Office Use Only: PP#

Cover Sheet for In-State Institutions
New Program or Substantial Modification to Existing Program

Institution Submitting Proposal	The Johns Hopkins University

Each action below requires a separate proposal and cover sheet.

- (●) New Academic Program
- ( ) New Area of Concentration
- ( ) New Degree Level Approval
- ( ) New Stand-Alone Certificate
- ( ) Off Campus Program
- ( ) Substantial Change to a Degree Program
- ( ) Substantial Change to an Area of Concentration
- ( ) Substantial Change to a Certificate Program
- ( ) Cooperative Degree Program
- ( ) Offer Program at Regional Higher Education Center

Payment Submitted: (●) Yes ( ) No	Payment Type: ( ) R*STARS # 12093985 (●) Check # 12093985	Payment Amount: $850	Date Submitted: 06/10/202

Department Proposing Program	Whiting School of Engineering	
Degree Level and Degree Type	Master of Science	
Title of Proposed Program	Data Analytics Engineering	
Total Number of Credits	30	
Suggested Codes	HEGIS:	CIP: 30.7199
Program Modality	( ) On-campus ( ) Distance Education (*fully online*) (●) Both	
Program Resources	(●) Using Existing Resources ( ) Requiring New Resources	
Projected Implementation Date	( ) Fall (●) Spring ( ) Summer Year: 2026	
Provide Link to Most Recent Academic Catalog	URL: https://e-catalogue.jhu.edu/	
Preferred Contact for this Proposal	Name: Westley Forsythe	
	Title: Academic Compliance Officer	
	Phone: (410) 516-0188	
	Email: wforsythe@jhu.edu	
President/Chief Executive	Type Name: Ray Jayawardhana	
	Signature: Ray Jayawardhana	Date: 06/30/2025
	Date of Approval/Endorsement by Governing Board:	

Revised 1/2021

JOHNS HOPKINS
UNIVERSITY

June 30, 2025

Sanjay Rai, PhD
Secretary
Maryland Higher Education Commission
217 E. Redwood Street, Suite 2100,
Baltimore, MD 21202

Dear Secretary Rai,

On behalf of Provost Jayawardhana, I write to request your review and endorsement of the enclosed proposal. The university proposes a new **Master Science in Data Analytics Engineering.**

The Master of Science in Data Analytics Engineering provides students with a core curriculum of advanced courses in data analytics, statistical methods and data analysis, data patterns and representations, sand ethics in intelligent systems, coupled with advanced graduate courses in one of five focus areas, and additional technical elective courses. The focus areas are Cybersecurity; Machine Learning and Cloud Computing; Data Engineering; Simulation and Modeling; and Artificial Intelligence.

The proposed program is consistent with the Johns Hopkins mission and the State of Maryland's Plan for Postsecondary Education. The proposal is endorsed by The Johns Hopkins University.

Should you have any questions or need further information, please contact Westley Forsythe at (410) 516-0188 or wforsythe@jhu.edu.

Thank you for your support of Johns Hopkins University.

Sincerely,

Janet Simon Schreck, PhD
Senior Associate Vice Provost for Academic Affairs

cc: Dr. Ray Jayawardhana
Dr. Westley Forsythe

Enclosures

The Johns Hopkins University
G.W.C. Whiting School of Engineering
Proposal for a New Academic Program
Master of Science in Data Analytics Engineering

A. Centrality to Institutional Mission and Planning Priorities

1. Provide a description of the program, including each area of concentration (if applicable), and how it relates to the institution's approved mission

The Johns Hopkins University's Whiting School of Engineering is pleased to submit a proposal for a new Master of Science in Data Analytics Engineering. This program is an outgrowth of the established Master of Science programs in Artificial Intelligence, Computer Science, Cybersecurity, Data Science, and Information Systems Engineering within the Whiting School of Engineering's Engineering for Professionals (JHU-EP) division. This Master of Science in Data Analytics Engineering will be offered as an online program (with in-person options for some courses), making it available to a broader population of engineers and scientists seeking to understand and apply the concepts and methodologies of data analytics engineering to real world systems and processes.

The proposed Master of Science in Data Analytics Engineering provides students with a core curriculum of advanced courses in data analytics, statistical methods and data analysis, data patterns and representations, sand ethics in intelligent systems, coupled with advanced graduate courses in one of five focus areas, and additional technical elective courses. The focus areas are:

- Cybersecurity
- Machine Learning and Cloud Computing
- Data Engineering
- Simulation and Modeling
- Artificial Intelligence

If approved, the program would begin accepting applicants for entry during the Fall 2025 semester.

The mission of The Johns Hopkins University is to educate its students and cultivate their capacity for life-long learning, to foster independent and original research, and to bring the benefits of discovery to the world. The mission of the JHU Whiting School of Engineering is to provide educational programs of the highest quality that will attract the most qualified and driven students and faculty. The vision of the JHU Whiting School of Engineering is to be a world-recognized leader in engineering education, to lead in the creation and dissemination of knowledge, and to translate those educational and research activities into solutions to important societal problems. The proposed degree program aligns with both the mission of Johns Hopkins University and the mission of the Whiting School of Engineering as discussed below.

2 Explain how the proposed program supports the institution's strategic goals and provide evidence that affirms it is an institutional priority

A strategic priority of the JHU Whiting School of Engineering is to provide students with innovative and distinctive educational opportunities. Part of the mission of the JHU Whiting School of Engineering is to "provide an outstanding engineering education that is innovative, rigorous, and relevant, and that prepares its graduates to be 21st century leaders." The Whiting School of Engineering supports this mission by developing contemporary master's degree offerings for full-time and part-time students, with flexible formats that respond to the needs of industry in both the domestic and international markets. An online program offers a flexible format and enables this program to more easily reach the international markets cited in this goal.

The Johns Hopkins University professional programs in the fields of engineering and applied science are among the oldest and largest in the United States. Administered by the Whiting School of Engineering through JHU-EP, this activity seeks to meet the lifelong education needs of working professionals in engineering and applied science. JHU-EP offers state-of-the-art courses combined with the convenience, flexibility, and accessibility that make these educational opportunities feasible for working adults.

In recent years, JHU-EP has moved steadily into the field of distance education, offering more and more courses online. This development meets two needs: (1) it contributes to the convenience and flexibility of existing offerings, by allowing students to take a mix of classroom and online courses, and (2) it opens this educational opportunity to a much larger market, enabling students throughout the country and, indeed, the world to take courses at Johns Hopkins University.

Johns Hopkins University is recognized as providing world-class education and research in engineering and applied mathematics and science. Through this online program (with in-person options for some courses), JHU-EP will continue its leadership role in preparing students with the knowledge and skills to apply industrial and operations engineering concepts and methodologies to systems and processes in both industry and government. This degree will be coordinated by the JHU-EP program in the Whiting School of Engineering and the Applied Physics Laboratory.

Through this proposed degree, engineers and scientists will develop the skills needed to apply industrial and operations engineering concepts and methodologies in the development of products and processes in the future. The program will provide in-depth knowledge and technical skills in the field of data analytics engineering and prepare students for technically significant careers within industry and governmental organizations.

3. Provide a narrative of how the proposed program will be adequately funded for at least the first five years of program implementation

The JHU-EP Program sets aside a portion of its tuition revenue each year as part of its budgeting process to fund the development of new programs and new courses. In addition, the tuition revenue from enrollments in the courses in any program is used to cover the instructional costs of the program before any excess is used for other JHU-EP efforts. If a new program finds that its instructional costs are greater than the tuition revenue, funds are allocated from elsewhere in the overall JHU-EP Program to cover the startup program's shortfalls during the first five years. Additional related information is provided in section L.

4. Provide a description of the institution's commitment to:

a. Ongoing administrative, financial, and technical support of the proposed program

The best evidence for the commitment that the JHU-EP Program makes to its students and to their employers to maintain ongoing support for the administrative, financial, and technical support for this program is the history of the JHU-EP Program. Several EP master's degree programs have been in existence for over 50 years going back to the days of the JHU Evening College. The programs developed more recently have flourished as well. JHU-EP does a careful program viability study for new programs based on prospective student and employer feedback, as well as the sort of information provided elsewhere in this proposal addressing market demand. The Whiting School of Engineering greatly values these part-time graduate offerings and the impact that they provide to the engineering community and society. The proposed program would receive the same sort of administrative, financial, and technical support as the other programs in JHU-EP's portfolio.

b. Continuation of the program for a period of time sufficient to allow enrolled students to complete the program

The JHU-EP Program is committed to providing all enrolled students the opportunity to complete the degree program, including under circumstances of low demand. As in the previous section, a historical example is the best evidence for this commitment. In the early 2000s, the part-time undergraduate programs administered by JHU-EP were discontinued after six decades due to a reduction of interest in the programs by both employers and students. After ceasing enrollment of new students, the program developed plans for each remaining student to complete the degree at significant cost to JHU-EP, since many classes needed to be offered with only two or three students attending.

B. Critical and Compelling Regional or Statewide Need as Identified in the State Plan

1. Demonstrate demand and need for the program in terms of meeting present and future needs of the region and the State in general

JHU-EP is focusing on the "need for advancement and evolution of knowledge" in the state of Maryland with this program. The Maryland Department of Labor Licensing and Regulation (DLLR), Maryland Long Term Occupational Projections (2022-2032) projects a need for 942 more data scientists (percent change of 39.3%) from 2022 to 2032.

2. **Provide evidence that the perceived need is consistent with the Maryland State Plan for Postsecondary Education**

   The proposed program is well aligned with the 2022 Maryland State Plan for Higher Education. The Master of Science in Data Analytics Enginreering is intended to prepare highly-trained scientists and engineers to work in organizations where they can contribute to the needs of society. The long-term success of JHU-EP programs for working professionals attests to the quality and effectiveness of these programs.

   Candidates can undertake course-related activities at a time and a location most convenient to them from any part of the state of Maryland. The online aspect allows students to participate in and to complete their program, even if their work schedules do not permit regular class attendance, thus supporting Goal 1, "Student Access: Ensure equitable access to affordable and high-quality postsecondary education for all Maryland residents."

   Similarly, the proposed program is consistent with Goal 2, "Student Success: Promote and implement practices and policies that will ensure student success." Students in the program will be supported by the Engineering for Professionals Student Academic Success Office, providing academic support (e.g., tutoring, success webinars, etc.) for those identified as being at risk to drop out.

   The proposed program is also consistent with Goal 3, "Innovation: Foster innovation in all aspects of Maryland higher education to improve access and student success." Here again, the remote nature of the coursework and program will grant educational access to working professionals across the State of Maryland who would otherwise not be able to study in-person on a campus.

   Lastly, the proposed Data Analytics Engineering program will deliver highly-applicable education to data analysts in the State of Maryland, only improving workforce outcomes for the State and Maryland residents.

C. Quantifiable and Reliable Evidence and Documentation of Market Supply and Demand in the Region and State:

1. **Describe potential industry or industries, employment opportunities, and expected level of entry (*ex: mid-level management*) for graduates of the proposed program**

   Jobs in data analytics are expected to grow rapidly in the next several years due to increased demand for data-driven decisions, the volume of data available, and the need for a skilled labor force to mine and analyze the large amounts of information and data collected.

   Data analytics jobs are primarily found in the computer systems design and related services industry sector (11.2%), followed by management of companies and enterprises (8.5%), and scientific research and development services (7.3%). Most jobs in data analytics require a bachelor's degree (49%), and 40 percent of jobs posted between September 2023 and September 2024 required a master's degree or higher. The minimum experience level for these positions was predominantly 4-6 years (23%), followed by 2-3 years (19%), 7-9 years (10%), and 10+ years (9%) (Lightcast Q3 2024 Data Set).

Job titles that relate to data analytics engineering are data scientist, data analyst, machine learning engineer, business intelligence analyst, enterprise architects, data modelers, and machine learning software engineers. Some top companies currently recruiting in the field of data analytics include Microsoft, IBM, Deloitte, and Oracle (Lightcast Q3 2024 Data Set). All these job opportunities could be filled by graduates of this proposed program. It is expected that the program will provide entry-level workers, mid-level managers and senior manager graduates for the workforce.

2. Present data and analysis projecting market demand and the availability of openings in a job market to be served by the new program

Occupations such as data scientists, statisticians, and other mathematical science occupations have a projected growth rate of 22 percent over the next five years. (Lightcast Q3 2024 Data Set). According to the Occupational Information Network (ONET) from the U.S. Department of Labor, data scientists, statisticians, and other mathematical science occupations are all considered occupations with a bright outlook, meaning they are projected to grow faster than average (employment increase of 6% or more) over the period 2023-2033 for the US nationwide or are projected to have 100,000 or more job openings over the period 2023-2033 for the US nationwide. Based on the projected market demand and the accessibility and convenience of an online program, we expect this degree program to be successful.

3. Discuss and provide evidence of market surveys that clearly provide quantifiable and reliable data on the educational and training needs and the anticipated number of vacancies expected over the next 5 years

As noted in sections C.1 and C.2 above, data analytics engineering as an occupation shows strong growth in the next ten years. Web searches for related job postings revealed thousands of job openings nationwide. We expect the interest from students in this Master of Science in Data Analytics Engineering to be strong.

4. Provide data showing the current and projected supply of prospective graduates

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The only other Maryland program that uses the 30.7199 (Data Analytics, Other) CIP code is the Healthcare Data Analytics program at Capitol Technology University, a program that has yet to graduate a student.

D. Reasonableness of Program Duplication

1. **Identify similar programs in the State and/or same geographical area. Discuss similarities and differences between the proposed program and others in the same degree to be awarded**

   JHU houses several data-intensive degree programs, all with a different focus than that of the proposed degree. The Whiting School's Master of Science in Data Science focuses on the technical design and development of data engineering pipelines and systems, grounded in the fundamentals of computer science, statistics, and applied mathematics. In contrast, the proposed Data Analytics Engineering program emphasizes the strategic application and deployment of data technologies to drive decision-making and innovation.

   The JHU Krieger School of Arts and Sciences offers a Master of Science in Data Analytics and Policy through its Advanced Academic Programs (AAP) division. This degree program has a strong focus on application to public policy and politics, and does not include the engineering aspects of the proposed Data Analytics degree.

   The Carey Business School's Master of Science in Business Analytics and Artificial Intelligence has an intense focus on application to a business environment, with core courses including Business Communication and Business Leadership and Human Values.

   Related graduate degrees offered in the State of Maryland are:

   - University of Maryland, Eastern Shore – MS in Data Science and Analytics Engineering
   - University of Maryland Global Campus – MS in Data Analytics
   - Morgan State University – MS in Data Analytics and Visualization
   - McDaniel College: MS in Data Analytics

   As data science and analytics programs continue to launch across Maryland's higher education institutions, differentiation has become critical. Institutions such as the University of Maryland Eastern Shore (UMES) and Morgan State University (MSU) offer graduate-level programs that, on the surface, seem similar to the proposed degree, these primarily emphasize applied analytics, business intelligence, and data communication.

   In contrast, the proposed Master of Science in Data Analytics Engineering at JHU is uniquely positioned to serve an under-addressed market: engineers and technical professionals seeking to integrate advanced analytics directly into the design, optimization, and operation of complex systems. Grounded in engineering theory, systems modeling, and decision science, JHU's DAE program addresses employer needs in high-tech sectors such as aerospace, defense, and advanced manufacturing -- sectors where generalist analytics training is insufficient.

The program's engineer-first philosophy is realized through its rigorous course sequence. EN.635.631 Foundations of Data Analytics and EN.625.603 Statistical Methods and Data Analysis establish the mathematical and inferential backbone, while EN.665.662 Data Patterns and Representations connects machine learning concepts to knowledge graph construction and digital twin modeling. EN.635.782 Ethics in Intelligent Systems applies standards like IEC 61508 and MIL-STD-882E to model assurance and safety-critical analytics.

Building on proficiency in calculus, probability, statistics, and Python, learners specialize through focus area electives:

- **Cybersecurity** courses translate reliability engineering and control theory optimization into secure system contexts.
- **Machine Learning and Cloud Computing** offerings deepen experimentation and large-scale model deployment.
- **Data Engineering** selections address robust pipeline design for information-centric systems.
- **Simulation and Modeling** courses extend digital twin capabilities.
- **Artificial Intelligence** electives bring control-theory driven optimization into autonomous decision-making.

Virtual analytics sandboxes and sponsored capstones translate classroom theory into high-touch projects in aerospace, defense, health technology, and smart manufacturing, ensuring graduates master both analytical depth and systems engineering breadth.

This document provides a comparative analysis of the JHU DAE program relative to regional peers at UMES and MSU, highlighting curricular distinctions, alignment with industry demands, delivery formats, and student market segmentation.

Curriculum Comparison:

Here is a focused comparison of **engineering-centric coursework** that distinctly sets the proposed **Johns Hopkins University (JHU) Data Analytics Engineering (DAE)** program apart from offerings at **University of Maryland Eastern Shore (UMES)** and **Morgan State University (MSU)**:

Course Category	JHU DAE	UMES	MSU
Modeling and Simulation	EN.605.716 Modeling and Simulation of Complex Systems EN.625.695 Time Series Analysis and Dynamic Modeling EN.625.741 Game Theory	Not offered	Not offered
Optimization / Systems Engineering	EN.625.734 Queuing Theory EN.635.601 Foundations of Information Systems Engineering EN.625.661 Statistical Models and Regression	DSEN 655 Predictive Analytics in Engineering and Aviation Systems *(somewhat relevant)*	Not offered

Course Category	JHU DAE	UMES	MSU
Engineering Decision Support	EN.635.621 Principles of Decision Support Systems EN.635.603 AI/ML Ops EN.605.724 Applied Game Theory	No comparable courses	No comparable courses
Data Engineering Infrastructure	EN.685.652 Data Engineering Principles and Practice EN.605.741 Large-Scale Database Systems EN.605.788 Big Data Processing	DSEN 645 Text Analysis; DSEN 625 Spatial Tech (applied tech, not foundational infrastructure)	IEGR 661 Data Engineering and Governance (limited scope)
Advanced Theoretical Foundations	EN.625.603 Statistical Methods and Data Analysis EN.625.664 Computational Statistics EN.625.742 Theory of Machine Learning	DSEN 600–615 (basic applied stats)	Elective stats/machine learning courses drawn from outside departments (e.g., EEGR 507)
Engineering Ethics & Compliance	EN.635.782 Ethics in Intelligent Systems EN.695.715 Assured Autonomy	Not emphasized	Not emphasized
Cyber-Physical Systems / AI Systems Design	EN.695.715 Assured Autonomy EN.635.775 Cyber Ops, Risk & Compliance	DSEN 668 Robotics (cross-listed under undergrad engineering)	No equivalent

Key Curriculum Differentiators:

- **JHU's engineering emphasis is structural and deliberate**: It integrates systems modeling, simulation, decision theory, infrastructure design, and AI/ML system deployment.
- **UMES** offers some applied analytics in engineering-adjacent contexts but lacks depth in systems theory, modeling, or optimization.
- **MSU** focuses on visualization, applied machine learning, and business communication, with minimal coursework in engineering theory.

The JHU DAE curriculum enables graduates to embed analytic capabilities within engineered environments -- a critical distinction from peer programs that prioritize general analytics or business intelligence applications.

Cost/Tuition Comparison:

University	MD Resident (per credit)	Non-Resident (per credit)	Fees (approx. per credit)	Total (MD)	Total (Non-MD)
Johns Hopkins	$1,818	$1,818	$0	$1,818	$1,818
Morgan State	$485	$950	$81.50	$566.50	$1,031.50
UMES	$353	$654	$92.00	$445.00	$746.00

There is a significant price difference between JHU tuition ($1,818) and that of the other two programs. For Maryland residents, the JHU program is over three times the cost of the MSE degree, and more than four times the cost of the UMES degree.

Summary

Overall, Maryland's competitive landscape for graduate data programs is diverse. Some options lean toward fully-online, accelerated degrees with broad, generalized curricula (e.g., UMGC, McDaniel), others provide single-location, evening cohort models (e.g., UMD College Park). The JHU program is distinctive in pairing asynchronous, flexible learning modules with structured, high-touch project engagements, supported by virtual analytics sandboxes and advanced online processing systems. Working engineers can move seamlessly between self-paced coursework and collaborative, applied sessions, gaining practical skills without compromising the depth and complexity their fields require.

Unlike regional competitors, the JHU EP DAE program is purpose-built to go beyond data consumption. It empowers engineers to **design**, **build**, and **operationalize** analytic capabilities *within* complex engineering systems—not just analyze outputs from them. This approach uniquely combines:

- **Deep engineering theory** (e.g., systems optimization, control theory, complex modeling)
- **Strategic information management** (architecture, governance, security frameworks)
- **Decision-oriented analytics** (predictive modeling, real-time system analytics)

Regional master's programs largely target broad market needs: basic data science skills, business analytics, policy applications, or data visualization. None currently offer an integrated engineering analytics model aligned with high-complexity industries such as aerospace, defense, advanced manufacturing, or infrastructure systems.

The proposed DAE program would thus establish a new category within Maryland's academic marketplace: a master's designed specifically for **engineers who must both engineer and analyze**, bridging technical system development and sophisticated decision analytics. It directly addresses an unmet market need and strategically positions JHU to continue setting the standard for graduate engineering education in an evolving data-driven economy.

2. Provide justification for the proposed program

This Master of Science in Data Analytics Engineering is unique in terms of the content and offering modality. The broad set of online data analytics engineering courses (with in-person options for some courses) available to engineers and scientists will attract a broad range of students. JHU is highly regarded as having expertise in these areas by practitioners and researchers alike, such that the value proposition of reputation, quality, and convenience is readily understood. There is no other Data Analytics Engineering master's degree program offered in the State of Maryland that focuses on the engineering aspects of designing and developing data analytics systems and methodologies that can be applied in many real-world situations. In view of the market demand for such a program, the online offering of the JHU-EP Master of Science in Data Analytics Engineering clearly meets a currently important need in the region.

E. Relevance to High-demand Programs at Historically Black Institutions (HBIs)

1. Discuss the program's potential impact on the implementation or maintenance of high-demand programs at HBI's

There is a Master of Science in Data Analytics and Visualization degree offered by Morgan State University, but it does not include the same course content or focus area opportunities as the proposed degree. The related Master of Science in Data Science and Analytics Engineering offered at the University of Maryland Eastern Shore does not appear to have content comparable with this proposed degree. See section C.4 above. There is no comparable fully-online degree program offered at any of the Historically Black Institutions in Maryland.

F. Relevance to the identity of Historically Black Institutions (HBIs)

1. Discuss the program's potential impact on the uniqueness and institutional identities and missions of HBIs

We do not anticipate that the proposed MS in Data Analytics Engineering wil have an impact on HBCUs' institutuional identities and mission.

G. Adequacy of Curriculum Design, Program Modality, and Related learning outcomes (as outlined in COMAR 13B.02.03.10):

1. Describe how the proposed program was established, and also describe the faculty who will oversee the program

This program was first conceived during discussions between the chairs of the JHU-EP Data Science program, the JHU-EP Information Systems Engineering program, the JHU-EP Applied and Computational Mathematics program, the JHU-EP Computer Science program, the JHU-EP Cybersecurity program, and the JHU-EP Artificial Intelligence program. They determined a need for such a degree program and brought the notion to the Whiting School administration. Over the past few months, the plans for this program were developed resulting in this degree proposal.

The qualifications of the faculty who will oversee this program are provided in Appendix B. Program oversight will be provided by Whiting School of Engineering faculty members and Applied Physics Laboratory professionals who are leading practitioners in the field.

2. Describe educational objectives and learning outcomes appropriate to the rigor, breadth, and (modality) of the program

Educational Objectives

Within two to five years after graduation, graduates from this program will be able to:

- Apply data analytics engineering theoretical concepts and practical methodologies in the development of systems and processes for use in industry, government, and personal settings.

Student Learning Outcomes

By the end of this program, students will be able to:

- Develop a systems description or design for real-world systems and processes.
- Describe the requirements, drivers, functions, components, interdependencies, risks and quality factors for various systems and processes.
- Lead the development of new data analytics engineering features into these systems and processes.
- Direct the evaluation of the performance of the data analytics engineering components of these systems and processes.

3. Explain how the institution will:

a. **Provide for assessment of student achievement of learning outcomes in the program**

During the design of the program's courses, the instructional designers on the JHU-EP staff assist the instructors in preparing learning assessments (assignments, projects, papers, exams, etc.) that are carefully linked to the program's learning outcomes. The instructors then grade these assessments using grading rubrics. The assessment grades indicate the achievement level of each learning outcome.

b. **Document student achievement of learning outcomes in the program**

The learning assessment scores are retained for the purposes of accreditation and program improvement. Grades are kept in the gradebook in Canvas and in separate learning assessment scorecards that are submitted to the EP Assistant Dean for Learning Design and Innovation at the end of each academic year. If learning outcomes are not met in a given year, the program is expected to change the way the outcome is taught in the related class and then reassessed post adjustment.

4. Provide a list of courses with title, semester credit hours and course descriptions, along with a description of program requirements

A full course listing with course titles and descriptions is provided in Appendix A. All JHU-EP courses are three (3) credits.

Admission Requirements

General admission requirements for master's degree candidates and others seeking graduate status are as follows: applicants must be in the last semester of undergraduate study or hold a bachelor's degree from a regionally accredited college or university.

Prior educational experience must include the following prerequisite courses: Calculus I and II (or equivalent), an introductory course in probability and statistics, and familiarity with the programing language Python (demonstrated through credit-bearing coursework, MOOC course completion with verification, or work experience). Students who select the Simulation and Modeling Focus Area must also have prior educational experience that must include the prerequisite course Calculus III (Multivariable Calculus). Applicants typically have earned a grade point average of at least 3.0 on a 4.0 scale (B or above) in the latter half of their undergraduate studies. Missing prerequisites may be completed with JHU-EP. These prerequisite courses do not count toward the degree requirements. Transcripts from all college studies must be submitted. When reviewing an application, the candidate's academic and professional background will be considered.

Degree Requirements

All courses are three (3) credit hours. To earn a Master of Science in Data Analytics Engineering, 10 courses (30 credits) approved by an advisor, must be completed within five years. In addition, all the following must be satisfied:

- Four (4) required core courses (12 Credits)

EN.635.631	Foundations of Data Analytics
EN.685.662	Data Patterns and Representations
EN.605.641	Principles of Database Systems
EN.635.782	Ethics in Intelligent Systems

- At least four (4) elective courses (12 credits) from the same focus area. Two (2) of these four courses must be at the 700 level.
- The remaining two (2) courses for the degree may be any courses from the focus area lists or any relevant course (as determined by the student) in the Computer Science, Cybersecurity, Applied and Computational Mathematics, Information Systems Engineering, Data Science, or Artificial Intelligence program.
- Only one (1) C-range (+/-) grade may be counted toward the master's degree.
- Core courses and focus area offerings may be subject to change, in alignment with program objectives, with program committee approval.

Core Courses for JHU-EP Data Analytics Engineering

EN.635.631	Foundations of Data Analytics
EN.605.641	Principles of Database Systems
EN.685.662	Data Patterns and Representations
EN.635.782	Ethics in Intelligent Systems

Focus Areas for JHU-EP Data Analytics Engineering

Cybersecurity
Machine Learning and Cloud Computing
Data Engineering
Simulation and Modeling
Artificial Intelligence

Cybersecurity Focus Area Courses

EN.695.601	Foundations of Information Assurance
EN.695.622	Web Security
EN.635.676	Cybersecurity in Information Systems
EN.625.680	Cryptography
EN.695.721	Network Security
EN.635.775	Cyber Operations, Risk, and Compliance
AS.470.731	Privacy in a Data Driven Society
AS.470.671	Risk Management Analytics

Machine Learning and Clou Computing Focus Area Courses

EN.685.621	Algorithms for Data Science
EN.705.601	Applied Machine Learning
EN.605.633	Social Media Analytics
EN.605.634	Crowdsourcing and Human Computation
EN.605.635	Cloud Computing
EN.605.646	Natural Language Processing
EN.625.742	Theory of Machine Learning
EN.605.744	Information Retrieval
EN.705.742	Advanced Applied Machine Learning
AS.470.643	Text as Data
AS.470.699	Applied Performance Analytics

Data Engineering Focus Area Courses

EN.685.652	Data Engineering Principles and Practice
EN.635.601	Foundations of Information Systems Engineering
EN.685.701	Data Science: Modeling and Analytics
EN.605.741	Large-Scale Database Systems
EN.605.788	Big Data Processing
AS.470.703	Urban Data Analytics
AS.470.764	Survey Methodology

Simulation and Modeling Focus Area Courses

EN.625.603	Statistical Methods and Data Analysis*
EN.605.631	Statistical Methods for Computer Science
EN.625.661	Statistical Models and Regression
EN.625.664	Computational Statistics
EN.625.695	Time Series Analysis and Dynamic Modeling
EN.625.740	Data Mining
EN.605.716	Modeling and Simulation of Complex Systems

EN.625.734	Queuing Theory with Applications to Computer Science
EN.625.741	Game Theory
AS.470.758	Data Driven Campaigns and Elections
AS.470.779	Computational Modeling for Policy and Security Analysis

*Required course for focus area. Course must be taken before any other focus area courses.

Artificial Intelligence Focus Area Courses

EN.685.621	Algorithms for Data Science
EN.635.627	Principles of Decision Support Systems
EN.605.645	Artificial Intelligence
EN.635.603	AI/ML Ops
EN.605.745	Reasoning Under Uncertainty
EN.695.715	Assured Autonomy
EN.605.724	Applied Game Theory
AS.473.602	Intelligence Analysis
AS.470.743	Data Mining and Predictive Analytics

5. **Discuss how general education requirements will be met, if applicable**

   Not applicable.

6. **Identify any specialized accreditation or graduate certification requirements for this program and its students**

   Not applicable.

7. **If contracting with another institution or non-collegiate organization, provide a copy of the written contract**

   Not applicable.

8. **Provide assurance and any appropriate evidence that the proposed program will provide students with clear, complete, and timely information on the curriculum, course and degree requirements, nature of faculty/student interaction, assumptions about technology competence and skills, technical equipment requirements, learning management system, availability of academic support services and financial aid resources, and costs and payment policies**

   All specific course-related information (e.g., course requirements, nature of faculty/student interaction, assumptions about technology competence and skills, and technical equipment requirements) is provided in the syllabus for each course and is available on the Canvas course site. Program-related information (e.g., degree requirements, learning management system information, availability of academic support services, financial aid resources, and tuition payment policies) can be found both on the JHU-EP website (http://ep.jhu.edu) and as well as in the Engineering for Professionals Academic Catalog (https://ep.jhu.edu/student-services/academic-services/academic-catalogs/).

Provide assurance and any appropriate evidence that advertising, recruiting, and admissions materials will clearly and accurately represent the proposed program and the services available.

The JHU-EP website (http://ep.jhu.edu) contains the same marketing, recruiting and admission materials that are used in print or other form and made available to the students. The JHU-EP academic catalog, which is available on the website, also contains the same material. We affirm that these materials represent a good faith effort to be totally clear and transparent in all our communications with current and new students. Incidentally, the need for clear and accurate program descriptions is also critical to the employers who are a very important factor in supporting our students in their academic pursuits.

H. Adequacy of Articulation

Not applicable.

I. Adequacy of Faculty Resources (as outlined in COMAR 13B.02.03.11).

1. **Provide a brief narrative demonstrating the quality of program faculty. Include a summary list of faculty with appointment type, terminal degree title and field, academic title/rank, status (full-time, part-time, adjunct) and the course(s) each faulty member will teach (in this program)**

   See Appendix B for a representative list of faculty who will teach in the proposed program. The program has identified highly-qualified faculty members. Each is a distinguished and experienced professional, and all have advanced degrees (MS, DSc, or PhD) in their fields of expertise. Each has demonstrated a strong commitment to excellence in teaching. Most are practicing engineers or scientists at the JHU Applied Physics Laboratory as well as faculty and researchers from the Whiting School of Engineering, or other local universities, corporations, or government, and many hold influential positions in their organizations. The JHU-EP program provides engineering education rooted in practice by relying heavily on practitioner faculty members.

2. **Demonstrate how the institution will provide ongoing pedagogy training for the faculty in evidenced-based best practices, including training in a. Pedagogy that meets the needs of the students, b. The learning management system and c. Evidenced-based best practices for distance education, if distance education is offered**

   Faculty support for the development of online courses is provided by JHU-EP's Center for Teaching and Learning Design (CTLD) consisting of 18 instructional designers and course support specialists as well as JHU-EP's Center for Media and Technology Solutions (CMTS), consisting of 9 multimedia technicians and instructional technologists. Faculty have multiple opportunities to receive training on the Canvas learning management system, and in the pedagogy of online learning. These opportunities are presented at various times throughout the year at events such as fall/spring annual faculty meetings, training webinars, and privately scheduled training sessions. Once an instructor has been identified to develop an online course, they are given access to a set of web-based resources that cover a broad range of topics on online pedagogy, use of instructional technologies and learning management system tutorials. Throughout the online course development, the instructor receives direct support and guidance from their assigned instructional designer, as well as from the instructional technology and multimedia staff. This could take the form of course design guidance based on best practices in online learning, course production support, and audio and video recording support. Once the course is built, the support staff continues to help the faculty member, offering best practices in course instruction and help desk support. After the course runs, these teams help the instructor make updates and improvements to the course.

J. Adequacy of Library Resources (as outlined in COMAR 13B.02.03.12).

Students have access to the Milton S. Eisenhower Library on the Homewood campus, which is ranked as one of the nation's foremost facilities for research and scholarship. Its collection of more than three million bound volumes, several million microfilms, and more than 13,000 journal subscriptions has been assembled to support the academic efforts of the University. The interlibrary loan department makes the research collection of the nation available to faculty and students. The library also provides easy access to a wide selection of electronic information resources, including the library's online catalog, and numerous electronic abstracting and indexing tools. Many of the databases are accessible remotely. Librarians help students electronically and the library maintains an extensive web site to take visitors through all its services and materials. To this are added more than 10,000 audiovisual titles available for on-site consultation.

K. Adequacy of Physical Facilities, Infrastructure and Instructional Equipment (as outlined in COMAR13B.02.03.13)

1. **Provide an assurance that physical facilities, infrastructure and instruction equipment are adequate to initiate the program, particularly as related to spaces for classrooms, staff and faculty offices, and laboratories for studies in the technologies and sciences. If the program is to be implemented within existing institutional resources, include a supportive statement by the President for adequate equipment and facilities to meet the program's needs**

   All required courses in the proposed program will be offered online (with in-person options for some courses). The program will have no discernible impact on the use of existing facilities and equipment beyond the standard requirements already in place. See additional details in section K.2 below.

2. **Provide assurance and any appropriate evidence that the institution will ensure students enrolled in and faculty teaching in distance education will have adequate access to a) an institutional electronic mailing system, and b) a learning management system that provides the necessary technological support for distance education**

a) All JHU students receive an Office 365 account including email capabilities (built on Outlook Live), as well as 25GB of online storage, and collaboration, blogging, photo-sharing, event-planning, instant messaging, and other tools. The email account is accessible from a variety of browsers on both the PC and Mac, including full support for Edge, Firefox, Google Chrome, and Safari.

b) This program will be delivered via JHU-EP's online programs infrastructure, which includes the Canvas course management system and the Zoom video conferencing system. These technologies are supported by the Whiting School and the university's IT infrastructure and provide password-protected online course sites and community management systems that enable ongoing collaborative exchange and provide convenient channels for synchronous and asynchronous learning. Canvas is one of the world's leading providers of e-learning systems for higher education institutions. This software focuses on educational outcomes and provides a highly flexible learning environment for students. Johns Hopkins is also outfitted with suitable technical and professional staff and a help desk to provide technical assistance to the students taking online courses. All the student services such as application processes, course registration, bookstore, ID service, and advising are currently provided online as well.

   The Whiting School already successfully delivers all its online and web-enhanced courses and programs using the above-mentioned platforms. As part of the program's development, the school's technical support team and business office have determined that JHU-EP possesses the necessary technology infrastructure and resources in place to support successful delivery of this online program.

L. Adequacy of Financial Resources with Documentation (as outlined in COMAR 13B.02.03.14)

Please see Appendix C.

M. Adequacy of Provisions for Evaluation of Program (as outlined in COMAR 13B.02.03.15).

1. Discuss procedures for evaluating courses, faculty and student learning outcomes

Once the Master of Science in Data Analytics Engineering program is launched, its courses enter the course evaluation system. Students in all JHU-EP courses receive two evaluations each term -- one after the first half and one at the end of the term. These evaluations ask students to reflect on the course structure, the course content, and the instructor's performance. Summary reports are reviewed by the faculty member, the program chair, and the JHU-EP administration to determine whether changes are necessary. The Program Committee will discuss these results as well to consider the broader context of the program's curriculum and course delivery mechanisms.

As described in section G.3, student learning outcomes are carefully and deliberately linked to in-class learning assessments (assignments, projects, papers, exams, etc.) throughout the curriculum. The instructors then grade these assessments using grading rubrics. The assessment grades indicate the achievement level of each learning outcome.

If learning outcomes are not met in a given year, the program is expected to change the way the outcome is taught in the related class and then reassess post adjustment.

2. **Explain how the institution will evaluate the proposed program's educational effectiveness, including assessments of student learning outcomes, student retention, student and faculty satisfaction, and cost-effectiveness.**

   Procedures for evaluating student satisfaction, instructor effectiveness, and student learning outcomes are mentioned in sections G.3 and M.1. The data that the program chair and program committee will need to evaluate performance and develop action plans where deficiencies are identified will be provided by the JHU-EP administrative staff. Student retention will be monitored by the JHU-EP institutional research staff and reported to JHU-EP leadership. Faculty satisfaction will be monitored by the individual EP program chairs through frequent informal communication, and at least once per year during a formal program-wide faculty meeting. The cost-effectiveness of the program will be monitored by the JHU-EP finance team and reported to JHU-EP leadership.

N. Consistency with the State's Minority Student Achievement Goals (as outlined in COMAR13B.02.03.05).

Any student meeting the admissions requirements can apply to the Master of Science in Data Analytics Engineering. The program will work to help all accepted students improve their workplace competitiveness and reach their professional goals; an aim consistent with the State's minority student achievement goals.

O. Relationship to Low Productivity Programs Identified by the Commission:

Not applicable.

P. Adequacy of Distance Education Programs (as outlined in COMAR 13B.02.03.22)

1. **Provide affirmation and any appropriate evidence that the institution is eligible to provide Distance Education.**

   JHU-EP has decades of experience administering successful online graduate programs. The Data Analytics Engineering program will be supported in the same way as the other twenty-three online master's degree programs in the Whiting School of Engineering.

2. **Provide assurance and any appropriate evidence that the institution complies with the C-RAC guidelines, particularly as it relates to the proposed program**

   a) **Online learning is appropriate to the institution's mission and purposes**

      The mission of The Johns Hopkins University is to educate its students and cultivate their capacity for life-long learning, to foster independent and original research, and to bring the benefits of discovery to the world. More simply stated, it's "Knowledge for the world." An online delivery format is not just appropriate, but truly a critical requirement of disseminating knowledge to students who are unable to travel to the Baltimore campus.

The institution's plans for developing, sustaining, and, if appropriate, expanding online learning offerings are integrated into its regular planning and evaluation processes

JHU-EP has fully embraced online education, to the extent that when a new program is developed, it is fully expected that the program will be delivered through an online modality. This part-time online division now reports up to the Whiting School of Engineering's Vice Dean for Graduate Education and Lifelong Learning, who also oversees all full-time residential graduate programs. As such, online education has increased exposure to Whiting School of Engineering leadership and is included in long-term planning, including student and faculty support systems. There is a clear vision for JHU-EP's online education enrollment growth documented in the program's five-year budget plan.

b) Online learning is incorporated into the institution's systems of governance and academic oversight

Johns Hopkins University reviews new online program proposals using the same systems of governance and academic oversight as that for new on-site programs. Before being shared with the deans of all JHU academic divisions, all proposals must first undergo a review by internal academic bodies, including discussions of fit with School mission, program viability, program rigor, instructor quality, and redundancy with existing programs. For Whiting School of Engineering programs, this entails a review by the Whiting School Graduate Committee, a faculty body with representation from both the part-time online and full-time residential program faculty. If approved, a proposal is then forwarded to the Homewood Academic Council for review by faculty from both the Whiting School of Engineering and the Krieger School of Arts and Sciences. As discussed in M.1, once a program is launched, its courses will enter the course evaluation system. Students in all JHU-EP courses receive two evaluations each term -- one after the first half and one at the end of the term. These evaluations ask students to reflect on the course structure, the course content, and the instructor's performance. Summary reports are reviewed by the faculty member, the program chair, and the JHU-EP administration to determine whether changes are necessary. The Program Committee will discuss these results as well to consider the broader context of the program's curriculum and course delivery mechanisms. Lastly, JHU-EP, and all the programs that it offers, undergoes a rigorous review by the Homewood Academic Council faculty every five years.

c) Curricula for the institution's online learning offerings are coherent, cohesive, and comparable in academic rigor to programs offered in traditional instructional formats

In many cases, a JHU-EP program's asynchronous online courses are first developed and run as synchronous courses (either on-site or online), and this provides a suitable benchmark for course rigor and workload. A formal online course development process is then used to support the development of all online courses. This process incorporates the Quality Matters™ research-based set of eight standards for quality online course design that help to ensure the academic rigor of the online course is comparable to or better than the traditionally offered course. A JHU-EP program is composed of courses that are appropriately sequenced to ensure students have adequate background for courses later in the program. Courses are offered frequently enough to ensure that students can complete a degree program within the 5-year maximum allowable timeframe. All JHU-EP courses have a maximum of 19 student enrollees so that students have adequate access to the instructor. Courses are built with components such as discussion boards to facilitate student-student and student-faculty interaction.

d) The institution evaluates the effectiveness of its online learning offerings, including the extent to which the online learning goals are achieved, and uses the results of its evaluations to enhance the attainment of the goals

As discussed in M.1, once a program is launched, its courses will enter the course evaluation system. Students in all JHU-EP courses receive two evaluations each term -- one after the first half and one at the end of the term. These evaluations ask students to reflect on the course structure, the course content, and the instructor's performance. Summary reports are reviewed by the faculty member, the program chair, and the JHU-EP administration to determine whether changes are necessary. The Program Committee will discuss these results as well to consider the broader context of the program's curriculum and course delivery mechanisms.

As discussed in G.3, during the design of the program's courses, the instructional designers on the JHU-EP staff assist the instructors in preparing learning assessments (assignments, projects, papers, exams, etc.) that are carefully linked to the program's learning outcomes. The instructors then grade these assessments using grading rubrics. The assessment grades indicate the achievement level of each learning outcome. The learning assessment scores are retained for the purposes of accreditation and program improvement. Grades are kept in the gradebook in Canvas and in separate learning assessment scorecards that are submitted to the EP Associate Vice Dean at the end of each academic year. If learning outcomes are not met in a given year, the program is expected to change the way the outcome is taught in the related class and then reassess post adjustment.

e) Faculty responsible for delivering the online learning curricula and evaluating the students' success in achieving the online learning goals are appropriately qualified and effectively supported

Any new instructor recruited to teach online must have a graduate degree in a relevant field, and they must have professional experience related to the course content.

Faculty support for the development of online courses is provided by JHU-EP's Center for Teaching and Learning Design (CTLD) consisting of 18 instructional designers and course support specialists as well as JHU-EP's Center for Media and Technology Solutions (CMTS), consisting of 9 multimedia technicians and instructional technologists. Faculty have multiple opportunities to receive training on the Canvas learning management system, and in the pedagogy of online learning. These opportunities are presented at various times throughout the year at events such as fall/spring annual faculty meetings, training webinars, and privately scheduled training sessions. Once an instructor has been identified to develop an online course, they are given access to a set of web-based resources that cover a broad range of topics on online pedagogy, use of instructional technologies and learning management system tutorials. Throughout the online course development, the instructor receives direct support and guidance from their assigned instructional designer, as well as from the instructional technology and multimedia staff. This could take the form of course design guidance based on best practices in online learning, course production support, or audio and video recording support. Once the course is built, the support staff continues to help the faculty member, offering best practices in course instruction and help desk support. After the course runs, these teams help the instructor make updates and improvements to the course.

f) The institution provides effective student and academic services to support students enrolled in online learning offerings

JHU-EP maintains numerous web-based resources to inform prospective students on the information they may need as an online student. These resources include: JHU-EP main website (http://ep.jhu.edu) and the JHU-EP online catalog (https://ep.jhu.edu/student-services/academic-services/academic-catalogs/), which both include detailed programmatic information, academic support services, financial aid, costs, policies, etc. and specific information for online learning. As new online students are admitted, they're introduced to the JHU-EP program and procedures through the fully online New Student Orientation, that includes information on registration, student advising, ordering textbooks, the JHU email system, and other online student services. All students who enroll in an online course are also enrolled in the New Online Student Orientation module, which focuses on introducing students to techniques that will enable them to be successful in an online course and trains them on the Canvas learning management system. Lastly, all new students are enrolled in a mandatory Academic Integrity training course -- a zero-credit, zero-tuition course that is geared towards helping students avoid behaviors linked to plagiarism, cheating and other violations of academic integrity.

Students are assigned an advisor when accepted. Students can work individually with the advisor to develop a course of study that meets the requirements of the program and the career goals of the student. Courses that deviate from the program plan and have not been approved by an advisor may not count toward degree requirements. All advising can be received remotely.

Students have online access to the Milton S. Eisenhower Library on the Homewood campus, ranked as one of the nation's foremost facilities for research and scholarship. The interlibrary loan department allows students access to resources at any other university in the nation. The library also provides easy access to a wide selection of electronic information resources, including the library's online catalog, and numerous electronic abstracting and indexing tools. Many of the databases are accessible remotely. Librarians are available to assist students remotely and the library maintains an extensive website to take visitors through all its services and materials.

The Johns Hopkins University is committed to making all academic programs, support services, and facilities accessible to qualified individuals with disabilities. Students with disabilities who require reasonable accommodations can contact the JHU-EP Disability Services Administrator and receive support remotely.

Student Health and Wellbeing cultivates and supports holistic well-being for individuals, relationships, groups, and the Hopkins community across all schools and divisions. Stress, personal problems, family conflict, and life challenges can affect the academic progress of students. Student Health and Wellbeing focuses on problem solving through short-term counseling. Online students may call a phone number for consultation and will be directed to the appropriate resource or office. All services are completely confidential. The program operates under State and Federal confidentiality legislation and is HIPAA compliant.

g) The institution provides sufficient resources to support and, if appropriate, expand its online learning offerings

The JHU-EP program prepares a five-year budget every year that includes sufficient resources to maintain all online programs and expand offerings, if desired. The budget contains funding for marketing and recruitment for all programs as well as staffing all programs in terms of admissions services, students and faculty support services, finance and administration services, and instructional design and instructional technology services. The budget also contains funding for new program viability analyses, new program marketing launches, and new course development costs. Faculty and staff development costs are included, as described in greater detail in section P.2.f above.

The JHU-EP Program collaborates with central Johns Hopkins University Information Technology to provide a robust and scalable, but also flexible, technical infrastructure that serves student and faculty member needs. These programs are delivered via JHU-EP's online programs infrastructure, which includes the Canvas course management system and the Zoom video conferencing system. These systems provide password-protected online course sites and community management systems that enable ongoing collaborative exchange and provide convenient channels for synchronous and asynchronous learning.

h) The institution assures the integrity of its online offerings

The Higher Education Opportunity Act (HEOA) enacted in 2008 requires that an academic institution that offers distance education opportunities to students: (1) has a process established to verify that the student who registers is the same student who participates in and completes the offering and receives academic credit for it, (2) has a process established to verify that student privacy rights are protected, and (3) has a process established that notifies the student about any additional costs or charges that are associated with verification of student identity. In JHU-EP programs, the following actions have been taken to satisfy these requirements: (1) students may only enter the academic website for the online courses they take by providing the unique student ID and password assigned after admission, (2) all FERPA privacy rights are preserved by limiting access very specifically in the University student information system to only those permitted by law to have access to restricted student information, and (3) there are no additional costs assessed to the student for the measures we use to verify student identity.

Other measures are taken as well to assure the integrity of JHU-EP online offerings. The Whiting School of Engineering's Graduate Academic Misconduct Policy applies to all JHU-EP online students, it clearly defines misconduct, and it includes references to the most common online student infractions. As referenced in section P.2.g, all new JHU-EP students are enrolled in a mandatory Academic Integrity training course -- a zero-credit, zero-tuition course that is geared towards helping students avoid behaviors linked to plagiarism, cheating and other violations of academic integrity. Lastly, JHU-EP has recently required that all essay-based coursework be submitted to SafeAssign, a Canvas integrated tool used to prevent plagiarism by identifying unoriginal content and creating opportunities to help students identify how to properly attribute sources rather than paraphrase.

Appendix A
Course List and Descriptions

Core courses

EN.635.631 Foundations of Data Analytics (3)
This foundation course provides an overview of data analysis process, and introduces students to common techniques for data preprocessing, feature extraction, and the creation of statistical models. In particular, students will develop competence in areas of high importance for data scientists and engineers, such as: exploring the trade-off between bias and variance, selecting and creating features, regularizing models, determining optimal hyperparameters, and evaluating model performance. Multiple datasets and data types (e.g., unstructured text, imagery, and time-varying signals) will be considered with the goal of building student confidence across a spectrum of analysis challenges. Particular topics include linear and non-linear regression, decision trees, various approaches to dimensionality reduction, clustering, topic modeling, Bayesian methods, and neural networks.

EN.605.641 Principles of Database Systems (3)
This course examines the underlying concepts and theory of database management systems. Topics include database system architectures, transaction management, data models, query languages, conceptual and logical database design, and physical organization. The entity-relationship (ER) model, using ER diagram (ERD) and Enhanced ERD, as well as relational models, are investigated in detail. Object-oriented databases are introduced along with legacy systems based on the network. Hierarchical models as well as big data and NoSQL are also briefly described. Mappings from the conceptual level to the logical level, integrity constraints, dependencies, and normalization are studied as a basis for formal design. Theoretical languages such as the relational algebra and the relational calculus are described, and high-level languages such as SQL, triggers and Stored Procedures are discussed. An overview of file organization and access methods is provided as a basis for discussion of query optimization and execution. The course also covers the causes of performance problems and how to improve database application performance during database design and implementation.

EN.685.662 Data Patterns and Representations (3)
This course will explore the practical application of data visualization and representation, employing lenses such as personas, to understand the different purposes of visualizations. Data visualization plays a crucial role in the entire data science process, serving multiple purposes such as communicating results and insights in a clear and understandable way, facilitating preliminary data exploration, and analyzing outcomes from physics-based or machine learning models and simulations. The course will introduce various tools and equip students with the knowledge to effectively choose the most suitable tool for a given problem. We will also explore various essential tools for data visualization, including Microsoft Excel, Python plotting libraries like matplotlib and plotly, Python graphical interfacing libraries such as streamlit, and Tableau, among others. As a Data Scientist, you will often need to collaborate in cross-functional teams of varying levels of technical expertise and with role-specific requirements. To prepare you for a well-rounded career in Data Science, the course project will focus on connecting

stakeholders with appropriate visualization methods and techniques, the aim of which is to enhance your skills in data visualization to effectively communicate insights to diverse audiences.

EN.635.782 Ethics in Intelligent Systems (3)
This course is to fortify and enrich the values-assessment and critical thinking skills of engineers as they grapple with the numerous ethical challenges in their professional and personal lives. To that end, the course will define and delineate some global, macro-level concepts and approaches to ethics; move on to review some ethical issues unique to engineers as they apply intelligent technologies such as artificial intelligence and machine learning to developing complex systems; and finally present some finite cases studies and concrete situations by which to apply these ethical principles. This class will stimulate students to help identify a critical thinking zeitgeist and framework by which to filter, absorb and resolve complex ethical problems and questions in both their professions and at the personal level. This class will be completely value-neutral and hence devoid of any one overarching governing ethical school of thought; thus, we are ecumenical in our approaches. Having said that, the IEEE ethically aligned design standards are noteworthy and very salutary to any exploration. This course will make use of a variety of current, recent historical and classical materials to illustrate major themes.

Cybersecurity Focus Area

EN.695.601 Foundations of Information Assurance (3)
This course surveys the broad fields of enterprise security and privacy, concentrating on the nature of enterprise security requirements by identifying threats to enterprise information technology (IT) systems, access control and open systems, and system and product evaluation criteria. Risk management and policy considerations are examined with respect to the technical nature of enterprise security as represented by government guidance and regulations to support information confidentiality, integrity and availability. The course develops the student's ability to assess enterprise security risk and to formulate technical recommendations in the areas of hardware and software. Aspects of security-related topics to be discussed include network security, cryptography, IT technology issues, and database security. The course addresses evolving Internet, Intranet, and Extranet security issues that affect enterprise security. Additional topics include access control (hardware and software), communications security, and the proper use of system software (operating system and utilities). The course addresses the social and legal problems of individual privacy in an information processing environment, as well as the computer "crime" potential of such systems. The class examines several data encryption algorithms.
Course Note(s): This course can be taken before or after EN.605.621 Foundations of Algorithms. It must be taken before other courses in the degree.

EN.695.622 Web Security (3)
Information technology security is a broad field. This course focuses on the foundational technologies that build the Web-based Internet (Web) as we know it today. The goal of this course is to guide the learner to adopt a professional security mindset by applying the techniques of threat modeling, risk assessment, and apply the foundational security principles from the two "triad" models: "confidentiality, integrity, and availability" (CIA) and "authentication,

authorization, and accounting" (AAA). The self-motivated learner will investigate vulnerabilities, threats, and mitigations with the objective of protecting the data, applications, frameworks, and the supporting complex technology stacks. Security at this level cannot be achieved by technology alone, the course will provide an opportunity to exercise a smart combination of methodologies and techniques that can build confidence and rapport to champion web security within their IT community. Applicable cryptology, digital certificates, and Public Key Infrastructure will be reviewed. Each module will involve hands-on labs that implement local virtual machines, containers, cloud computing environments, and an operative blockchain enabling the learner to probe more deeply into the cybersecurity challenge of each technology solution. The assignments will involve programming and system configuration thus a novice-level exposure of Python, PHP, JavaScript, Linux Commands, basic Internet architecture and common protocols is recommended.
Prerequisite(s): EN.605.202 Data Structures

EN.635.676 Cybersecurity in Information Systems (3)
This course describes the systems security engineering process, focusing on security during the design and implementation of information systems. Topics include architecture and design principles, risk assessment, resiliency, and security metrics. The course addresses emerging topics in cybersecurity including wireless security, cloud security, cross domains and the government standards and processes for secure information systems; surveys many aspects of cybersecurity and its impact on the enterprise; and lays the groundwork to architect and build a natively more secure system that can withstand hacking attacks and continue to deliver basic functionality to the enterprise. We will address the federal government standards and recommendations as well as industry's best practices. Students will cover the basic concepts of information security and research the latest security incidents including external attacks and internal leaks to assess and analyze the exploited vulnerabilities. By learning from current incidents, students can build systems that adapt quickly to emerging threats and potentially continue to serve the enterprise, even while under attack. Additionally, the course addresses the assessment of emerging technologies to determine the potential threats to the enterprise as well as the usability to secure the enterprise. Finally, we will address the subject of legal and ethical access control and the balance between privacy and security,

EN.625.680 Cryptography (3)
An important concern in the information age is the security, protection, and integrity of electronic information, including communications, electronic funds transfer, power system control, transportation systems, and military and law enforcement information. Modern cryptography, in applied mathematics, is concerned not only with the design and exploration of encryption schemes (classical cryptography) but also with the rigorous analysis of any system that is designed to withstand malicious attempts to tamper with, disturb, or destroy it. This course introduces and surveys the field of modern cryptography and will explore the following topics in the field: foundations of cryptography, public key cryptography, probabilistic proof systems, pseudorandom generators, elliptic curve cryptography, and fundamental limits to information operations. Mathematical preliminaries from probability theory, algebra, computational complexity, and number theory will also be covered.

EN.695.721 Network Security (3)

This course covers concepts and issues pertaining to network security and network security architecture and evolving virtualization and related cloud computing security architecture. Topics include mini cases to develop a network security context. For example, we will assess the NIST (National Institute of Standards and Technology) unified information security framework. This framework is supported by information security standards and guidance, such as a risk management framework (RMF) and continuous monitoring (CM) process. Applied cryptography and information security—encryption algorithms, hash algorithms, message integrity checks, digital signatures, security assessment and authentication, authorization and accounting (AAA), security association, and security key management (generation, distribution, and renewal)—are discussed with consideration given to emerging cryptographic trends, such as SD-WAN (Software-Defined Wide Area Networks). This course presents network and network security architecture viewpoints for selected security issues, including various security mechanisms, different layers of wired/wireless security protocols, different types of security attacks and threats and their countermeasures or mitigation, Next Generation Network (NGN) security architecture that supports the merging of wired and wireless communications, and Internet Protocol version 6 implementation and transition. The course concludes with more comprehensive cases that consider network security aspects of virtualization and cloud computing architecture.

EN.635.775 Cyber Operations, Risk, and Compliance (3)
This course provides a solid foundation of potential civil and criminal areas of liability, and certain areas in which compliance and risk management are critical. The overarching theme is detection and reduction of potential legal/cybersecurity risks. We start by exploring the legal and regulatory environment that influences and supports cyber-based activities and programs, focusing on multidisciplinary or integrated views of enterprise risk management. We will address key risk management issues from the legal and cybersecurity aspects and analyze legal/ cybersecurity issues in several of the critical infrastructure sectors, such as the financial services, healthcare and public health, and transportation systems sectors. We also review legal and regulatory compliance issues to address cybersecurity risk management for systems development, acquisition, and operation. This includes material impacting the manner in which the cyber community operates, for example, FITARA (Federal Information Technology Acquisition Reform Act) Enhancement Act of 2017. We then review the authoritative guidance provided by the National Institute of Standards and Technology (NIST) Cybersecurity Framework. The Framework is voluntary for the sixteen critical information sectors and mandatory for the federal government, hence the focus on NIST. Risk management threat detection and avoidance is analyzed from an integrated legal/cybersecurity perspective, including system objectives to avert legal liability and minimize enterprise and human loss. Examples address financial services, healthcare and public health, and transportation (mobile devices and autonomous vehicles) systems, and cyber-physical systems (CPS) or Internet of Things (IoT). The overall constitutional and statutory basis within which all cyber law and policy operates is identified and reviewed.

EN.xxx.741 Data Analytics for Cybersecurity (*New Course*) (3)
Course description needed

AS.470.731 Privacy in a Data Driven Society (3)
This course addresses the legal, policy and cultural issues that challenge the government and its citizens in the increasingly complex technical environment of privacy. We will examine the challenges in balancing the need for information and data against the evolving landscape of individual privacy rights. The course will examine privacy at all levels: by analyzing the shifting views of individual privacy by citizens as well as the technological challenges in both protecting and analyzing personal information for government use. Using case studies and hypotheticals, we will discuss the issue of transparency in the government use and retention of data. The cases will range from Facebook to healthcare.gov to sunshine laws to national security uses of information. We will trace the development of legal and policy measures relevant to privacy concerns and envision future solutions needed in an era of great technological innovation including the use of big data.
Prerequisite: none

AS.470.671 Risk Management Analytics (3)
Risk management has always been in the vanguard of data analytics because risk measurement is a critical element in calculating risk/return tradeoffs. This course will examine both qualitative and quantitative analytical methods commonly used in risk management. Qualitative tools include impact/likelihood analysis; event and fault trees; threats, vulnerability, and consequences (TVC); and failure mode and effects analysis (FMEA). However, a key lesson in risk management is that what gets measured gets managed. As a result, a major part of the course will focus on quantitative tools, including modeling and stochastic simulations. We will use the @Risk software to build realistic risk models, including one in assessing project management risks. The objective of the course is to equip students with practical tools they can apply in risk-based decision making.
Prerequisites: 470.681 Probability and Statistics; working knowledge of Excel

Machine Learning and Cloud Computing Focus Area Courses

EN.685.621 Algorithms for Data Science (3)
This course offers an in-depth journey through the algorithmic concepts vital for mastering the intricacies of data science. It begins with an intensive examination of algorithm analysis, with a special focus on understanding the runtime complexities essential for addressing real-world data problems. The curriculum encompasses thorough training in data preprocessing, along with foundational knowledge in probability and statistics, equipping students to proficiently clean and interpret data. The course introduces key mathematical transformations such as Eigen decomposition, FFT, DCT, and Wavelets. These tools are crucial for unearthing underlying patterns in data by creating innovative feature spaces. Students will explore a seamless blend of diverse algorithm types, including intelligent algorithms, statistical algorithms, optimization algorithms, graph algorithms, and learning algorithms. This comprehensive approach, enriched with optimization techniques, forms a holistic toolkit for the contemporary Data Scientist. Moving beyond theoretical concepts, the course delves into practical aspects of analysis, visualization, and understanding of complexity classes. Occasional forays into algorithmic proofs enhance the theoretical grounding of students, bridging theory with practical application. The course culminates in modules focused on data modeling and visualization, enabling students to

adeptly apply algorithmic techniques to produce insightful and meaningful data representations. Upon completing this course, students will be thoroughly equipped with both practical and theoretical algorithmic strategies, preparing them to confidently address a wide array of challenges in the data science field. Students can only earn credit for one of EN.605.620, EN.605.621, or EN.685.621.

EN.705.601 Applied Machine Learning (3)
Machine Learning (ML) is the art of solving a computation problem using a computer without an explicit program. ML is now so pervasive that various ML applications such as image recognition, stock trading, email spam detection, product recommendation, medical diagnosis, predictive maintenance, cybersecurity, etc. are constantly used by organizations around us, sometimes without our awareness. In this course, we will rigorously apply machine learning techniques to real-world data to solve real-world problems. We will briefly study the underlying principles of diverse machine learning approaches such as anomaly detection, ensemble learning, deep learning with a neural network, etc. The main focus will be applying tool libraries from the Python-based Anaconda and Java-based Weka data science platforms to datasets from online resources such as Kaggle, UCI KDD, open source repositories, etc. We will also use Jupyter notebooks to present and demonstrate several machine learning pipelines.

EN.605.633 Social Media Analytics (3)
Today an immense social media landscape is being fueled by new applications, growth of devices (e.g., Smartphones and devices), and human appetite for online engagement. With a myriad of applications and users, significant interest exists in the obvious question, “How does one better understand human behavior in these communities to improve the design and monitoring of these communities?” To address this question a multidisciplinary approach that combines social network analysis (SNA), natural language processing, and data analytics is required. This course combines all these topics to address contemporary topics such as marketing, population influence, etc. There will be several small projects.
Prerequisite(s): Knowledge of Python or R; matrix algebra.

EN.605.634 Crowdsourcing and Human Computation (3)
Crowdsourcing and human computation reverses the typical approach to computing. Rather than using computers to conduct computation that is too difficult for a human, many humans are used to conduct computation that is too difficult for a computer. This course explores computer science topics that lie at the intersection of data science and social psychology. Topics include crowdsourcing, social media, social network analysis, games, gamification, ubiquitous computing, and computer supported cooperative work. Laboratory exercises will involve hands-on data collection and analysis to include Mechanical Turk and require programming in R or Python depending on student preference/proficiency.

EN.605.635 Cloud Computing (3)
Cloud computing helps organizations realize cost savings and efficiencies without spending capital resources up front, while modernizing and expanding their IT capabilities. Cloud-based infrastructure is rapidly scalable, secure, and accessible over the Internet—you pay only for what you use. So, enterprises worldwide, big and small, are moving toward cloud-computing solutions for meeting their computing needs, including the use of Infrastructure as a Service (IaaS) and

Platform as a Service (PaaS). We have also seen a fundamental shift from shrinkwrapped software to Software as a Service (SaaS) in data centers across the globe. Moreover, providers such as Amazon, Google, and Microsoft have opened their datacenters to third parties by providing low-level services such as storage, computation, and bandwidth. This trend is creating the need for a new kind of enterprise architect, developer, QA, and operational professional—someone who understands and can effectively use cloud-computing technologies and solutions. In this course, we discuss critical cloud topics such as cloud service models (IaaS, PaaS, SaaS); virtualization and how it relates to cloud; elastic computing; cloud storage; cloud networking; cloud databases; cloud security; and architecting, developing, and deploying apps in the cloud. The format of this course will be a mix of lectures, and hands-on demos. Upon completing this course, students will have a deeper understanding of what cloud computing is and the various technologies that make up cloud computing, along with hands-on experience working with a major cloud provider.
Prerequisite(s): EN.605.202 Data Structures.

EN.605.646 Natural Language Processing (3)
This course surveys the principal difficulties of working with written language data, the fundamental techniques that are used in processing natural language, and the core applications of NLP technology. Topics covered in the course include language modeling, text classification, labeling sequential data (tagging), parsing, information extraction, question answering, machine translation, and semantics. The dominant paradigm in contemporary NLP uses supervised machine learning to train models based on either probability theory or deep neural networks. Both formalisms will be covered. A practical approach is emphasized in the course, and students will write programs and use open source toolkits to solve a variety of problems. Course prerequisite(s): There are no formal prerequisite courses, although having taken any of EN.605.649 Introduction to Machine Learning, EN.605.744 Information Retrieval, or EN.605.645 Artificial Intelligence is helpful. Course note(s): A working knowledge of Python is assumed. While some of the assigned exercises can be done in any programming language, we will sometimes provide example code in Python, and many of the labs are best solved in Python.
Course note(s): A working knowledge of Python is assumed. While some of the assigned exercises can be done in any programming language, we will sometimes provide example code in Python, and many of the labs are best solved in Python.

EN.625.742 Theory of Machine Learning (3)
This course introduces various machine learning algorithms with emphasis on their derivation and underlying mathematical theory. Topics include the mathematical theory of linear models (regression and classification), anomaly detectors, tree-based methods, regularization, fully connected neural networks, convolutional neural networks, and model assessment. Students will gain experience in formulating models and implementing algorithms using Python. Students will need to be comfortable with writing code in Python to be successful in this course. At the end of this course, students will be able to implement, apply, and mathematically analyze a variety of machine learning algorithms when applied to real-world data. Course Note(s): Although students will have coding assignments, this course differs from other EP machine learning courses in that the primary focus is on the mathematical foundations underlying the algorithms.

EN.605.744 Information Retrieval (3)

A multibillion-dollar industry has grown to address the problem of finding information. Commercial search engines are based on information retrieval: the efficient storage, organization, and retrieval of text. This course covers both the theory and practice of text retrieval technology. Topics include automatic index construction, formal models of retrieval, Internet search, text classification, multilingual retrieval, question answering, and related topics in NLP and computational linguistics. A practical approach is emphasized and students will complete several programming projects to implement components of a retrieval engine. Students will also give a class presentation based on an independent project or a research topic from the IR literature.
Prerequisite(s): EN.605.202 Data Structures or permission of the instructor

EN.705.742 Advanced Applied Machine Learning (3)
Machine learning is a subset of artificial Intelligence to build and utilize data models based on sound analytical algorithms. Still, it takes more than just applying a set of algorithms to datasets or experiment a list of toolbox library to successfully build effective machine learning subsystems in an AI system. In this course, we will study a variety of advanced topics involving solutions and novel techniques to various machine learning problems. Starting from Machine Learning Operations, these topics include model analysis such as Recommender Systems, Hyperparameter Optimization, Transfer Learning, and Explainable AI. Moreover, we will study and implement Neural Network machine learning algorithms such as Generative Adversarial Networks, Recurrent Neural Networks, Transformers, and Graph Neural Networks. The course will keep a balance between the theoretical and mathematical specifications of an algorithm and the actual engineering of an algorithm. In addition, we will apply these methods and models, such as GPT, to a variety of real-world problems in realistic course assignments. The course will also keep a research thread with discussions about recent developments, and emerging technologies in the current literature. Students will be expected to write a research paper throughout the course.

AS.470.643 Text as Data (3)
In this course students will develop expertise in using the tools necessary to collect, analyze, and visualize large amounts of text. The course begins with a hands-on introduction to the programming concepts necessary to collect and process textual data. The course then proceeds to cover key statistical concepts in machine learning and statistics that are used to analyze text as data. Throughout the course, students will develop a research project that culminates in the display of results from a large-scale textual analysis.
Prerequisite: 470.681 Probability and Statistics.

AS.470.699 Applied Performance Analytics (3)
Data are everywhere, and many elected officials and government managers understand they need it. But how can they use it to solve problems and shape policy? What is the best way to make decisions based on a data analysis? How can they communicate those decisions, and the rationale behind them, to employees, citizens, and stakeholders? This course will provide students with an experiential learning opportunity based on real-world scenarios. Students will each take on a role (mayor, police commissioner, human capital director, budget director, public works director, public health director) and participate in a simulated public policy scenario. Working in small groups, students will apply a practical performance analytics process to develop solutions to

address governmental challenges. Students will begin by studying foundational concepts and techniques of data collection, analytics, and decision support. They will also learn how to navigate multiple interests, asymmetrical information, and competing political agendas as they make difficult decisions about resource allocation and public policy. Along the way, they will learn how to turn insights into action by effectively communicating the results of analysis to busy executives and decision makers at all levels of the organization.
Prerequisites: none required (470.681 Probability and Statistics recommended)

Data Engineering Focus Area Courses

EN.685.652 Data Engineering Principles and Practice (3)
Data Engineering is the ingestion, transformation, storage and serving of data in ways that enable data scientists or applications to use and derive insights from data. In this course, we will look at various file-based data formats, data collection, data cleansing, data transformation, and data modeling for both relational and NoSQL databases. The course will also cover movement of data into data warehouses and/or data lakes using pipelines and workflow automation. Finally, we will discuss data security, governance, and compliance. The format of this course will be a mix of lectures, hands-on demos, and labs. Upon completing this course, students will have a deeper understanding of what a data engineer does and the various technologies that make up data engineering, along with hands-on experience working with various tools and processes.

EN.635.601 Foundations of Information Systems Engineering (3)
Creating and operating large-scale information systems requires a holistic approach that manages the blending of software, hardware, networks, and security inherent in modern systems. This course introduces key elements and processes required for designing, analyzing, developing, and integrating complex information systems. The course focuses on the systems engineering approach with specific emphasis on design, development, and deployment. Topics covered include requirements engineering, architecture development, security engineering, cost-benefit analysis, information and networking technologies, and operations.
Course Note(s): The required foundation courses may be taken in any order but must be taken before other courses in the degree.

EN.685.701 Data Science: Modeling and Analytics (3)
This course advances the design of data modeling as it applies to the field of data science while leveraging key concepts from AI, machine learning, and statistics. Data modeling is a combination of various fields which allow the processing of various data types, and representing the data in an expressive way that shows the relationships between data points and intrinsic patterns. The course will show how to identify, design, and implement the modeling process by outlining the framework, determining the appropriate model type, evaluating the model, and representing the outputs in an explainable way. The models used will be based on intelligent algorithms (reasoning, optimization, and pattern recognition), machine learning algorithms (supervised and unsupervised), and statistical methods (descriptive statistics, inferential statistics, multi-variate, and regression). The focus will be developing and applying models using Python-based frameworks to datasets from online resources such as Kaggle, Data.gov, and open-source repositories.

EN.605.741 Large-Scale Database Systems (3)
This course investigates the theory and practice of modern large-scale database systems. Large-scale approaches include distributed relational databases; data warehouses; and non-relational databases including HDFS, Hadoop, Accumulo for query and graph algorithms, and Mahout bound to Spark for machine learning algorithms. Topics discussed include data design and architecture; database security, integrity, query processing, query optimization, transaction management, concurrency control, and fault tolerance; and query formulation, graph algorithms, and machine learning algorithms on large-scale distributed data systems. At the end of the course, students will understand the principles of several common large-scale data systems including their architectures, performance, and costs. Students will also gain a sense of which approach is recommended for different requirements and circumstances.

EN.605.788 Big Data Processing (3)
Organizations today are generating massive amounts of data that are too large and too unwieldy to fit in relational databases. Therefore, organizations and enterprises are turning to massively parallel computing solutions such as Hadoop for help. The Apache Hadoop platform, with Hadoop Distributed File System (HDFS) and MapReduce (M/R) framework at its core, allows for distributed processing of large data sets across clusters of computers using the map and reduce programming model. It is designed to scale up from a single server to thousands of machines, offering local computation and storage. The Hadoop ecosystem is sizable in nature and includes many subprojects such as Hive and Pig for big data analytics, HBase for real-time access to big data, Zookeeper for distributed transaction process management, and Oozie for workflow. This course breaks down the walls of complexity of distributed processing of big data by providing a practical approach to developing applications on top of the Hadoop platform. By completing this course, students will gain an in-depth understanding of how MapReduce and Distributed File Systems work. In addition, they will be able to author Hadoop-based MapReduce applications in Java and also leverage Hadoop subprojects to build powerful data processing applications.
Course Note(s): This course may be counted toward a three course track in Data Science and Cloud Computing.

AS.470.703 Urban Data Analytics (3)
This class applies data analytic skills to the urban context, analyzing urban problems and datasets. Students will develop the statistical skills to complete data-driven analytical projects using data from city agencies, federal census data, and other sources, including NGOs that work with cities. We will examine a variety of data sets and research projects both historical and contemporary that examine urban problems from a quantitative perspective. Over the course of the term, each student will work on a real-world urban data problem, developing the project from start to finish, including identifying the issue, developing the research project, gathering data, analyzing the data, and producing a finished research paper.
Prerequisite: 470.681 Probability and Statistics

AS.470.764 Survey Methodology (3)
This course is a comprehensive examination of all aspects of designing questionnaires, conducting survey research, and analyzing survey data. The class will cover question

construction, measurement, sampling, weighting, response quality, scale and index construction, IRBs, ethics, integrity and quality control, modes of data collection (including telephone, mail, face to face and focus groups), post collection processing and quantitative analysis of data (including chi-square and ANOVA), as well as report writing fundamentals. The class culminates by fielding a survey of student created questions and writing an executive summary of the survey with a paper discussing the research findings.
Prerequisite: 470.681 Probability and Statistics

Simulation and Modelling Focus Area Courses

EN.625.603 Statistical Methods and Data Analysis (3)
This course introduces statistical methods that are widely used in modern applications. A balance is struck between the presentation of the mathematical foundations of concepts in probability and statistics and their appropriate use in a variety of practical contexts. Foundational topics of probability, such as probability rules, related inequalities, random variables, probability distributions, moments, and jointly distributed random variables, are followed by foundations of statistical inference, including estimation approaches and properties, hypothesis testing, and model building. Data analysis ranging from descriptive statistics to the implementation of common procedures for estimation, hypothesis testing, and model building is the focus after the foundational methodology has been covered. Software, for example R-Studio, will be leveraged to illustrate concepts through simulation and to serve as a platform for data analysis.
Prerequisite(s): Multivariable Calculus, Calc III.

EN.625.661 Statistical Models and Regression (3)
Introduction to regression and linear models including least squares estimation, maximum likelihood estimation, the Gauss-Markov Theorem, and the Fundamental Theorem of Least Squares. Topics include estimation, hypothesis testing, simultaneous inference, model diagnostics, transformations, multicollinearity, influence, model building, and variable selection. Advanced topics include nonlinear regression, robust regression, and generalized linear models including logistic and Poisson regression.

EN.625.664 Computational Statistics (3)
Computational statistics is a branch of mathematical sciences concerned with efficient methods for obtaining numerical solutions to statistically formulated problems. This course will introduce students to a variety of computationally intensive statistical techniques and the role of computation as a tool of discovery. Topics include numerical optimization in statistical inference [expectation-maximization (EM) algorithm, Fisher scoring, etc.], random number generation, Monte Carlo methods, randomization methods, jackknife methods, bootstrap methods, tools for identification of structure in data, estimation of functions (orthogonal polynomials, splines, etc.), and graphical methods. Additional topics may vary. Coursework will include computer assignments.

EN.625.695 Time Series Analysis and Dynamic Modeling (3)
This course will be a rigorous and extensive introduction to modern methods of time series analysis and dynamic modeling. Topics to be covered include elementary time series models, trend and seasonality, stationary processes, Hilbert space techniques, the spectral distribution

function, autoregressive/ integrated/moving average (ARIMA) processes, fitting ARIMA models, forecasting, spectral analysis, the periodogram, spectral estimation techniques, multivariate time series, linear systems and optimal control, state-space models, and Kalman filtering and prediction. Additional topics may be covered if time permits. Some applications will be provided to illustrate the usefulness of the techniques.
Course Note(s): This course is also offered in the Department of Applied Mathematics and Statistics (Homewood campus) as EN.553.639.

EN.625.740 Data Mining (3)
The field of data science is emerging to make sense of the growing availability and exponential increase in size of typical data sets. Central to this unfolding field is the area of data mining, an interdisciplinary subject incorporating elements of statistics, machine learning, artificial intelligence, and data processing. In this course, we will explore methods for preprocessing, visualizing, and making sense of data, focusing not only on the methods but also on the mathematical foundations of many of the algorithms of statistics and machine learning. We will learn about approaches to classification, including traditional methods such as Bayes Decision Theory and more modern approaches such as Support Vector Machines and unsupervised learning techniques that encompass clustering algorithms applicable when labels of the training data are not provided or are unknown. We will introduce and use open-source statistics and data-mining software such as R. Students will have an opportunity to see how data mining algorithms work together by reviewing case studies and applying techniques learned in hands-on projects.

EN.605.716 Modeling and Simulation of Complex Systems (3)
This multi-disciplinary course focuses on the application of modeling and simulation principles to complex systems. A complex system is a large-scale nonlinear system consisting of interconnected or interwoven parts (such as a biological organism, an ecological system, the economy, fluids or strongly-coupled solids). The subject is interdisciplinary with foundations in mathematics, nonlinear science, numerical simulations and statistical physics. The course begins with an overview of complex systems, followed by modeling techniques based on nonlinear differential equations, networks, and stochastic models. Simulations are conducted via numerical calculus, analog circuits, Monte Carlo methods, and cellular automata. In the course we will model, program, and analyze a wide variety of complex systems, including dynamical and chaotic systems, cellular automata, and iterated functions. By defining and iterating an individual course project throughout the term, students will gain hands-on experience and understanding of complex systems that arise from combinations of elementary rules. Students will be able to define, solve, and plot systems of linear and non-linear systems of differential equations and model various complex systems important in applications of population biology, epidemiology, circuit theory, fluid mechanics, and statistical physics.
Course prerequisite(s): Knowledge of elementary probability and statistics and previous exposure to differential equations. Students applying this course to the MS in Bioinformatics should also have completed at least one Bioinformatics course prior to enrollment.
Course note(s): This course may be counted toward a three-course concentration in Bioinformatics.

EN.625.734 Queuing Theory with Applications to Computer Science (3)

Queues are a ubiquitous part of everyday life; common examples are supermarket checkout stations, help desk call centers, manufacturing assembly lines, wireless communication networks, and multi-tasking computers. Queuing theory provides a rich and useful set of mathematical models for the analysis and design of service process for which there is contention for shared resources. This course explores both theory and application of fundamental and advanced models in this field. Fundamental models include single and multiple server Markov queues, bulk arrival and bulk service processes, and priority queues. Applications emphasize communication networks and computer operations but may include examples from transportation, manufacturing, and the service industry. Advanced topics may vary.

EN.625.741 Game Theory (3)
Game theory is a field of applied mathematics that describes and analyzes interactive decision making when two or more parties are involved. Since finding a firm mathematical footing in 1928, it has been applied to many fields, including economics, political science, foreign policy, and engineering. This course will serve both as an introduction to and a survey of applications of game theory. Therefore, after covering the mathematical foundational work with some measure of mathematical rigor, we will examine many real-world situations, both historical and current. Topics include two-person/N-person game, cooperative/non-cooperative game, static/dynamic game, combinatorial/strategic/coalitional game, and their respective examples and applications. Further attention will be given to the meaning and the computational complexity of finding of Nash equilibrium.

AS.470.758 Data Driven Campaigns and Elections (3)
Analytics inform the decision-making process, strategizing, and forecasting of modern American campaigns. This course focuses on the role that analytics play in campaigns and elections in America. Campaign strategists, policy analysts, and social scientists leverage data from voter rolls, consumption and public opinion polls to make better choices. This course surveys the theoretical and empirical literature in American electoral politics to examine how campaigns and political organizations are using field experiments, microtargeting, and public opinion polling to tackle the challenges of getting out the vote and increasing registration and voting rates. Other topics covered include voting behavior, public opinion, partisanship, and campaign finance. Students will gain a rich understanding of how analytics has become a key component of the electoral process. Students will also gain experience analyzing data through simulations and data analysis exercises.
Prerequisites: 470.681 Probability and Statistics

AS.470.779 Computational Modeling for Policy and Security Analysis (3)
This course will introduce computational modeling and demonstrate how it is used in the policy and national security realms. Specifically, the course will focus on agent-based modeling, which is a commonly used approach to build computer models to better understand proposed policies and political behavior. Agent-based models consist of a number of diverse "agents,'' which can be individuals, groups, firms, states, etc. These agents behave according to behavioral rules determined by the researcher. The interactions with each other and their environment at the micro-level can produce emergent patterns at the macro-level. These models have been used to understand a diverse range of policy issues including voting behavior, international conflict, segregation, health policy, economic markets, ethnic conflict, and a variety of other policy

issues. The course will consist of two parts: First, we will examine the theoretical perspective of computational modeling. Second, you will be introduced to a software platform that is commonly used to develop computational, and, in particular agent-based modeling.
No prerequisite

Artificial Intelligence Focus Area Courses

EN.685.621 Algorithms for Data Science (3)
This course offers an in-depth journey through the algorithmic concepts vital for mastering the intricacies of data science. It begins with an intensive examination of algorithm analysis, with a special focus on understanding the runtime complexities essential for addressing real-world data problems. The curriculum encompasses thorough training in data preprocessing, along with foundational knowledge in probability and statistics, equipping students to proficiently clean and interpret data. The course introduces key mathematical transformations such as Eigen decomposition, FFT, DCT, and Wavelets. These tools are crucial for unearthing underlying patterns in data by creating innovative feature spaces. Students will explore a seamless blend of diverse algorithm types, including intelligent algorithms, statistical algorithms, optimization algorithms, graph algorithms, and learning algorithms. This comprehensive approach, enriched with optimization techniques, forms a holistic toolkit for the contemporary Data Scientist. Moving beyond theoretical concepts, the course delves into practical aspects of analysis, visualization, and understanding of complexity classes. Occasional forays into algorithmic proofs enhance the theoretical grounding of students, bridging theory with practical application. The course culminates in modules focused on data modeling and visualization, enabling students to adeptly apply algorithmic techniques to produce insightful and meaningful data representations. Upon completing this course, students will be thoroughly equipped with both practical and theoretical algorithmic strategies, preparing them to confidently address a wide array of challenges in the data science field. Students can only earn credit for one of EN.605.620, EN.605.621, or EN.685.621.

EN.605.645 Artificial Intelligence (3)
This is a foundational course in Artificial Intelligence. Although we hear a lot about machine learning, artificial intelligence is a much broader field with many different aspects. In this course, we focus on three of those aspects: reasoning, optimization, and pattern recognition. Traditionally, the first was covered under “Symbolic AI” or “Good Old Fashioned AI” and the latter two were covered under “Numeric AI” (or more specifically, “Connectionist AI” or “Machine Learning”). However, despite the many successes of machine learning algorithms, practitioners are increasingly realizing that complicated AI systems need algorithms from all three aspects. This approach falls under the ironic heading “Hybrid AI”. In this course, the foundational algorithms of AI are presented in an integrated fashion emphasizing Hybrid AI. The topics covered include state space search, local search, example based learning, model evaluation, adversarial search, constraint satisfaction problems, logic and reasoning, expert systems, rule based ML, Bayesian networks, planning, reinforcement learning, regression, logistic regression, and artificial neural networks (multi-layer perceptrons). The assignments weigh conceptual (assessments) and practical (implementations) understanding equally.

EN.635.603 AI/ML Ops (3)

This course is designed to provide an in-depth understanding of AI/ML Ops, a discipline that combines artificial intelligence (AI) and machine learning (ML) with operations and IT practices. The course covers the introduction to AI and ML Ops, including the framework for building and deploying AI/ML models, the infrastructure for ML, data management, and the road to AI adoption. The course also provides insights into model training and deployment, AI/ML Ops features, stages of AI/ML Ops, preparing for production, deploying to production, AI/ML security, governance, and future trends in AI/ML Ops. The course will conclude with practical applications of AI/ML Ops. By the end of the course, students will have the skills to design and implement an MLOps strategy for an organization.
Prerequisites: Working knowledge of Python

EN.635.627 Intelligent Decision Support Systems (3)
Businesses and organizations are flooded with a variety of data from a vast number of sources. Data analysis and use of data analytics in data-driven decision-making processes has become the go-to strategy for business success and for gaining sustainable competitive advantage. This course will introduce students to the technologies that are generally and collectively called "analytics" used to support effective decision-making processes for business. Course topics will cover the latest trends in analytics, including scalable AI, machine learning, IoT, and smart/robo-collaborative assisting systems, composable data and analytics, data fabric, small data models, and XOps. This course will enable students to apply deep knowledge of predictive, descriptive analytics, big data, and web analytics to the development of the best business solutions for their organizations. They will also know which kinds of analytics to apply to specific decision contexts.

EN.605.745 Reasoning Under Uncertainty (3)
This course is concerned with the problems of inference and decision making under uncertainty. It develops the theoretical basis for a number of different approaches and explores sample applications. The course discusses foundational issues in probability and statistics, including the meaning of probability statement, and the necessity of a rational agent acting in accord with probability theory. We will look at possible generalizations of Bayesian probability, including Dempster-Shafer theory. Next, we will develop algorithms for Bayesian networks—graphical probabilistic models—for exact and approximate inference and consider several application areas. Finally, the course will examine the problem of making optimal decisions under uncertainty. We will explore the conceptual foundations of decision theory and then consider influence diagrams, which are graphical models extending Bayesian networks to the domain of decision analysis. As time permits, we will also look at Bayesian games and Markov decision processes. Pertinent background in probability and theoretical computer science is developed as needed in the course.

EN.695.715 Assured Autonomy (3)
Autonomic systems leverage the growing advances in control, computer vision, and machine learning coupled with technological advances in sensing, computation, and communication. While this emerging highly connected, autonomous world is full of promise, it also introduces safety and security risks that are not present in legacy systems. This course focuses on the complexities inherent in autonomous systems and the multifaceted and multilayered approaches necessary to assure their secure and safe operation. As these systems become more pervasive,

guaranteeing their safe operation even during unforeseen and unpredictable events becomes imperative. There are currently no real solutions to provide these runtime guarantees necessitating cutting-edge research to provide state awareness, intelligence, control, safety, security, effective human-machine interaction, robust communication, and reliable computation and operation to these systems. This online course in a seminar-style format leads the students to participate in learning activities, record summary presentation of a selection of papers, write a peer-reviewed publication-quality paper, and record a workshop presentation for virtual panel review.

EN.605.724 Applied Game Theory (3)
In many organizations in the private and the public sectors, there is a need to support complex decisions that include a game-theoretic aspect. These decisions impact activities ranging from tactical to strategic, and play out in a number of problems, including monitoring and management of ongoing operations, the dynamics of organizational relationships in the competitive environment, and military force planning. This course extends treatment of game theoretic concepts and constructs, and explores their implementation and application, highlighting key issues such as decision space exploration and analysis, visualization, and the creation and use of models for specific domains. Students will have the opportunity to design a course project based on their area of professional or personal interest.

AS.473.602 Intelligence Analysis (3)
Intelligence analysis is fundamentally about understanding and communicating to decision makers what is known, not known, and surmised, as it can best be determined. Students will read seminal texts on intelligence analysis, discuss the complex cognitive, psychological, organizational, ethical, and legal issues surrounding intelligence analysis now and in the past, and apply analytic methodologies to real-world problems.

AS.470.743 Data Mining and Predictive Analytics (3)
Many government agencies engage in data mining to detect unforeseen patterns and advanced analytics (such as classification techniques) to predict future outcomes. In this course, students will utilize IBM SPSS Modeler to investigate patterns and derive predictions in policy areas such as fraud, healthcare, fundraising, human resource and others. In addition, students will build segmentation models using clustering techniques in an applied manner. Integration with other statistical tools and visualization options will also be discussed.
Prerequisite: 470.681 Probability and Statistics; Recommended: 470.709 Quantitative Methods

Appendix B

Data Analytics Engineering Faculty

Faculty Name	Highest Degree	Degree Field	Employer	Status at JHU	Engineering School Title	Classes Taught
Anthony Johnson	Ph.D.	Computational Analysis	United States Military Academy West Point	FT	Program Manager	635.631
Arthur Reynolds	JD	Jurisprudence	U.S. Department of Defense	PT	Lecturer	635.775, 635.782
Bassam Farroha	Ph.D.	Electrical Engineering	U.S. Government	PT	Lecturer	635.676
Benjamin Johnson	M.S.	Applied Mathematics	Accenture Federal Services	PT	Lecturer	685.662
Benjamin Rodriguez	Ph.D.	Electrical and Computer Engineering - Statistical Signal Processing	JHU Applied Physics Laboratory	FT	Program Chair	685.621, 685.701, 605.645
Beryl Castello	Ph.D.	Applied Mathematics and Statistics	JHU Whiting School of Engineering	FT	Lecturer	625.741
Cetin Savkli	Ph.D.	Theoretical Physics	JHU Applied Physics Laboratory	FT	Lecturer	625.603, 625.661
Christine Nickel	Ph.D.	Mathematics	JHU Whiting School of Engineering	PT	Lecturer	625.680, 625.734
Daniel Wiley	Ph.D.	Applied Mathematics	U.S. Government	PT	Lecturer	605.716
Dar-Ning Kung	Ph.D.	Mechanical Engineering	National Institutes of Health	PT	Lecturer	605.641
David Heinbuch	M.S.	Computer Science	JHU Applied Physics Laboratory	FT	Lecturer	695.601, 695.721
David Silberberg	Ph.D.	Computer Science	JHU Applied Physics Laboratory	FT	Program Chair	605.741
Erhan Guven	Ph.D	Computer Science	JHU Applied Physics Laboratory	FT	Lecturer	705.601, 705.742
James Mayfield	PHD	Computer Science	JHU Applied Physics Laboratory	FT	Lecturer	605.646
James Mosko	MS	Electrical Engineering	Georgia Institute of Technology	PT	Lecturer	685.652
Jeffrey Chavis	DENG	Computer Science	JHU Applied Physics Laboratory	FT	Lecturer	635.601
Karthik Shyamsunder	M S	Computer Science	VeriSign, Inc.	PT	Lecturer	605.635
Kiran Chittargi	MS	Information Systems	Johns Hopkins University	PT	Lecturer	635.603
Marc Johnson	MBA	Business	Accenture Federal Services	PT	Lecturer	605.745
Michael Weisman	PhD	Applied Mathematics	U.S. Army Research Laboratory	PT	Lecturer	625.74
Nandi Leslie	PHD	Applied and Computational Mathematics	Raytheon	PT	Lecturer	625.664

Paul McNamee	Ph.D.	Computer Science	JHU Applied Physics Laboratory	FT	Lecturer	605.744
Perry Wilson	M S	Info Sys & Tec	JHU Applied Physics Laboratory	FT	Lecturer	605.788
Richard Cost	PhD	Computer Science	Johns Hopkins University	PT	Lecturer	605.724
Tamim Sookoor	Ph.D	Computer Science	JHU Applied Physics Laboratory	FT	Lecturer	695.715
Zerotti Woods	Ph.D	Mathematics	JHU Applied Physics Laboratory	FT	Lecturer	625.742

APPENDIX C

Table 1: Program Resources

RESOURCES	2025-26	2026-27	2027-28	2028-29	2029-30
1. Reallocated Funds	$0	$0	$0	$0	$0
2. Tuition/Fee Revenue (c + g below)	$354,575	$513,695	$683,280	$863,980	$1,056,369
a. Number of F/T Students	0	0	0	0	0
b. Annual Tuition/Fee Rate	NA	NA	NA	NA	NA
c. Total F/T Revenue (a x b)	$0	$0	$0	$0	$0
d. Number of P/T Student Enrollments	65	91	117	143	169
e. Credit Hour Rate	$1,818	$1,882	$1,947	$2,014	$2,084
f. Credits Per Course	3	3	3	3	3
g. Total P/T Revenue (d x e x f)	$354,575	$513,695	$683,280	$863,980	$1,056,369
3. Grants, Contracts & Other Ext Sources	$0	$0	$0	$0	$0
4. Other Sources	$0	$0	$0	$0	$0
TOTAL (Add 1 – 4)	**$354,575**	**$513,695**	**$683,280**	**$863,980**	**$1,056,369**

Resources Narrative

1. Reallocated Funds: The proposed program will be funded by tuition revenue and will make no use of reallocated funds.
2. Tuition and Fee Revenue: The enrollment projections in Table 1 are a reasonable estimate based on growth of other JHU-EP master's degree programs. The Master of Science in Data Analytics Engineering is a part-time degree program, so no full-time students are expected. JHU-EP students take, on average, three 3-credit courses per year, which is reflected in the "Annual Credit Hour Rate."
3. Grants and Contracts: No grants or contacts are required for the successful implementation of the program.
4. Other Sources: The program does not expect any funding from other source.

Table 2: Program Expenditures

EXPENDITURES	2025-26	2026-27	2027-28	2028-29	2029-30
1. Faculty (b + c below)	$86,831	$126,701	$168,130	$197,090	$227,141
a. # FTE	1.2	1.7	2.2	2.5	2.8
b. Total Salary	$80,399	$117,315	$155,676	$182,491	$210,315
c. Total Benefits	$6,432	$9,385	$12,454	$14,599	$16,825
2. Admin. Staff (b + c below)	$46,241	$47,886	$49,592	$51,360	$53,193
a. # FTE	0.75	0.75	0.75	0.75	0.75
b. Total Salary	$43,994	$45,553	$47,169	$48,844	$50,579
c. Total Benefits	$2,246	$2,333	$2,423	$2,516	$2,613
3. Support Staff (b + c below)	$24,494	$38,026	$52,476	$54,313	$56,214
a. # FTE	0.25	0.375	0.5	0.5	0.5
b. Total Salary	$18,211	$28,272	$39,016	$40,381	$41,795
c. Total Benefits	$6,283	$9,754	$13,460	$13,932	$14,419
4. Equipment	$0	$0	$0	$0	$0
5. Library	$0	$0	$0	$0	$0
6. New or Renovated Space	$0	$0	$0	$0	$0
7. Other Expenses	$100,425	$144,813	$191,774	$241,422	$293,876
TOTAL (Add 1 – 7)	**$257,990**	**$357,426**	**$461,972**	**$544,185**	**$630,423**

Expenditures Narrative

1. Faculty: The Engineering for Professionals lecturers are paid $10,152 (for 2024-2025) per course taught and $11,166 per course developed. These were used as base rates. For years 1 – 5, an additional 2% was added to the salary rate. The fringe rate is estimated at 8%.
2. Administrative Staff: Includes salary for Program Chair and advisors.
3. Support Staff: Includes pro-rated salaries for F/T Instructional Designers, Instructional Technologists and Multimedia Technicians to assist in developing online courses.
4. Equipment: No direct equipment costs are identified.
5. Library: Existing library facilities are sufficient to meet the needs of the program.
6. New or Renovated Space: No new or renovated space will be needed.
7. Other Expenses: Indirect program costs plus direct expenses associated with the Program Chair (conferences, travel, task support) are provided here.