and attachments to UGPC@fau.edu one week before the UGPC meeting so that materials may be viewed on the UGPC website prior to the meeting.

FAU
FLORIDA ATLANTIC UNIVERSITY

Division of Academic Affairs
New Degree Program Approval
Routing and Signature Form

Proposed Program Title: M.S. in Data Science and Analytics **CIP:** 30.0601

Degree Level: Graduate Degree

Department: Information Tech & Operations Mgmt _____ 01/232019
Chair/Director's Signature Date

College: Business _____ 2.6.19
Dean's Signature Date

Academic Affairs: _____ _____
Associate Provost for Programs and Assessment's Signature Date

_____ _____
Associate Provost for Planning and Budget's Signature Date

Team for Assurance of Student Learning (TASL): _____ _____
Committee Chair's Signature Date

Undergraduate Studies: _____ _____
Dean's Signature (For Undergraduate Degree) Date

Graduate College: _____ _____
Dean's Signature (For Graduate Degree) Date

UFS – GPC or UPC [circle one]: _____ _____
Chair's Signature Date

UFS – Academic Planning and Budget: _____ _____
Chair's Signature Date

University Faculty Senate: _____ _____
UFS President's Signature Date

Provost: _____ _____
Provost's Signature Date

FLORIDA ATLANTIC UNIVERSITY

NEW/CHANGE PROGRAM REQUEST
Graduate Programs

Department Information Technology and Operations Management

College Business

UGPC Approval _____
UFS Approval _____
Banner Posted _____
Catalog _____

Program Name	**New Program**	**Effective Date** *(TERM & YEAR)*
Business Analytics Concentration for MBA	**Change Program**	Fall 2019

Please explain the requested change(s) and offer rationale below or on an attachment

The Business Analytics Concentration. Students electing the Business Analytics concentration will take the basic core as listed above and four of the following elective courses: ISM 6136, Data Mining and Predictive Analytics; ISM 6404, Introduction to Business Analytics and Big Data; ISM 6405, Advanced Business Analytics; ISM 6555, Social Media and Web Analytics; ISM 6562, Data Management and Analysis with Excel; or other approved Special Topics courses.

Please see attached for detailed description and rationale.

Faculty Contact/Email/Phone	**Consult and list departments that may be affected by the change(s) and attach documentation**
Derrick Huang / dhuang@fau.edu / 7-2776	CEECS and Mathematics; approval attached

Approved by	***Date***
Department Chair	1/30/2019
College Curriculum Chair	2/5/19
College Dean	2.6.19
UGPC Chair	
UGC Chair	
Graduate College Dean	
UFS President	
Provost	

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University of Central Florida

Department of Statistics

Shunpu Zhang, Ph.D.
Chair and Professor of Statistics
Department of Statistics
University of Central Florida
4000 Central Florida Blvd
Orlando, FL 32816-2370
Office: 407-823-1566
Fax: 407-823-3930

02/06/2019

Lianfen Qian, Ph.D.
Professor & Associate Dean of Academic Affairs
FAU Charles E. Schmidt College of Science
Florida Atlantic University
777 Glades Road
Boca Raton, FL 33431

Dear Dr. Qian,
The proposed interdisciplinary MS-DSA degree program at FAU is academically sound. The curriculum involves faculty with a wide range of expertise from Statistics, computer Science, Information Technology to Political Science. The four concentrations are well designed to meet the soaring demand for analytical professionals in the job market.

As Chair of Department of Statistics at University of Central Florida, I fully support this program. I expect the proposed program very successful.

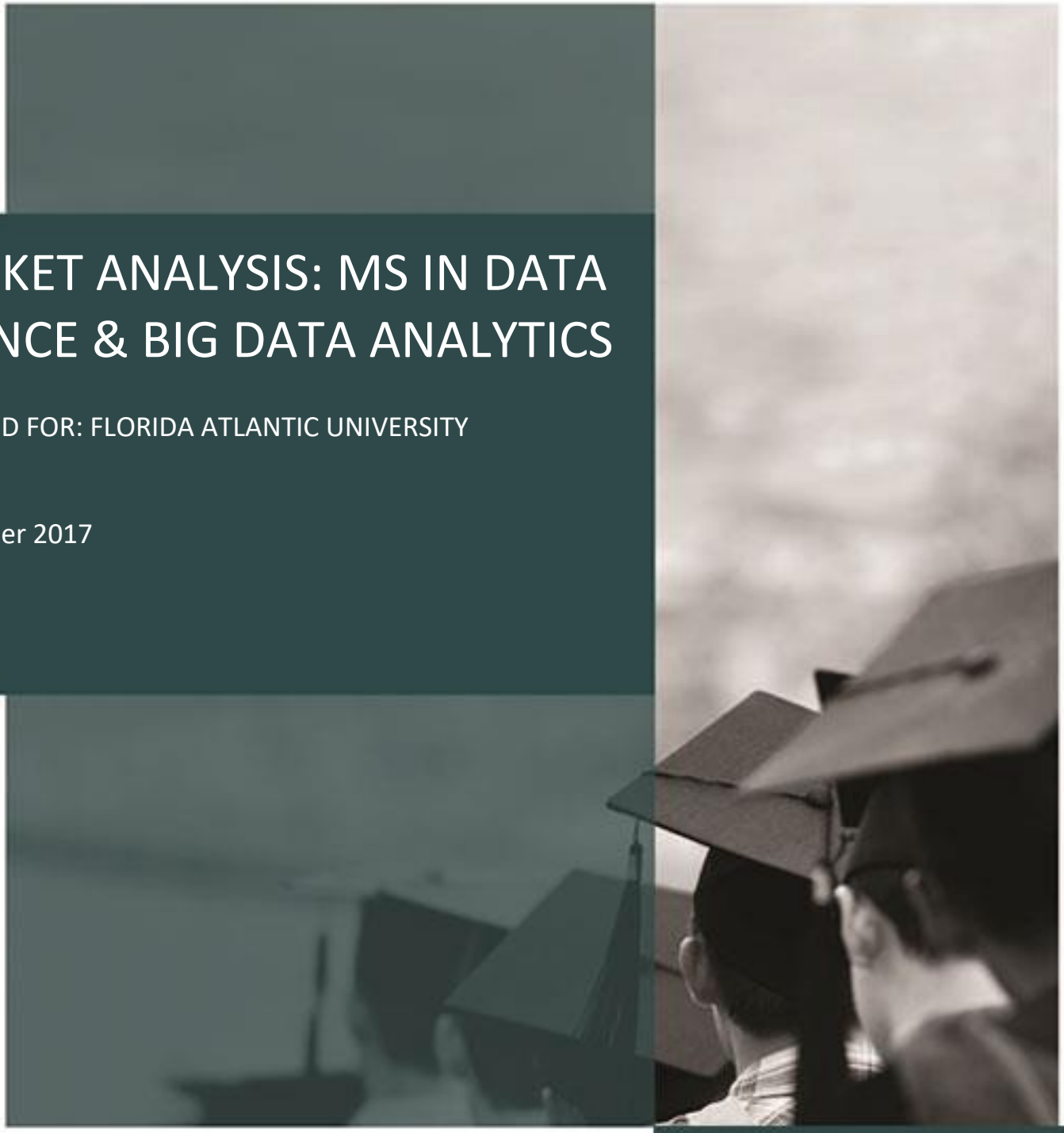
Best regards,

Shunpu Zhang

MARKET ANALYSIS: MS IN DATA SCIENCE & BIG DATA ANALYTICS

PREPARED FOR: FLORIDA ATLANTIC UNIVERSITY

December 2017



In the following report, Hanover examines demand for a master's degree in data science and analytics. The report assesses potential applications of data science in business, natural sciences, and social sciences; reviews program elements; and analyzes demand trends using recent degree completions data and occupational projections for related professions to present an overview of the data analytics programming landscape.

HANOVER RESEARCH

www.hanoverresearch.com

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EXECUTIVE SUMMARY AND KEY FINDINGS

INTRODUCTION

Data science is the study of structured and unstructured data to generate new knowledge.[1] In recent years, rapidly improving technologies have created a demand for professionals who are capable of working with large, sometimes unstructured data sets for the purpose of informing organizational decision-making. Data scientists and analysts, therefore, must possess strong quantitative skills—including the ability to write code and apply complex mathematical models—as well as soft skills, such as effective communication and business acumen.[2]

While business and industry have spurred the growth of relevant programs across the country, data science also has important implications for natural science and social science applications and research. For example, data science and analytics is expected to revolutionize health care services and the ability of doctors to diagnose diseases in patients,[3] as well as the ways in which humanitarian aid organizations will develop strategies to respond to disasters such as earthquakes and the Syrian crisis.[4]

To assist Florida Atlantic University (FAU) in the approval process for its proposed MS in Data Science & Big Data Analytics, the following report reviews market trends, common program features, and the competitive landscape for this degree. The report comprises the following sections:

- **Section I: Trends in Data Analytics** discusses data science applications and recent data science trends.
- **Section II: Demand Trends** analyzes recent degree completions in fields related to data science, including informatics, management information sciences, medical informatics, and geographic information systems. This section also discusses occupational trends for professions related to these degree programs.
- **Section III: Review of Program Features & Local Competition** highlights data science program trends based on a representative national sample of 14 master's programs in data science and analytics. The analysis concludes with a review of public universities in Florida that currently offer master's degrees in data science and analytics fields.

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[1] Dhar, V. "Data Science and Prediction." *Communications of the ACM,* 56:12, pp. 64-73. http://cacm.acm.org/magazines/2013/12/169933-data-science-and-prediction/abstract#F3

[2] Lipman, B. "Universities Increasing Programs for Data Scientists." *Information Week*, December 29, 2014. http://www.wallstreetandtech.com/careers/universities-increasing-programs-for-data-scientists/d/d-id/1318139

[3] Shah, N.D., and J. Pathak. "Why Health Care May Finally Be Ready for Big Data." *Harvard Business Review*, December 3, 2014. https://hbr.org/2014/12/why-health-care-may-finally-be-ready-for-big-data

[4] Meier, P. "Does the Humanitarian Industry Have a Future in The Digital Age?" iRevolutions, April 9, 2012. http://irevolution.net/2012/04/09/humanitarian-future/

RECOMMENDATION

On the whole, student and labor market demand indicators point to a viable market for FAU's proposed MS in Data Science & Big Data Analytics. However, competition is rapidly increasing– with half of Florida's public universities already offering graduate programs in this space. It will therefore be particularly important for FAU to differentiate its program – either through offering specializations in niche yet in-demand areas such as the natural and social sciences – or different delivery formats (e.g., online, hybrid).

KEY FINDINGS

- **Data science and analytics account for the largest share of growth in the information technology sector, with one study finding that nearly half of surveyed businesses have implemented or plan to launch data initiatives in the near future.** However, several companies have expressed concern about the shortage of employees trained in data science, particularly in managing and analyzing "big data" (i.e., large volumes of often unstructured data). One survey of 750 companies found that nearly 40 percent of businesses lack the skilled labor needed to enact data initiatives, with an anticipated shortage of 1.5 million trained data analysis professionals by 2018.
- **Data science has likewise generated new directions for research in the natural sciences and social sciences.** The White House pledged $200 million of financial support in 2012 to fund new data-driven projects in the sciences. The "big data" revolution in physics has advanced previously challenging research on dark matter, dark energy, and the Higgs boson, for example. In addition, the expansion of data technologies, such as machine learning and geographic information systems (GIS), has allowed "digital humanitarians" to respond to international disasters through "crisis mapping," a visual representation of critical areas of need that can be constructed using reports gathered from news websites and social media.
- **To meet the industry need for employees who can tackle "big data" initiatives, dozens of higher institutions have developed new data science and analytics programs in recent years.** University administrators attribute student demand partly to the recent media focus on the abundant job opportunities and desirable salaries associated with data science positions. For example, in 2012, the *Harvard Business Review* branded the data scientist as "the sexiest job of the 21st Century." Admissions administrators at top-tier institutions like Columbia University and University of California-Berkeley report very high numbers of applicants for their newly launched master's degree programs in data science, despite their intention to keep enrollment in the new programs small and highly selective.

- **National degree completions trends indicate growing demand for data science programs, particularly in the natural sciences and social sciences.** While comparatively few programs are offered in these areas, the number of programs and awarded degrees at the master's level has grown during the past five years. In comparison, degrees related to business analytics (e.g., management information systems, management science) show some evidence of market saturation. FAU might therefore consider offering concentrations in these areas as part of its Data Science curriculum.
- **While growing, student completions in data science-related fields in Florida are more modest than for the nation as a whole**. Data science completions have increased at an average annual rate of about three percent across Florida, compared to roughly 10 percent across the United States. Information Science/Studies and Medical Informatics have made the largest gains, with both showing significant increases in student conferrals over the past five years.
- **Data Science graduates should encounter a favorable job market, both nationally and locally.** Nationally, employment projections for occupations with a strong business and data focus, such as operations research analysts, are optimistic. The employment outlook for graduates with skills in data science/analytics is similarly strong across Florida and Palm Beach County, with relevant occupations projected to grow at above average rates through 2024.
- **It would be feasible for FAU to offer the proposed MS in Data Science & Big Data Analytics in a fully online or hybrid format**. Across the United States and Florida, the number of online data science programs has increased at a rate faster than for onsite programs. Moreover, half of all data science-related master's degrees in Florida currently have a distance option, which suggests online delivery formats are currently in demand. Nevertheless, Hanover identified only one *public* university in Florida (FIU) that offers a similar degree fully online.
- **However, half of Florida's public universities already offer graduate programs in data science onsite.** These institutions include: The New College of Florida, University of Central Florida, University of Florida, Florida Gulf Coast University, Florida Polytechnic University, and Florida International University. While each program goes by a different name, they all offer similar core curricula.
- **Hanover's national review of 14 master's programs found that data science/ analytics programs are commonly housed in mathematics, science, engineering, and technology colleges or departments.** This association reflects the strong mathematics and computer programming aspects of data science. Statistics is also the most universal core course required for students enrolled in master's degree programs, and programs may or may not offer concentrations. Such concentrations can range across various fields, including public health, cyberterrorism, and marketing and consumer analytics.

SECTION I: TRENDS IN DATA ANALYTICS

This section presents an overview of the data science landscape and highlights trends in the field based on a review of recently published media sources. The section also discusses three specific areas that have emerged with a strong data emphasis: business and management, science and mathematics, and the social sciences.

OVERVIEW

Data analytics, or data science, represents the intersection of statistics and computer science, with applications across industries such as business, marketing, health sciences, and technology.[5] The emergence of the field of data science can be largely attributed to the expansion of technologies that produce massive quantities of data (i.e., "big data"), including websites, mobile devices, and sensor technologies.[6] In addition to the integration of large volumes of information, data science is distinctive from other analytical approaches in that it emphasizes decision-making processes. Irving Wladawsky-Berger elaborates in a 2014 *Wall Street Journal* article:

> *Data analysis has been generally used as a way of explaining some phenomenon by extracting interesting patterns from individual data sets with well-formulated queries. Data science, on the other hand, aims to discover and extract actionable knowledge from the data, that is,* ***knowledge that can be used to make decisions and predictions, not just to explain what's going on.***[7]

In response to industry demand for data analytics, dozens of higher education institutions have launched new degree programs.[8] Many of the fastest-growing national statistics programs, which have adopted data science instruction, observed that demand for their programs burgeoned after the publication of media reports highlighting analysts' impressive salaries and abundant career opportunities.[9] In particular, student demand has likely been affected by articles such as the *Harvard Business Review* editorial that named the data scientist as "the sexiest job of the 21st Century." The article noted that these individuals serve the unique role of "hybrid hacker, analyst, communicator, and trusted advisor."[10]

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[5] "A Peek into the Largest, Fastest-Growing Undergraduate Statistics Departments." *Amstat News*, February 1, 2015. http://magazine.amstat.org/blog/2015/02/01/undergraduatedepts_feb2015/

[6] "Insight White Paper." Insight Data Science Fellows Program. p. 3. http://insightdatascience.com/Insight_White_Paper.pdf

[7] Wladawsky-Berger, I. "Why Do We Need Data Science When We've Had Statistics for Centuries?" *The Wall Street Journal*, May 2, 2014. http://blogs.wsj.com/cio/2014/05/02/why-do-we-need-data-science-when-weve-had-statistics-for-centuries/

[8] Miller, C.C. "Universities Offer Courses in a Hot New Field: Data Science." *The New York Times*, April 11, 2013. http://www.nytimes.com/2013/04/14/education/edlife/universities-offer-courses-in-a-hot-new-field-data-science.html?_r=0

[9] "A Peek into the Largest, Fastest-Growing Undergraduate Statistics Departments," Op. cit.

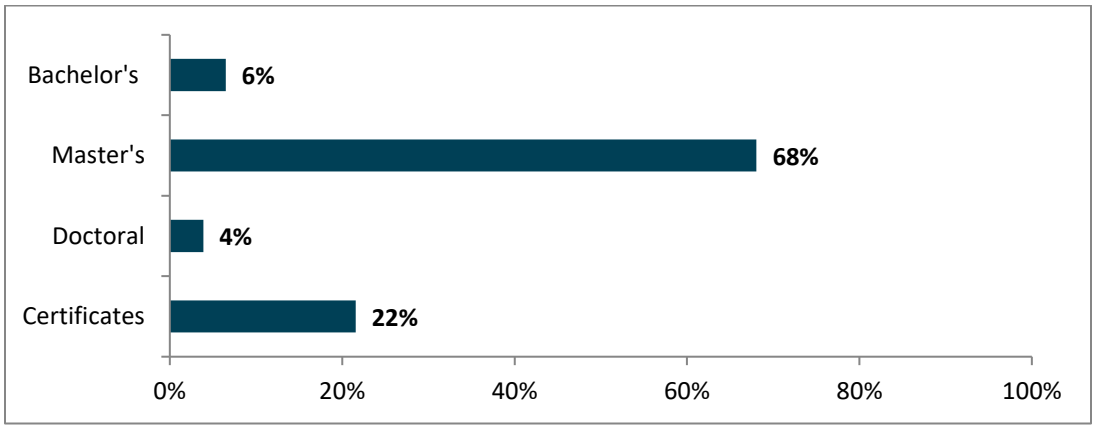
[10] Davenport, T.H. and D.J. Patel. "Data Scientist: The Sexiest Job of the 21st Century." Harvard Business Review, October 2012. https://hbr.org/2012/10/data-scientist-the-sexiest-job-of-the-21st-century/

Data science is an emerging field, and locating well-qualified faculty and designing appropriate curricula may present a challenge for some institutions. Curricula must provide students with opportunities to acquire both intensive technical skills and the accompanying business acumen and communication skills that many employers often seek.[11] In addition, data science synthesizes content from many disparate disciplines (e.g., statistics, computer science, information technology, mathematics), and programs rely on cross-departmental collaboration to deliver a coherent program of study.

EDUCATIONAL OFFERINGS

A listing of data science programs published on DataScience.Community, a "Community for all things Data Science," includes a total of 302 programs data science-related programs in the United States at the bachelor's, master's, and doctoral levels as of November 2015. An additional 83 certificate programs are noted.[12] Figure 1.1 shows the distribution of these programs by award type. **Most of these degrees are offered at the master's level (68 percent)**; just 6 percent are at the baccalaureate level; 4 percent are doctoral programs; and 22 percent are certificate offerings.

Figure 1.1: Distribution of Data Science and Analytics Programs by Degree Type, 2015



Source: DataScience.Community[13]

Arizona State University's W.P. Carey School of Business dean notes that **master's degrees are particularly popular because they can build on the backgrounds of students who completed their undergraduate studies in quantitative fields such as math, engineering, and science.**[14] Master's programs, particularly at top-tier institutions, have also experienced particularly high student demand (discussed in more detail in Section II). For example, the University of California-Berkeley was "flooded with applications" since launching its Master

[11] Lipman, Op. cit.

[12] Note: Includes majors and minors (e.g., undergraduate major in Big Data Analytics, Data Science minor, MS in Mathematical Data Mining, MS or MBA in Business Analytics, Computational Science and Statistics doctorate, Informatics doctorate). See: "Colleges & Universities with Data Science Degrees." DataScience.Community, Last updated November 2, 2015. http://datascience.community/colleges

[13] Ibid.

[14] Hillman, A. "The Rise in Business-Analytics Degrees." *Huffington Post,* May 14, 2013. http://www.huffingtonpost.com/amy-hillman/the-rise-in-businessanaly_b_3273749.html

of Information and Data Science program in 2014 and accepts less than one-third of applicants,[15] and Columbia University received 800 applications for a limited number of seats in its Master of Science in Data Science program. Columbia's program launched in 2013 and expanded upon the University's Certificate of Professional Achievement in Data Sciences program.[16]

BUSINESS INTELLIGENCE AND ANALYTICS

Business intelligence and analytics accounts for the largest share of applications for data science and is currently "the fastest-growing segment in the Information Technology industry." [17] Through a survey of over 750 companies, marketing consulting firm IDG Enterprise found that 49 percent of respondents have implemented or plan to implement big data analytics in the near future, resulting in an estimated expenditure of $8 million on data initiatives in 2014.[18] Figure 1.2 highlights several key statistics about this space.

Figure 1.2: Business Analytics and "Big Data" Industry and Employment Statistics

Sources: Gartner, Inc.[19]; IDG Enterprise[20]; McKinsey and Company[21]

[15] "Addressing Data Science's Big Bell: UC Berkeley I School's Master of Information and Data Science Program." *Library Connect*, November 13, 2014. http://libraryconnect.elsevier.com/articles/addressing-data-science-s-big-bell-uc-berkeley-i-school-s-master-information-and-data

[16] Chan, J.C. "Master's Program at Institute for Data Sciences and Engineering Takes Interdisciplinary Approach." *Columbia Spectator*, September 29, 2014. http://columbiaspectator.com/news/2014/09/29/masters-program-institute-data-sciences-and-engineering-takes-interdisciplinary

[17] "Global Business Intelligence and Analytic Tools Market Analysis, Growth, Trends and Forecast by 2023." Transparency Market Reseaerch, October 21, 2015. http://globenewswire.com/news-release/2015/10/21/778418/10153523/en/Global-Business-Intelligence-and-Analytic-Tools-Market-Analysis-Growth-Trends-and-Forecast-by-2023.html

[18] [1] "Beyond Big: The Analytically Powered Organization." AT Kearney, January 2014. https://www.atkearney.com/analytics/featured-article/-/asset_publisher/FNSUwH9BGQyt/content/beyond-big-the-analytically-powered-organization/10192
[2] "Big Data: Growing Trends and Emerging Opportunities." IDG Enterprise, January 6, 2014. http://www.idgenterprise.com/report/big-data-2

[19] "Gartner Says Big Data Creates Big Jobs: 4.4 Million IT Jobs Globally to Support Big Data By 2015." Gartner, Inc., October 22, 2012. http://www.gartner.com/newsroom/id/2207915

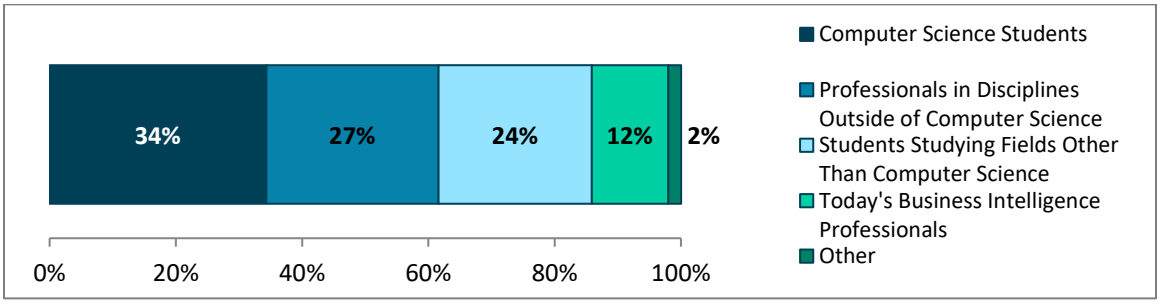
[20] "Big Data: Growing Trends and Emerging Opportunities," Op. cit.

[21] Manyika, J., et al. "Big Data: The Next Frontier for Innovation, Competition, and Productivity." McKinsey and Company, May 2011. http://www.mckinsey.com/insights/business_technology/big_data_the_next_frontier_for_innovation

The rapid industry shift toward sophisticated analytics focused on big data, particularly for driving business, management, and marketing decisions, has caused a significant shortage of skilled labor, however. In a 2012 interview, Peter Sondergaard, vice president of the information technology consulting firm Gartner, Inc., noted that higher education has failed to keep pace with the demand for skilled data analysts: "There is not enough talent in the industry. Our public and private education systems are failing us. Therefore, only one-third of the IT jobs will be filled."[22] In recent years, higher education institutions have responded by developing new business analytics degrees, with several programs beginning enrollment in 2015.[23]

A 2011 international data scientist study found that more than one-third of professionals thought that the most promising new source of data science talent would come from students in computer science (Figure 1.3). Moreover, only 12 percent reported that "today's business intelligence professionals" were the most promising source of data scientist talent. This suggests that **organizations may value skills in computer science over skills traditionally seen in the business intelligence community when seeking data scientist professionals**.

Figure 1.3: Perceptions of the "Best Source of New Data Science Talent"



Source: EMC Data Scientist Study, 2011[24]

EXAMPLES OF BIG DATA APPLICATIONS

HEALTH CARE

Data analytics has multiple applications in public health and health care, such as predicting disease risk in patients or determining the spread of epidemics.[25] Medical operations have transitioned to electronic file systems, with the goal of more accurate and secure storage, transfer, and retrieval of large volumes of patient information.[26] A recent editorial by the *Harvard Business Review* describes comprehensive analyses that account for nurse's notes, laboratory results, family history, and prescriptions when diagnosing patients, noting that

[22] "Gartner Says Big Data Creates Big Jobs: 4.4 Million IT Jobs Globally to Support Big Data By 2015," Op. cit.
[23] Lipman, Op. cit.
[24] Rogers, S. "What Is a Data Scientist?" *The Guardian*, March 2, 2012. http://www.theguardian.com/news/datablog/2012/mar/02/data-scientist
[25] Marr, B. "How Big Data Is Changing Healthcare." *Forbes*, April 21, 2015. http://www.forbes.com/sites/bernardmarr/2015/04/21/how-big-data-is-changing-healthcare/
[26] Bates, D.W., et al. "Big Data In Health Care: Using Analytics To Identify And Manage High-Risk And High-Cost Patients." *Health Affairs*, 33, July 2014. http://content.healthaffairs.org/content/33/7/1123.abstract

"[b]etter knowledge and efficient assessment of disparate facts about patients at risk could mean the difference between timely intervention and a missed window for treatment."[27]

Recent policy changes also incentivize providers to deliver more efficient results by requiring physicians to demonstrate outcomes for patients to receive maximum compensation from health care payers.[28] The often complex interaction of different medical and pharmaceutical approaches makes demonstrating the value of prescribed treatments increasingly dependent on technologies that can synthesize large amounts of patient data and identify the contributing effect of specific procedures.[29]

SCIENCE RESEARCH

In 2012, the White House's Office of Science and Technology Policy announced a commitment of $200 million to fund an initiative to integrate big data into scientific research.[30] The initiative was partly spurred by concerns that the scientific community has been slower to implement big data practices compared to business and industry.[31]

Despite an initially slow adoption process, big data has had significant impacts on the efficacy and results produced through scientific research in recent years. Rather than issuing broad-based tests of new treatments, biomedical researchers have been able to target testing toward smaller, affected segments of the population using genetic data, for example.[32] Astronomers have used digital sensors to scan the sky and collect data on distant universes, allowing scientists to construct maps that show a "visual representation of the evolution of the universe."[33] The incorporation of big data approaches in physics has advanced studies on neutrinos, dark energy, and dark matter. Moreover, new technological tools for gathering and processing data resulted in finding the Higgs boson in 2012, considered "the most exciting year in physics in at least 50 years."[34]

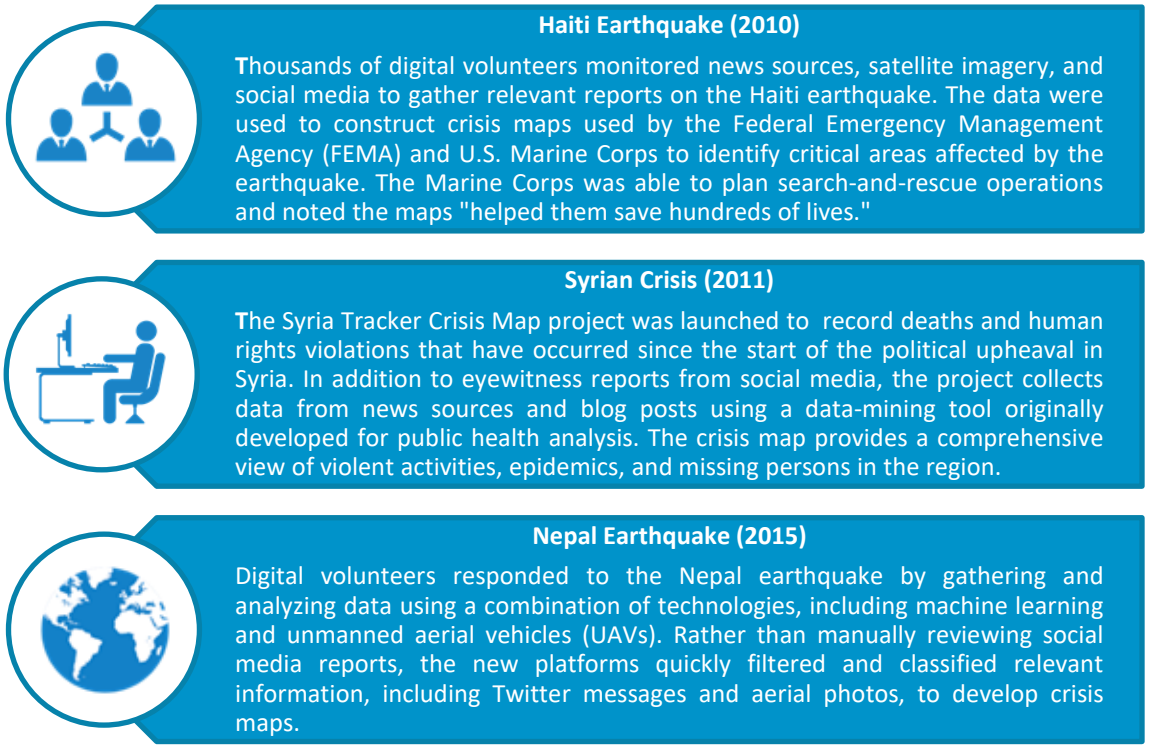
> *"Data, in my view, is a transformative new currency for science, engineering, education, commerce and government… Foundational research in data management and data analytics promise breakthrough discoveries and innovations across all disciplines." – Farnam Jahanian, National Science Foundation*

[27] Shah and Pathak, Op. cit.
[28] Kayyali, B., D. Knott, and S. Van Kuiken. "The Big-Data Revolution in US Health Care: Accelerating Value and Innovation." McKinsey and Company, April 2013. http://www.mckinsey.com/insights/health_systems_and_services/the_big-data_revolution_in_us_health_care
[29] Ibid.
[30] Lohr, S. "New US Research Will Aim at Flood of Digital Data." *The New York Times*, March 29, 2012. http://www.nytimes.com/2012/03/29/technology/new-us-research-will-aim-at-flood-of-digital-data.html
[31] Hannay, T. "Science's Big Data Problem." *Wired*, August 2014. http://www.wired.com/insights/2014/08/sciences-big-data-problem/
[32] LaMonica, M. "Why Science Really Needs Big Data." CNET, March 29, 2012. http://www.cnet.com/news/why-science-really-needs-big-data/
[33] Lohr, Op. cit.
[34] Wall, D., C. Hagen, and K. Khan. "The Science of Big Data." AT Kearney, January 2013. https://www.atkearney.com/strategic-it/ideas-insights/article/-/asset_publisher/LCcgOeS4t85g/content/the-science-of-big-data/10192

DIGITAL HUMANITARIANISM

Crisis management organizations can rapidly process large amounts of data to guide emergency responses by leveraging commonly available mapping applications, social media platforms, and crowdsourcing technology. The adoption of technological tools has partly been advanced by "digital volunteerism" or "digital humanitarianism," a movement in which volunteers use technology to assist in relief efforts from remote locations.[35] In some recent examples, digital volunteers conducted geospatial analysis (i.e., "crisis mapping") to prioritize neighborhoods requiring attention in affected disaster areas.[36] Interest has continued to grow for the adoption of data analytics tools, such as data mining and machine learning (i.e., artificial intelligence), to increase the efficacy of analyzing large volumes of incoming information during disasters.[37]

Figure 1.4: Examples of Recent Applications of Digital Humanitarianism



Sources: Meier, 2012[38]; Meier, 2015[39]; Ragovin, 2015[40]; Syria Tracker[41]

[35] Greenberg, B. "Disasters and Technology: How We Are Innovating in a Network Age." DisasterNet, Inc., April 10, 2013. http://www.disasternet.co/blog/2013/04/10/disasters-and-technology-how-we-are-innovating-in-a-network-age

[36] Meier, P. "Digital Humanitarians, Big Data and Disaster Response." Brookings Institution, February 19, 2015. http://www.brookings.edu/blogs/techtank/posts/2015/02/19-digital-humanitarians-meier

[37] Ibid.

[38] Meier, P. "Crisis Mapping Syria: Automated Data Mining and Crowdsourced Human Intelligence." iRevolutions, March 25, 2012. http://irevolution.net/2012/03/25/crisis-mapping-syria/

[39] Meier, "Digital Humanitarians, Big Data and Disaster Response," Op. cit.

[40] Ragovin, H. "Navigating Disaster." Tufts University, June 25, 2015. http://now.tufts.edu/articles/navigating-disaster

[41] "Syria Tracker." Syria Tracker. https://syriatracker.crowdmap.com/

While digital humanitarianism continues to serve an important role in crisis management, higher education opportunities to study this field are currently limited. One researcher notes that digital humanitarianism evolves quickly and does not conform to "traditional hierarchies" of crisis management practices,[42] which could indicate the field may be potentially difficult to capture through a formalized curriculum. Northeastern University currently offers a GIS course in "Crisis Mapping for Humanitarian Action," which includes a hands-on project that requires students to respond to current crises, such as the West Africa Ebola outbreak or 2015 cyclone in Vanuatu.[43]

However, a scan of educational institutions' offerings shows that most academic activities related to digital humanitarianism take place in the form of faculty or graduate research. For example, professors at Wright State University and Ohio State University have received a $750,000 Social Computational Systems grant for its Ontology of Crisis Coordination project,[44] which will use real-world social media data to develop a simulation platform for estimating responses to organizational strategies.[45] In another notable example, faculty members at the Qatar Computing Research Institute have launched a "Social Computing" research group, which develops tools for analyzing online communication data for crisis management.[46]

[42] Meier, "Does the Humanitarian Industry Have a Future in The Digital Age?," Op. cit.
[43] Guay, J.P. "Crisis Mapping for Humanitarian Action: Course Syllabus." Northeastern University, College of Professional Studies. http://scholar.harvard.edu/files/impacttechnologies/files/guay_and_purcell_crisis_mapping_spring_2015.pdf
[44] "Wright State Research Seeks Sense from Social Media to Aid in Emergencies." Wright State University, November 2011. http://www.wright.edu/email/transfer_enewsletter/archives/november2011.html#news
[45] "SoCS: Social Media Enhanced Organizational Sensemaking in Emergency Response." Wright State University, Kno.e.sis. http://knoesis.wright.edu/projects/socs
[46] "Social Computing." Qatar Computing Research Institute. http://qcri.com/our-research/social-computing

SECTION II: DEMAND TRENDS

In this section, Hanover assesses market demand for FAU's proposed MS in Data Science & Big Data Analytics program by assessing recent degree completions and the employment outlook for individuals with relevant training. This is done at three geographic levels: National, State, and Local.

For a detailed description of the methodology used to analyze completions and labor trends, including explanations of terminology, see the appendix.

STUDENT DEMAND TRENDS

This subsection analyzes completions data for master's programs related to data science and analytics. Degree completions are reported through the National Center for Education Statistics' (NCES) Integrated Postsecondary Education Data System (IPEDS), which organizes programs of study according to a hierarchical system called the Classification of Instructional Programs (CIPs).[47] In the absence of specific CIP categories for data science or data analytics, this study assesses codes that best represent these areas, including associated applications, shown in Figure 2.1.

Figure 2.1: CIP Codes and Titles for Programs Related to Data Science and Analytics

Information Sciences Programs

- 11.0104 - Informatics
- 11.0401 - Information Science/Studies

Business and Management Programs

- 52.1201 - Management Information Systems, General
- 52.1299 - Management Information Systems and Services, Other
- 52.1301 - Management Science
- 52.1399 - Management Sciences and Quantitative Methods, Other

Science and Mathematics Programs

- 27.0304 - Computational and Applied Mathematics
- 30.3001 - Computational Science
- 51.2706 - Medical Informatics

Social Sciences Programs

- 45.0702 - Geographic Information Science and Cartography

[47] All degree completions data in this report are drawn from: "IPEDS Data Center." National Center for Education Statistics. http://nces.ed.gov/ipeds/datacenter/

MASTER'S DEGREE TRENDS IN DATA SCIENCE & ANALYTICS

The number of conferrals for many master's programs related to data analytics has grown nationally, particularly in science/mathematics and GIS, in the last five years (Figure 2.2). In total, master's degree awards related to data science and analytics increased from 9,755 in 2012 to over 14,000 in 2016. This represents an average annual growth rate of 10.1 percent – significantly faster than the average growth across all master's degrees.

Specifically, the number of institutions offering GIS or Medical Informatics programs more than doubled over the period. However, while the number of computational mathematics and computational science programs has also increased, completions volumes at institutions remain relatively low, with most programs reporting fewer than 10 awards per year.

Overall, master's-level completions in relevant business and management programs have increased at an annualized rate of 5.4 percent. However, trends vary by specific program of study. Completions numbers declined for programs focused on management information systems and increased for those with an emphasis on management science.

Figure 2.2: National Master's Degree Completions, 2012 to 2016

PROGRAM OF STUDY	2012	2013	2014	2015	2016	CAGR	AAC	STDEV
Information Science Programs	**4,202**	**4,434**	**4,863**	**5,678**	**6,674**	**12.3%**	**618**	**303**
Informatics	248	274	319	314	336	7.9%	22	18
Information Science/Studies	3,954	4,160	4,544	5,364	6,338	12.5%	596	312
Business and Management Programs	**5,066**	**5,416**	**5,341**	**6,018**	**6,259**	**5.4%**	**298**	**269**
Management Information Systems, General	3,458	3,419	3,043	2,649	2,348	-9.2%	-278	142
Management Information Systems and Services, Other	130	168	19	142	160	5.3%	8	99
Management Science	1,252	1,611	1,666	2,523	2,580	19.8%	332	327
Management Sciences and Quantitative Methods, Other	226	218	613	704	1,171	50.9%	236	200
Science and Mathematics Programs	**310**	**449**	**576**	**707**	**948**	**32.2%**	**160**	**47**
Computational and Applied Mathematics	48	49	63	74	113	23.9%	16	14
Computational Science	26	24	56	84	168	59.4%	36	31
Medical Informatics	236	376	457	549	667	29.7%	108	23
Social Sciences Programs	**177**	**298**	**327**	**422**	**473**	**27.9%**	**74**	**36**
Geographic Information Science and Cartography	177	298	327	422	473	27.9%	74	36
Total – All Data Science Fields	**9,755**	**10,597**	**11,107**	**12,825**	**14,354**	**10.1%**	**1,150**	**493**

Source: IPEDS

Figures 2.3 and 2.4 display master's degree completions for data science-related fields in Florida and FAU's local region, including St. Lucie, Martin, Palm Beach, Broward, and Miami-Dade counties. While still growing, **student completions in data science-related fields in Florida are more modest than for the nation as a whole, increasing at an average annual rate of about three percent.** Of these fields, Information Science/Studies and Medical Informatics have made the largest gains, with both showing significant increases in student conferrals over the past five years.

Figure 2.3: Florida Master's Degree Completions, 2012 to 2016

Program of Study	2012	2013	2014	2015	2016	CAGR	AAC	STDEV
Information Science Programs	**93**	**128**	**117**	**186**	**235**	**26.1%**	**36**	**29**
Informatics	--	--	1	12	1	--	--	--
Information Science/Studies	93	128	116	174	234	25.9%	35	29
Business and Management Programs	**383**	**448**	**308**	**240**	**241**	**-10.9%**	**-36**	**77**
Management Information Systems, General	281	290	288	215	208	-7.2%	-18	32
Management Information Systems and Services, Other	90	117	--	--	--	--	--	--
Management Science	12	41	20	25	21	15.0%	2	18
Management Sciences and Quantitative Methods, Other	--	--	--	--	12	--	--	--
Science and Mathematics Programs	**23**	**26**	**37**	**63**	**89**	**40.3%**	**17**	**10**
Computational and Applied Mathematics	--	--	--	--	--	--	--	--
Computational Science	11	7	10	4	7	-10.7%	-1	4
Medical Informatics	12	19	27	59	82	61.7%	18	11
Social Sciences Programs	**15**	**8**	**11**	**13**	**12**	**-5.4%**	**-1**	**4**
Geographic Information Science and Cartography	15	8	11	13	12	-5.4%	-1	4
Total – All Data Science Fields	**514**	**610**	**473**	**502**	**577**	**2.9%**	**16**	**91**

Source: IPEDS

Generally, local master's degree conferrals in data science-related fields have remained flat between 2012 and 2016, in contrast to the growth seen at the national and state levels. However, this is primarily due to trends at Florida International University, which reported 65 completions in Management/Information Systems in 2014 and then zero completions during 2015 and 2016. It is unclear whether this sudden drop was due to FIU disbanding their program, or rather due to FIU reclassifying this program in IPEDS.

Nevertheless, almost all other institutions in FAU's region reported increasing conferrals rates in data science-related fields over the period, including Nova Southeastern University and DeVry University Florida.

Figure 2.4: Local Master's Degree Completions, 2012 to 2016

Program of Study	2012	2013	2014	2015	2016	CAGR	AAC	STDEV
Information Science Programs	**52**	**76**	**60**	**94**	**99**	**17.5%**	**12**	**19**
Informatics	--	--	--	--	--	--	--	--
Information Science/Studies	52	76	60	94	99	17.5%	12	19
Business and Management Programs	**92**	**106**	**120**	**29**	**41**	**-18.3%**	**-13**	**45**
Management Information Systems, General	92	106	120	29	41	-18.3%	-13	45
Management Information Systems and Services, Other	--	--	--	--	--	--	--	--
Management Science	--	--	--	--	--	--	--	--
Management Sciences and Quantitative Methods, Other	--	--	--	--	--	--	--	--
Science and Mathematics Programs	**12**	**19**	**27**	**27**	**20**	**13.6%**	**2**	**6**
Computational and Applied Mathematics	--	--	--	--	--	--	--	--
Computational Science	--	--	--	--	--	--	--	--
Medical Informatics	12	19	27	27	20	13.6%	2	6
Social Sciences Programs	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Geographic Information Science and Cartography	--	--	--	--	--	--	--	--
Total – All Data Science Fields	**156**	**201**	**207**	**150**	**160**	**0.6%**	**1**	**37**

Source: IPEDS
Note: Table includes St. Lucie, Martin, Palm Beach, Broward, and Miami-Dade counties.

Delivery Format

To determine the feasibility of offering the proposed MS in Data Science & Big Data Analytics in an online format, this sub-section assesses trends in how data science-related programs are delivered. As shown in Figure 2.5, the total number of master's degrees in data science-related fields increased by 39 percent between 2012 and 2016. However, the number of programs delivered online increased by over 93 percent during the same period. This suggests rising demand for data science master's degrees in a distance format.

Figure 2.5: National Data Science Master's Programs by Delivery Format, 2012-2016

Degree Program	2012	2013	2014	2015	2016
All Programs – Onsite and Distance					
Informatics	3	6	9	14	15
Information Science/Studies	115	127	125	128	134
Computational and Applied Mathematics	6	8	10	10	12
Computational Science	7	7	9	14	21
Geographic Information Science and Cartography	20	28	31	37	42
Medical Informatics	23	40	46	48	55
Management Information Systems, General	150	154	147	143	135
Management Information Systems and Services, Other	9	9	8	9	10
Management Science	39	45	51	64	73
Management Sciences and Quantitative Methods, Other	9	10	17	20	32

Degree Program	2012	2013	2014	2015	2016
Grand Total	**381**	**434**	**453**	**487**	**529**
Distance Programs					
Informatics	2	2	3	7	7
Information Science/Studies	26	56	56	52	55
Computational and Applied Mathematics	0	0	0	0	2
Computational Science	0	0	0	4	5
Geographic Information Science and Cartography	4	4	5	8	8
Medical Informatics	10	15	18	18	24
Management Information Systems, General	33	38	38	38	41
Management Information Systems and Services, Other	3	3	1	4	4
Management Science	11	13	19	22	25
Management Sciences and Quantitative Methods, Other	2	2	5	3	5
Grand Total	**91**	**133**	**145**	**156**	**176**

Source: IPEDS

As shown in Figure 2.6, Florida has experienced similar trends, with distance programs increasing at a rate of 50 percent over the past five years, faster than the 26 percent growth seen across all data science-related programs. Moreover, half of all data science-related master's degrees in Florida currently have a distance option (Figure 2.7).

On the whole, these trends suggest it would be feasible for FAU to offer the proposed MS in Data Science & Big Data Analytics in a fully online or hybrid format. However, these trends also suggest that FAU would face increasing competition from other online providers in Florida as well as nationally.

Figure 2.6: Florida Data Science Master's Programs by Delivery Format, 2012-2016

Modality	2012	2013	2014	2015	2016	Total Growth
All Programs - Onsite & Distance	**19**	**21**	**21**	**23**	**24**	**+26.3%**
Distance Programs	**7**	**9**	**12**	**12**	**14**	**+50%**

Source: IPEDS

Figure 2.7: Distance Programs as a Percentage of Total Programs at the Master's Level

FIELD	FLORIDA	NATIONAL
Informatics	100.0%	44.7%
Information Science/Studies	52.0%	39.0%
Computational and Applied Mathematics	N/A	4.3%
Computational Science	0.0%	15.5%
Geographic Information Science and Cartography	0.0%	18.4%
Medical Informatics	71.4%	40.1%
Management Information Systems, General	50.0%	25.8%
Management Information Systems and Services, Other	50.0%	33.3%
Management Science	57.1%	33.1%
Management Sciences and Quantitative Methods, Other	100.0%	19.3%
Grand Total	**50.0%**	**30.7%**

EMPLOYMENT DEMAND

In this sub-section, Hanover examines the labor market for graduates trained in data science and analytics. The analysis considers the future job outlook for occupations related to data science. Occupational projections are drawn from data published by the Bureau of Labor Statistics (BLS) and the Florida Department of Economic Opportunity.

RELEVANT OCCUPATIONS

Figure 2.8 displays the occupations that correspond to relevant degree programs examined in the previous sub-section. To limit the analysis to the most relevant occupations, the figure excludes all management occupations other than Computer and Information Systems Management, as well as all secondary and postsecondary teaching occupations and other less relevant occupations. A complete list of occupations and related degree programs is located in the appendix.

Figure 2.8: Occupations for Relevant Degree Programs

SOC CODE	SOC TITLE
11-3021	Computer and Information Systems Managers
15-1111	Computer and Information Research Scientists
15-1131	Computer Programmers
15-1132	Software Developers, Applications
15-1133	Software Developers, Systems Software
15-1199	Computer Occupations, All Other
15-2021	Mathematicians
15-2031	Operations Research Analysts
15-2041	Statisticians
15-2099	Mathematical Science Occupations, All Other
17-1021	Cartographers and Photogrammetrists

OCCUPATIONAL PROJECTIONS

Figure 2.9 presents projections data for occupations associated with data science and analytics. With the exception of *Computer Programmers,* all careers linked to related programs of study are expected to produce jobs at a faster rate than the aggregate rate of growth for all occupations (6.5 percent). In particular, projections indicate accelerated job growth for *Operations Research Analysts and Statisticians.* In addition, computer programmers and application/software programmers are projected to add over 50,000 job openings per year. **Altogether, the data suggest that employment prospects for students with degrees related to Data Science and other analytics programs are promising at the national level.**

Figure 2.9: National Occupational Projections, 2014 to 2024

SOC TITLE	EMPLOYMENT		CHANGE 2014-2024		AVG. ANNUAL OPENINGS
	2014	2024	NUMBER	PERCENT	
Computer and Information Systems Managers	343,330	419,080	75,750	22.1%	11,730
Computer and Information Research Scientists	23,120	27,240	4,120	17.8%	730
Computer Programmers	320,410	323,910	3,500	1.1%	9,280
Software Developers, Applications	726,010	931,180	205,170	28.3%	31,030
Software Developers, Systems Software	398,640	484,630	85,990	21.6%	14,270
Computer Occupations, All Other	226,850	249,660	22,810	10.1%	5,280
Mathematicians	1,760	2,130	370	21.0%	50
Operations Research Analysts	90,040	122,440	32,400	36.0%	4,900
Statisticians	31,050	42,280	11,230	36.2%	1,730
Mathematical Science Occupations, All Other	1,040	1,160	120	11.5%	300
Cartographers and Photogrammetrists	11,670	15,660	3,990	34.2%	770
Total – All Data Science Occupations	**2,173,920**	**2,619,370**	**445,450**	**20.5%**	**79,800**

Source: Bureau of Labor Statistics[48]

[48] "Employment Projections." U.S. Bureau of Labor Statistics. http://data.bls.gov/projections/occupationProj

As shown in Figure 2.10 **the employment outlook for data science/analytics graduates in Florida is also strong,** with relevant occupations projected to grow at a rate of 23.8 percent through 2024. Again, this is significantly faster than the aggregate rate of growth for all occupations in Florida (18.3 percent).

Figure 2.10: Florida Occupational Projections, 2014 to 2024*

SOC Title	Employment		Change 2014-2024		Avg. Annual Openings
	2014	2024	Number	Percent	
Computer and Information Systems Managers	10,560	13,210	2,650	25.1%	390
Computer and Information Research Scientists	510	570	60	11.8%	10
Computer Programmers	12,550	12,580	30	0.2%	310
Software Developers, Applications	30,710	40,090	9,380	30.5%	1,380
Software Developers, Systems Software	13,290	16,470	3,180	23.9%	510
Computer Occupations, All Other	7,750	9,220	1,470	19.0%	250
Mathematicians	120	150	30	25.0%	10
Operations Research Analysts	6,270	8,450	2,180	34.8%	330
Statisticians	820	1,310	490	59.8%	60
Cartographers and Photogrammetrists	540	830	290	53.7%	50
Total – All Data Science Occupations	**83,120**	**102,880**	**19,760**	**23.8%**	**3,300**

Source: Projections Central
*Some occupations are not listed due to lack of available data at the state level.

To assess local demand, Hanover consulted occupational data available through the Florida Department of Economic Opportunity, which publishes long-term projections (2016-2024) by workforce region.[49] Figure 2.11 shows occupational projections data for Palm Beach County, the workforce region most closely aligned to FAU's main campus.

The employment outlook for graduates with skills in data science/analytics is similarly strong in Palm Beach County, with relevant occupations projected to grow at an above average 15.2 percent between 2016 and 2024. (By comparison the aggregate rate of growth for all occupations in the county is 12.6 percent). Employment prospects are particularly promising for ***Computer and Information Systems Managers*** and ***Applications/Systems Software Developers***, which are expected to grow at faster than average rates and add large numbers of jobs each year.

[49] "2016-2024 Statewide and Regional Projections." Florida Department of Economic Opportunity. http://www.floridajobs.org/labor-market-information/data-center/statistical-programs/employment-projections

Figure 2.11: Palm Beach County Occupational Projections, 2016 to 2024*

SOC Title	Employment		Change 2016-2024		Avg. Annual Openings
	2016	2024	Number	Percent	
Computer and Information Systems Managers	970	1,172	202	20.8%	36
Computer Programmers	1,054	1,029	-25	-2.4%	26
Software Developers, Applications	3,010	3,542	532	17.7%	108
Software Developers, Systems Software	802	934	132	16.5%	28
Computer Occupations, All Other	360	415	55	15.3%	11
Operations Research Analysts	288	373	85	29.5%	16
Statisticians	22	32	10	45.5%	2
Total – All Data Science Occupations	**6,506**	**7,497**	**991**	**15.2%**	**227**

Source: Florida Department of Economic Opportunity
*Some occupations are not listed due to lack of available data at the county level.

SECTION III: REVIEW OF PROGRAM FEATURES & LOCAL COMPETITION

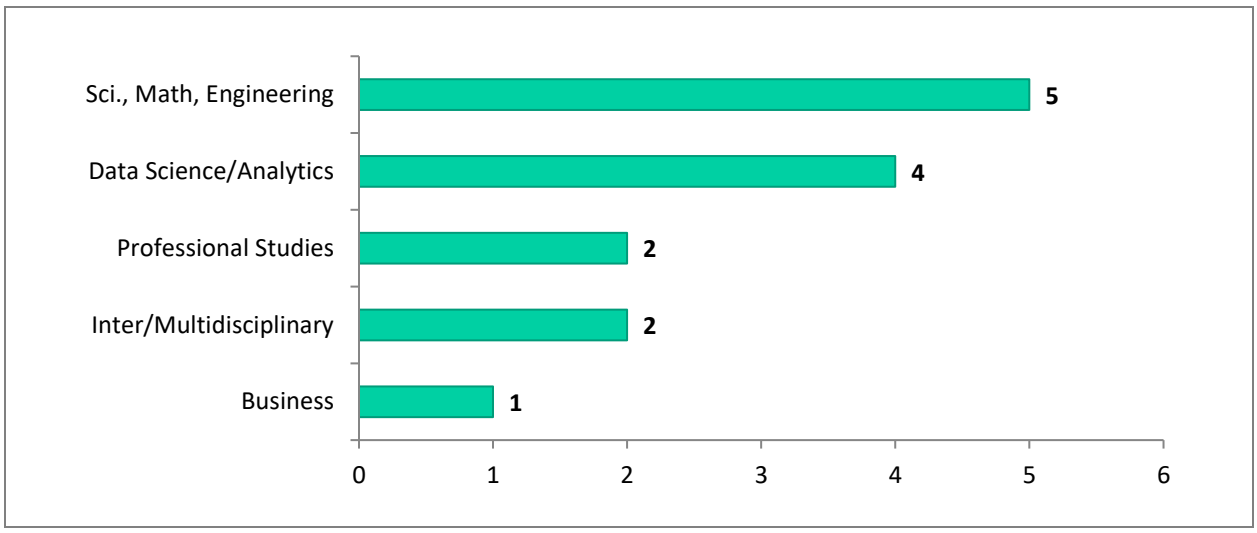
As part of the analysis of potential market factors that could influence FAU's proposed program, this section summarizes key features of 14 national master's degree programs in data science/analytics (the programs reviewed are listed in the appendix). The section concludes with a review of FAU's most likely competitors - public universities in Florida that currently offer master's degrees in data science and analytics fields.

ACADEMIC UNIT AFFILIATION

To evaluate the characteristics of data analytics programs Hanover reviewed a representative sample of 14 master's programs, including those of various sizes, locations, and control, including public, private not-for-profit, and private for-profit

At the graduate level, data science and analytics programs are commonly affiliated with colleges or departments housing science, mathematics, engineering, and/or technology programming (Figure 3.1). Four master's programs had dedicated data science departments. In addition, two universities— Michigan Technological University and the University of Massachusetts-Dartmouth—house their programs within units for interdisciplinary or multidisciplinary studies. Furthermore, some universities' business departments offering this type of program reflect the joint emphasis on data analytics and business/management, such as Carnegie Mellon University's School of Information Systems and Management and Webster University's College of Business and Technology.

Figure 3.1: Institutional Affiliation of Data Science and Analytics Programs

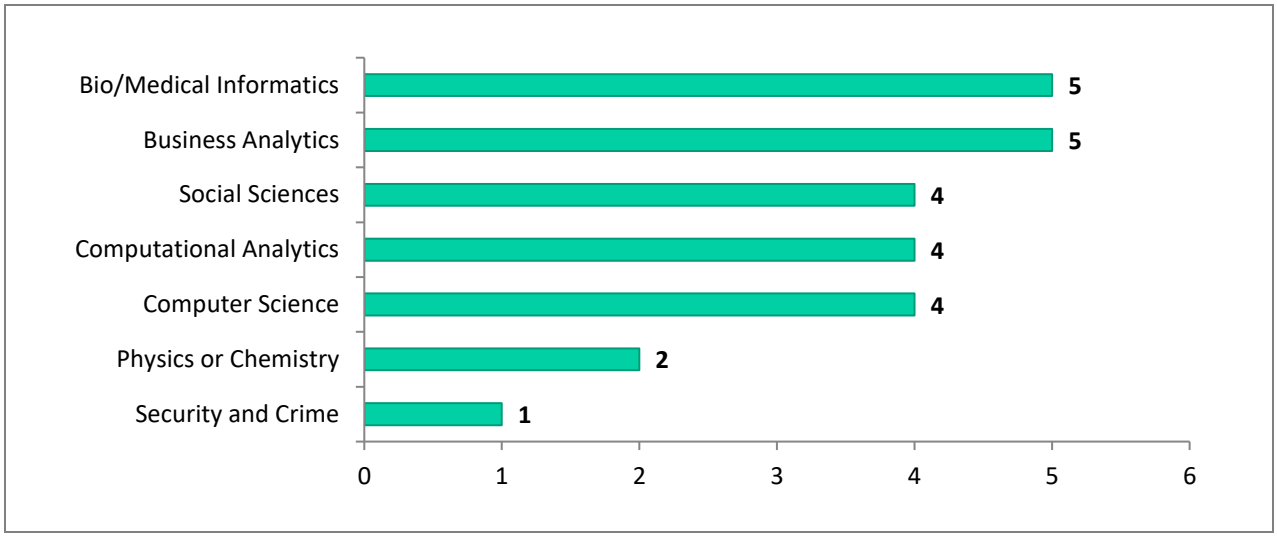


Source: Institutional websites

PROGRAM CONCENTRATIONS

Business analytics and bioinformatics/medical informatics are the most frequently offered concentrations in data science programs at the master's level (Figure 3.2). Becker College also provides a number of data science concentrations, including crime and policing analytics, cyberterrorism, financial and risk analytics, and marketing and consumer analytics.[50] However, several institutions do not offer concentrations; specifically, six graduate programs do not have specializations or concentrations.

Figure 3.2: Concentrations Offered by Data Science and Analytics Programs



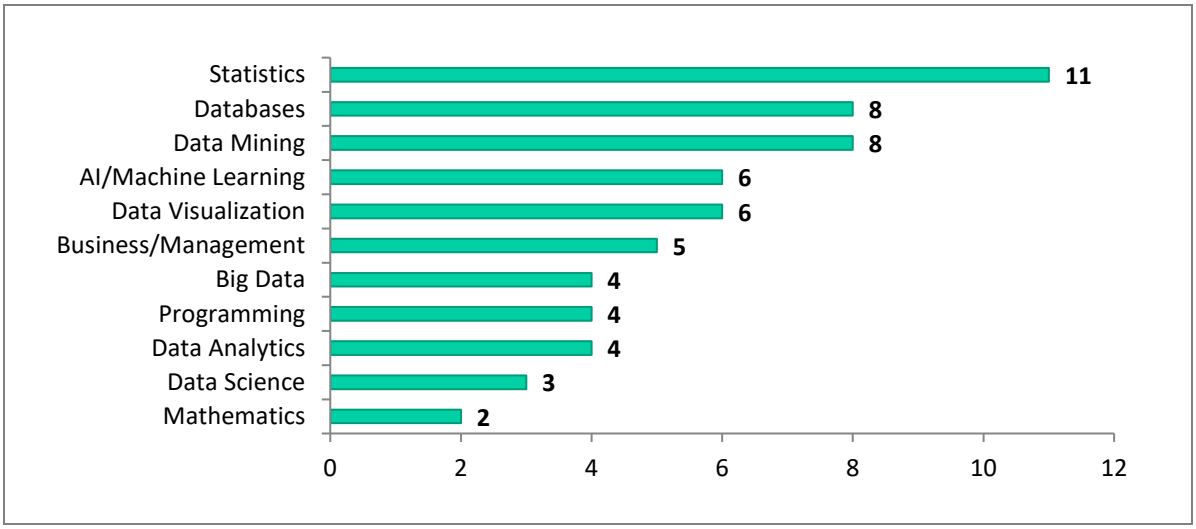
Source: Institutional websites

CORE COURSEWORK

Figure 3.3 provides an overview of typical courses included as part of the core curricula at programs reviewed in the scan. For master's programs, statistics is the most frequently required course. Graduate curricula also place a strong emphasis on data visualization and databases (e.g., database development, database management, database systems).

[50] "Bachelor of Science in Data Science." Becker College. http://www.becker.edu/academics/departments-programs/data-science

Figure 3.3: Required Coursework in Data Science and Analytics Programs*



Source: Institutional websites
* Note: This figure provides a sample of common courses but is not intended to comprehensively list all courses that may be required by examined programs.

LOCAL COMPETITORS

Six out of the 12 institutions in Florida's public university system currently offer master's degrees in data science or analytics (Figure 3.4). Notably, only one of these programs is offered in an online format – Florida International University's forthcoming MS in Data Science.[51] This suggests a potential opening for FAU to develop the proposed degree in a fully online or hybrid format.

In-state tuition rates for these programs varies widely, from a low of $11,211 at Florida Gulf Coast University to a high of $36,300 at the University of Central Florida.

[51] FIU notes: "Almost all of our graduate classes are evening classes to cater to working students. Some are even scheduled on Saturdays. FIU is slowly converting all courses to have an online or a hybrid version." "FAQs: Masters in Data Science." Florida International University. https://www.cis.fiu.edu/academics/degrees/graduate/masters-data-science/

Figure 3.4: Florida Public Universities Offering Degrees in Data Science and Analytics

Institution	Degree Program*	Delivery Format	Program Cost (In-State)	Credit Hours
New College of Florida	MS, Data Science	On-campus	$17,079	36
University of Central Florida	MS, Data Analytics	On-campus	$36,300	30
University of Florida	MS, Information Systems and Operations Management	On-campus	$29,300	36-40
Florida Gulf Coast University	MS, Information Systems and Analytics	On-campus	$11,211	30
Florida International University	MS, Data Science	On-campus, Online in progress	$13,680	30
Florida Polytechnic University	MS, Innovation and Technology	On-campus	$11,550	30

Source: Institution Websites
*Program websites hyperlinked below

APPENDIX: METHODOLOGY

STUDENT DEMAND METHODOLOGY

Hanover uses recent completions data from the National Center for Education Statistics (NCES) to estimate student demand for programs in data analytics. NCES uses a taxonomic system of numeric codes to classify postsecondary academic programs, known as the Classification of Instructional Programs (CIP) system. All degree conferral data presented in this report were drawn from NCES's Integrated Postsecondary Education Data (IPEDS) Data Center.[52]

When interpreting completions data, some considerations should be taken into account:

- Institutions classify their programs independently, meaning that two programs that share identical content could hypothetically be classified under different CIP codes. In addition, for any given institution, it cannot be assumed that IPEDS completions data for an individual CIP classification correspond directly to an individual program. Therefore, the actual number of programs related to data analytics in the United States may not be fully captured based on included IPEDS data.
- Newer programs may be excluded from completions data, as recently launched programs will not have graduated students yet.

Hanover analyzes completions trends in terms of compound annual growth rate (CAGR), average annual change (AAC), and the standard deviation of the year-to-year changes (STDEV):

- **CAGR** reflects the percentage growth that would occur each year if one assumed the same change occurred yearly between the first year and the final year. It gives an impression of a theoretical, steady growth rate by ignoring data presented during middle years.
- **AAC** shows average year-to-year differences. It allows for a more comprehensive view of the yearly average change in completions, with each year playing a role in determining the figure.
- **STDEV** indicates how significantly each year's change varies from the AAC. The larger the STDEV, the greater amount of variance present over a five-year period. Inconsistency in STDEV does not necessarily mean a negative outcome—growth patterns that rapidly accelerate over time will have a higher STDEV than generally consistent ones.

[52] "IPEDS Data Center, Op. cit.

CIP CATEGORIES

Figure A.1 provides CIP titles and descriptions for fields of study related to data analytics. The selected CIP categories represent four broad subject areas with a strong data emphasis: information sciences, business and management, science and mathematics, and social sciences. In the absence of a specific CIP category for peace technology or digital humanitarianism, Hanover estimates potential student interest in data-focused social sciences fields using *Geographic Information Science and Cartography*, which often examines social issues using spatial data.

Figure A.1: CIP Codes, Titles, and Descriptions Related to Data Analytics

CIP CODE	CIP TITLE	DESCRIPTION
Information Sciences Programs of Study		
11.0104	Informatics	A program that focuses on computer systems from a user-centered perspective and studies the structure, behavior and interactions of natural and artificial systems that store, process and communicate information. Includes instruction in information sciences, human computer interaction, information system analysis and design, telecommunications structure and information architecture and management.
11.0401	Information Science/Studies	A program that focuses on the theory, organization, and process of information collection, transmission, and utilization in traditional and electronic forms. Includes instruction in information classification and organization; information storage and processing; transmission, transfer, and signaling; communications and networking; systems planning and design; human interfacing and use analysis; database development; information policy analysis; and related aspects of hardware, software, economics, social factors, and capacity.
Business and Management Programs of Study		
52.1201	Management Information Systems, General	A program that generally prepares individuals to provide and manage data systems and related facilities for processing and retrieving internal business information; select systems and train personnel; and respond to external data requests. Includes instruction in cost and accounting information systems, management control systems, personnel information systems, data storage and security, business systems networking, report preparation, computer facilities and equipment operation and maintenance, operator supervision and training, and management information systems policy and planning.
52.1299	Management Information Systems and Services, Other	Any program in business information and data processing services not listed above.
52.1301	Management Science	A general program that focuses on the application of statistical modeling, data warehousing, data mining, programming, forecasting and operations research techniques to the analysis of problems of business organization and performance. Includes instruction in optimization theory and mathematical techniques, data mining, data warehousing, stochastic and dynamic modeling, operations analysis, and the design and testing of prototype systems and evaluation models.
52.1399	Management Science and Quantitative Methods, Other	Any instructional program in business quantitative methods and management science not listed above.

CIP CODE	CIP TITLE	DESCRIPTION
Science and Mathematics Programs of Study		
27.0304	Computational and Applied Mathematics	A program that focuses on the application of a broad range of mathematical and computational methods to modeling, analysis, algorithm development, and simulation for the solution of complex scientific and engineering problems. Includes instruction in numerical analysis, discrete mathematics, operations research, optimization, differential equations, statistics, scientific computation, and applications to specific scientific and industrial topics.
30.3001	Computational Science	A program that focuses on the study of scientific computing and its application. Includes instruction in scientific visualization, multi-scale analysis, grid generation, data analysis, applied mathematics, numerical algorithms, high performance parallel computing, and numerical modeling and simulation with applications in science, engineering and other disciplines in which computation plays an integral role.
51.2706	Medical Informatics	A program that focuses on the application of computer science and software engineering to medical research and clinical information technology support, and the development of advanced imaging, database, and decision systems. Includes instruction in computer science, health information systems architecture, medical knowledge structures, medical language and image processing, quantitative medical decision modeling, imaging techniques, electronic medical records, medical research systems, clinical decision support, and informatics aspects of specific research and practice problems.
Social Sciences Program of Study		
45.0702	Geographic Information Science and Cartography	A program that focuses on the systematic study of map-making and the application of mathematical, computer, and other techniques to the analysis of large amounts of geographic data and the science of mapping geographic information. Includes instruction in cartographic theory and map projections, computer-assisted cartography, geographic information systems, map design and layout, photogrammetry, air photo interpretation, remote sensing, spatial analysis, geodesy, cartographic editing, and applications to specific industrial, commercial, research, and governmental mapping problems.

Source: NCES[53]

LABOR MARKET DEMAND METHODOLOGY

Similar to the CIP classification system developed by NCES, the Bureau of Labor Statistics (BLS) maintains a classification system for occupations using Standard Occupational Classification (SOC) codes. To identify relevant occupations associated with each academic program, Hanover consulted a crosswalk provided by the NCES that links CIP codes to SOC codes.[54] Using the 2010 CIP-SOC crosswalk, Hanover identified several occupations associated with data science and analytics, shown in Figure A.2. Less relevant occupations or those that are less likely to primarily focus on data science, such as *Chief Executive* or *Natural Sciences Managers*, are excluded from the analysis in Section II.

[53] Language verbatim from: "CIP 2010." IPEDS Data Center, National Center for Education Statistics. https://nces.ed.gov/ipeds/cipcode/browse.aspx?y=55

[54] "CIP 2010 Search." National Center for Education Statistics. http://nces.ed.gov/ipeds/cipcode/search.aspx?y=55

Figure A.2: SOC-to-CIP Crosswalk for Data Science and Analytics Programs

CIP Code	CIP Title	SOC Code	SOC Title
11.0104	Informatics	15-1111	Computer and Information Research Scientists
		15-1132	Software Developers, Applications
		15-1133	Software Developers, Systems Software
11.0401	Information Science/Studies	11-3021	Computer and Information Systems Managers
		15-1111	Computer and Information Research Scientists
		15-1133	Software Developers, Systems Software
		15-1199	Computer Occupations, All Other
		25-1021	Computer Science Teachers, Postsecondary
52.1201	Management Information Systems, General	11-3021	Computer and Information Systems Managers
		15-1131	Computer Programmers
52.1299	Management Information Systems and Services, Other	No Match	No Match
52.1301	Management Science	11-1011	Chief Executives
		11-1021	General and Operations Managers
		15-2031	Operations Research Analysts
		25-1011	Business Teachers, Postsecondary
52.1399	Management Sciences and Quantitative Methods, Other	No Match	No Match
27.0304	Computational and Applied Mathematics	11-9121	Natural Sciences Managers
		15-2011	Actuaries
		15-2021	Mathematicians
		15-2041	Statisticians
		15-2099	Mathematical Science Occupations, All Other
		25-1022	Mathematical Science Teachers, Postsecondary
30.3001	Computational Science	11-9121	Natural Sciences Managers
		15-1199	Computer Occupations, All Other
		15-2099	Mathematical Science Occupations, All Other
		25-1199	Postsecondary Teachers, All Other
51.2706	Medical Informatics	15-1111	Computer and Information Research Scientists
		15-1132	Software Developers, Applications
		15-1199	Computer Occupations, All Other
45.0702	Geographic Information Science and Cartography	11-9199	Managers, All Other
		17-1021	Cartographers and Photogrammetrists
		25-1064	Geography Teachers, Postsecondary

Source: NCES[55]

REVIEW OF PROGRAMS METHODOLOGY

To evaluate the characteristics of data analytics programs Hanover reviewed a representative sample of 14 master's programs, including those of various sizes, locations, and control, including public, private not-for-profit, and private for-profit. Figure A.3 shows the institutions and programs reviewed.

[55] "CIP 2010." National Center for Education Statistics. http://nces.ed.gov/ipeds/cipcode/resources.aspx?y=55

Figure A.3: Programs Reviewed

INSTITUTION	PROGRAM
Carnegie Mellon University	MS in Information Technology
City University of New York (CUNY)	MS in Data Analytics
Lewis University	MS in Data Science
Michigan Technological University	MS in Data Science
National University	MS in Data Analytics
New York University	MS in Data Science
Northwestern University	MS in Analytics
Rutgers University	MBS in Analytics and Data Sciences
Texas A&M University-Commerce	MS in Computational Science
University of California-Berkeley	Master of Information and Data Science
University of Massachusetts-Dartmouth	MS in Data Science
University of New Hampshire	MS in Analytics
University of Rochester	MS in Data Science
University of San Francisco	MS in Analytics

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4401 Wilson Boulevard, Suite 400
Arlington, VA 22203
P 202.559.0500 **F** 866.808.6585
www.hanoverresearch.com